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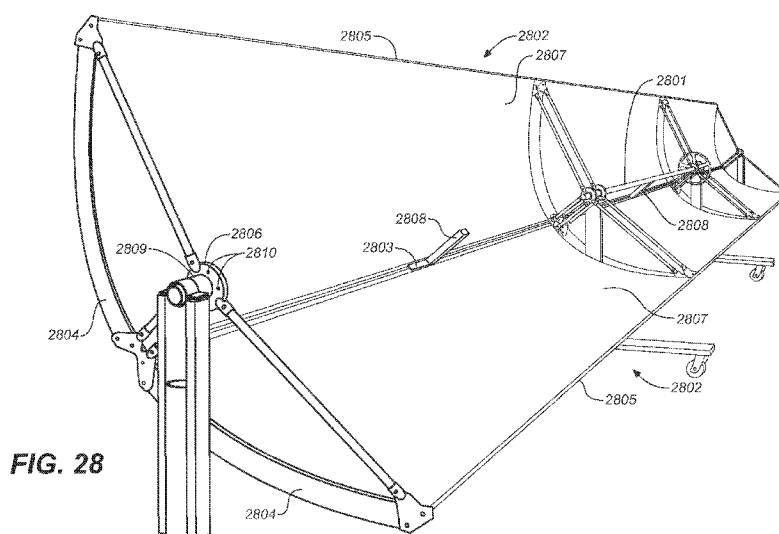
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(54) Title: SOLID CORE STRUCTURE PARABOLIC TROUGH SOLAR ENERGY COLLECTION SYSTEM



(57) Abstract: Foam backed solid support structure and trough solar energy collector. A support structure has foam or other polymeric material, a plurality of end arms, and a plurality of end caps secured to the formed foam material. The foam material is cut into a parabolic or semi-parabolic shape, and a reflective element may be placed onto the formed foam material and secured mechanically, with adhesion, and/or integrated with the surface. A solar energy collector formed using a polymeric core may have longitudinally-extending cowlings, end caps, and end arms as described.



SOLID CORE STRUCTURE PARABOLIC TROUGH SOLAR ENERGY COLLECTION SYSTEM

Cross References To Related Applications

[0001] This application claims the benefit of priority to U.S. App. Ser. No. 61/274,046 filed Aug. 11, 2009 and entitled "Solid Core Structure Parabolic Trough Solar Energy Collection System," inventors Kip H. Dopp and Darren T. Kimura, which application is incorporated by reference in its entirety.

[0002] This application also incorporates by reference the following patent applications that are referred to elsewhere in the text in their entirety as if put forth in full below: U.S. App. No. 11/811,329 (filed June 8, 2007) "Mirror Assemblies for Concentrating Solar Energy"; U.S. App. No. 11/811,109 (filed June 8, 2007) "Use of Brackets and Rails in Concentrating Solar Energy Collectors"; U.S. App. No. 11/811,027 (filed June 8, 2007) "Protecting Solar Energy Collectors from Inclement Weather"; U.S. App. No. 11/811,073 (filed June 8, 2007) "Use of Identical Components in Solar Energy Collectors"; U.S. App. No. 11/811,153 (filed June 8, 2007) "Support of Heat Collectors in Solar Energy Collectors"; PCT App. No. PCT/US2007/013618 (filed June 8, 2007) "Apparatus and Methods for Concentrating Solar Power"; PCT App. No. PCT/US2009/041171 (filed April 20, 2009) "Parabolic Trough Solar Energy Collection System"; PCT App. No. PCT/US2008/007115 (filed June 6, 2008) "Parking Solar Energy Collectors".

[0003] The present invention relates to the structural improvement of a concentrating parabolic trough collector through the use of non-conventional core materials that enable the reduction in metal frame structures, weight, and fasteners and that may increase the collector's durability and integrity.

Background and Summary of the Invention

[0004] Solar energy is an environmentally friendly source of renewable and sustainable energy that does not necessarily rely on the use of fossil fuels and reduces the release of green house gases that are attributed to global warming and related environmental problems. In many cases, solar energy can be captured and used locally, thereby reducing requirements for transportation or importation of fuels such as petroleum. Concentrating

solar power (CSP) systems are one of several technologies that may be used to harness solar energy from the sun.

[0005] Solar heaters, such as concentrating troughs, focus sunlight from mirrors and/or lenses onto a central receiver which can be a tube through which a heat transfer fluid flows. The trough collector may be positioned to track the sun so the reflected solar energy is concentrated onto the tube. The heated tube warms the fluid, and high quality heat from the heated fluid can be used to generate electricity, create air conditioning, drinking water from sea water or as steam. Trough solar energy collectors have been designed and manufactured to numerous specifications. The Micro Concentrated Solar Power (MicroCSP™) collectors, for instance, may provide a modular and scalable approach to solar technology suitable for electricity generation, process heat or other energy use.

[0006] Various MicroCSP™ collectors have been described in the prior patent applications referenced above. Provided herein is a frame assembly that may be used to construct solar energy collection and conversion systems using a suitable rigid material such as expanded polystyrene or extruded polystyrene, polyurethane, fiberglass, or recyclable materials for example, to support the reflective surface. Preferably, a foam material such as expanded polystyrene or extruded polystyrene may be used as the support surface in lieu of ribs or complex metal frames previously described in patent applications incorporated by reference above, may provide increased solar energy collection efficiency, reduced manufacturing costs, lighter in weight, provides for easy assembly, prolonged life, improved durability, larger or smaller collector apertures, and a modular structure suitable for ground, rooftop or trellis application.

[0007] Also provided herein is a method of achieving the desired panel shape by hot wire cutting the foam material with a CNC machine, a laser cutting machine or other device, or by molding or extruding the foam like material into the parabolic form. The collectors are formed into partial parabolic shapes whereby two or more pieces are used to form a complete parabolic trough collector. This design allows for efficient nesting of the pieces thereby minimizing shipping costs and reducing manufacturing costs. Once the panel is cut or molded to shape, a reflective element may then be applied. The reflective elements may also be applied to the foam material prior or during the creation of the parabolic form.

[0008] Further, provided herein are various methods of applying the reflective element to the panel, which may include attachment, adhesion or integration with the

surface. Once applied to the formed foam material, the reflective element may be reinforced with cowlings or other fastening devices on each side of the parabola piece(s) in order to provide rigidity, reflective stability and to hold the reflector in place. End caps or other fastening components may also be applied at each end of the panel to further lock the reflective element in place, to provide additional structural strength to the panel design, and to provide a point of attachment for the arm, tracking system or for cosmetic treatment.

[0009] In addition to the foam material being formed into an appropriate shape giving the collector its parabolic functional characteristics, a method of maintaining the reflector's parabolic shape with the formed foam material may include the use of embedded inserts to secure the end caps and cowlings. An interconnect piece may be used to tie the parabolic shapes together and provide a support for a stanchion to hold the receiver tube and glass envelope in position. A method of connecting multiple panel rows together may comprise using connectors to tie the panels together. The connecting piece may serve to improve multiple collector row strength, may be decorative, and may be used for torsion control.

[00010] Thus, in one instance, disclosed is a trough solar energy collector having a rotational axis comprising

- a collector tube,
- a first reflective panel and a second reflective panel,
- each of said first and second reflective panels comprising
 - a polymeric core having an arc-shaped surface
 - a reflector on the arc-shaped surface of the polymeric core
 - cowling along a longitudinal edge extending along the polymeric core
 - and extending parallel to the rotational axis of the solar collector
- the first reflective panel being positioned to illuminate a first side of the collector tube,
- the second reflective panel being positioned to illuminate a second side of the collector tube.

[00011] Also disclosed is an end arm in assembled or disassembled form comprising a hub fitting having an opening,

a plurality of top fittings configured to engage with top portions of respective ones of a first reflective panel and a second reflective panel,
a bottom fitting configured to engage with bottom portions of each of the first reflective panel and the second reflective panel, and
5 a plurality of fitting couplers securing the plurality of top fittings and the bottom fitting to the hub fitting.

[00012] In addition, disclosed is a method comprising
simultaneously slicing a plurality of arcuate reflector cores from a polymer blank,
placing reflective surfaces on concave portions of the arcuate reflector cores,
10 affixing cowling along edges of the arcuate reflector cores to form arc-shaped reflectors.

[00013] Further, disclosed is a method comprising
using a first set of sliced polymeric cores to form a first plurality of arc-shaped reflectors;
15 using a second set of sliced polymeric cores to form a second plurality of arc-shaped reflectors;
affixing a first and second reflector selected from said first plurality of arc-shaped reflectors and said second plurality of arc-shaped reflectors along an adjacent edge of each of said first and second arc-shaped reflectors at a mid-point between a larger
20 arc formed by the first and second arc-shaped reflectors and distant from ends of the first and second arc-shaped reflectors.

[00014] These and other aspects of the inventions are discussed further below in the text as well as the claims, which are hereby incorporated by reference into the text herein.

Brief Description of the Figures

25 [00015] Figs. 1 and 2 depict a support structure comprised of a foam material, end arms, and end caps.

[00016] Fig. 3 illustrates hot wire cutting with a CNC machine.

[00017] Fig. 4 depicts an outer coating.

- [00018] Fig. 5 illustrates two panels forming the wings, which may fit together using an H-clip that also attaches a stanchion.
- [00019] Fig. 6 illustrates reflective panels on a foam material.
- [00020] Fig. 7 illustrates a foam material with end caps, cowlings and inserts for a support structure.
- [00021] Fig. 8 shows decorative end caps for a support structure.
- [00022] Fig. 9 depicts an end arm assembly.
- [00023] Fig. 10 shows a corner end panel interconnect.
- [00024] Fig. 11 illustrates inserts in an end cap.
- [00025] Fig. 12 shows an H-clip.
- [00026] Fig. 13 illustrates a receiver tube.
- [00027] Fig. 14 illustrates a stanchion that is used to hold a receiver tube.
- [00028] Figs. 15-18 depict a U-bolt assembly with a receiver tube bearing, a receiver tube bearing attachment, a receiver tube bearing attachment screw, and a stanchion bracket.
- [00029] Fig. 19 shows a silicone foam gasket.
- [00030] Fig. 20 depicts a glass envelope.
- [00031] Fig. 21 shows inner and outer reflective covers with an insulating material.
- [00032] Fig. 22 shows a locator tube.
- [00033] Fig. 23 depicts a locator tube collar.
- [00034] Fig. 24 illustrates a stand for a support structure.
- [00035] Fig. 25 depicts torsion cables to adjust tension on a support structure.
- [00036] Fig. 26 illustrates multiple cores, one bare (2603), one 2601 with reflector panel 2602, and one 2601 with a backing panel 2604 applied.
- [00037] Fig. 27 likewise shows two cores, one with a backing panel.
- [00038] Fig. 28-30 provide various views of partially-assembled collectors ganged together (Fig. 28 and 29) and alone.

[00039] Fig. 31-32 illustrate inserts into cores that can be used in conjunction with screws or bolts to secure cowling, end caps, clips, backing, or other components to reflector cores.

[00040] Fig. 33 illustrates two end arms, each attached to a locator tube collar in a bearing assembly in a stand.

[00041] Fig. 34 illustrates some details of a panel-joining fitting.

[00042] Fig. 35 illustrates two arc-shaped reflective panels joined to one another by a clip 3504 as well as a stanchion 3501 supporting the collector tube.

[00043] Fig. 36 illustrates telescoping glass tubes (with one tube withdrawn) concentric with the collector tube.

[00044] Fig. 37A and 37B depict cross sectional views of two clips.

Detailed Description of Example Embodiments

[00045] Various aspects of the inventions disclosed herein may be understood better by reference to the following discussion in conjunction with the figures, which form a part of this specification and are incorporated by reference. The discussion of particular examples does not limit the scope of the invention, and the discussion is provided only to aid in understanding various aspects of the inventions disclosed herein. The claims are to be afforded a broad interpretation consistent with the principles, as well as the general and specific description herein.

[00046] By way of introduction to various parts and combinations of parts, Fig. 28-30 illustrate a partially-assembled solar energy trough collector which may include a collector tube 2801, a plurality of arc-shaped reflectors 2802 connected by at least one fastener 2803 at a midpoint of the larger arc formed by joining the arc-shaped reflectors, and end arms 2806. An arc-shaped reflector may have a core, a reflective portion 2807, cowlings 2805, and optional end caps 2804 as described more fully below. A support structure is a trough collector as discussed above that does not have a reflective portion.

[00047] Fig. 1 illustrates how one particular collector may be formed using a core such as a foam material 201, a plurality of end arms 102, and a plurality of end caps 103. Each of these pieces is discussed below in further detail.

1. Core

[00048] A core may be a polymer, a polymeric foam material, or a honeycomb material such as a composite honeycomb sheet (e.g. aluminum honeycomb core with rigid sheets sandwiching the honeycomb and/or rigid polymer filling the interstices). A core is preferably rigid, so that a concave arcuate surface on the core may have a reflective surface applied that conforms in shape to that of the concave arcuate surface.

[00049] The concave arcuate surface may be parabolic, cylindrical, or other concave arc on one side of the core. The opposite side of the core may be of convex curvature that is a mirror image of the curvature of a second core, as explained later. The opposite side may therefore be of convex curvature or may have no curvature.

[00050] A core that is flexible may be used if it retains accurate concave curvature when other pieces such as cowling, end caps, reflective element, backing, and/or end arms are applied.

(i) Polymeric core

[00051] A core may be a polymer such as a rigid or semi-rigid polymer. The core may be solid or a foam that has cells (either open or closed). Preferably, a closed cell foam material is used because of its moisture resistant characteristics. The polymer may have sufficient rigidity and surface strength such that the curved surface deforms little when a reflective material is applied to the surface. The core's curved surface therefore accurately imparts its curvature to an applied material.

[00052] As shown in Figs. 1, 2, and 26, a core formed from a foam material 201, 2601 such as expanded polystyrene (EPS), extruded polystyrene (XPS), or expanded extruded polystyrene (XEPS) may be used to form the arc-shaped reflectors 101 of the collector. Other suitable materials like polyurethane, fiberglass or epoxy may alternatively be used to form the panels. XPS, for instance, has good moisture resistant characteristics. Different densities of foam may be used, and density may be around two or three pounds per cubic foot, for instance.

[00053] Foam is inexpensive to manufacture and may be locally produced, shaped, and modified. Using foam may reduce the number of parts required because tooling is not required to achieve the collector shape. The foam allows for single piece manufacturing (e.g. a core may be formed as a single piece in a mold or cut from a block of foam) and is

easy to handle, thereby reducing assembly time and easing field assembly. The foam material 201, 2601 is also lightweight while maintaining sufficient strength to bear wind loads, significant advantages for roof-mount applications. The formed foam material may easily be shaped and sized to various apertures. For instance, a wider aperture increases the amount of reflective surface per panel, thereby allowing higher temperatures to be reached and therefore providing greater power conversion efficiencies.

[00054] In addition, the foam core 201, 2601 may provide a better substrate for the reflective element 601 (Fig. 6) and 2602 (Fig. 26) because, when adhered to a reflective element such as polished metal, the composite is a significantly stronger and a more accurately formed structure. One reason for this is that the reflective element 601, 2602 is supported by a solid substance, the foam material 201, 2601 rather than spanning a set of ribs, as described in prior patent applications incorporated by reference above. The formed foam material 201, 2601 may provide structural integrity and resistance to forces that may flex or twist the support structure. Thus, the foam core 201, 2601 provides better support as well as a protective backing to the arcuate reflective surface.

[00055] Any core may have other materials applied to it or incorporated into it, such as moisture barrier layer or layers, adhesive, UV blocker or absorbent, and strengthening layer or layers. Thus, various protective layers of material may be applied to any or all surfaces of the core (e.g. convex and/or concave arcuate surfaces), or anchors may be incorporated into a core, for instance.

(i) Honeycomb core

[00056] As mentioned, a honeycomb core may be e.g. an aluminum honeycomb sheet. The sheet may be made rigid by applying rigid or semi-rigid layers to one or more surfaces of the core or by solidifying a material such as a polymer in the interstices of the honeycomb. These layers may include any of the rigid or semi-rigid polymers such as polycarbonate, polyurethane, and polystyrene.

[00057] Any core will have a concave arcuate surface on which a reflective layer is placed and optionally a convex arcuate surface as well on which a backing material or materials may be placed.

2. Method to Achieve the Desired Collector Panel Shape

[00058] As shown in Fig. 3, the foam material 201 (Fig. 2), 2601 (Fig. 26) may be shaped into its desired panel shape by hot wire cutting one or more foam blanks 302 such as one or more blocks of foam using a CNC machine 301, or by using a laser cutting machine or other device. In the system depicted in Fig. 3, a plurality of cores are formed simultaneously by using hot wires 303 to cut one or a plurality of foam blanks. Multiple cores are therefore formed simultaneously from polymer blanks. The foam blank may be molded and cut into one or more cores 201 close to the location of any given project site thereby reducing shipping costs.

10 [00059] Use of a CNC hot wire 301 cutting machine to cut the foam material 201 may reduce overall tooling costs as compared to the tooling costs of stamping out ribs, described in prior patent applications incorporated by reference above. The collectors may be shaped to form parabolically shaped wings 501 (Fig. 5) whereby two pieces are positioned together along their longitudinal ends to form a complete parabolic trough
15 collector 501 having a larger arc-length than either of the pieces. This design allows for efficient nesting of the pieces during fabrication and shipment to reduce material drop when cutting and also minimizes shipping costs. The foam sections 201, 2601 may be cut with areas of greater or lesser thicknesses to provide features like reflector stops that stand above the overall surface and help hold a reflector panel in place, height adjustment to
20 accommodate parts that interface with the core, and areas of increased strength where needed (e.g. in the vicinity of fasteners and/or cowling).

[00060] A bottom or convex face of a core may be identical in curvature to a top or concave face of another core if desired, especially if the cores are both sliced simultaneously from the same polymer blank.

25 [00061] It is thought that a polymeric core may be uniform in tension and compression throughout the polymer of the core, especially where the core or multiple cores are formed by slicing a foam blank (such as a block) into the desired shape without further heating and bending of the bulk foam material. While a core may also be made by extruding the foam or by molding it, it is theorized that heating and bending foam that has already
30 polymerized introduces compression and tension into the foam (especially into closed-cell foam), as may polymerizing a polymer in an arcuately-shaped mold.

[00062] Further, slicing a foam blank provides cores than are “skinless” as compared to a core that is formed in a mold. A core cut from a polymeric blank has little to no skin. Any skin formed by slicing a foam blank using hot wires or laser cutting is typically quite thin and/or discontinuous and is believed to be thinner overall than skin formed during polymerization in a mold. A core formed in a mold typically has a skin with physical properties much different from the bulk foam beneath the skin. When a core is sliced from a foam blank, the surface of the core is very much like the bulk foam beneath the surface. The core sliced from a blank is therefore expected to be more uniform than a core formed in a mold. Methods of slicing a core from a blank therefore provide a skinless core as distinguished from a polymeric core formed in a mold.

[00063] Further, a foam core sliced from a blank may have already been formed at a higher temperature than foam formed in a mold. Foam typically has low thermal conductivity, and it is anticipated that a large blank of foam during polymerization experiences a higher temperature within much of the foam because of the large size of the blank and/or a high temperature for a much greater period of time than does a core formed in a mold. The much smaller quantity of foam in a mold for a core can cool more quickly, providing a lower temperature at which polymerization occurs in most or all of the foam and/or a much faster cool-down time. It is therefore believed that a foam core sliced from a blank will have already been subjected to a higher temperature and/or a higher temperature for a longer period of time than a molded core experiences, a sort of “pretreatment” of the foam that may lead to longer service life for a core formed from a polymer blank.

3. Outer Coating

[00064] As shown in Fig. 4 and Fig. 27, the outer surface 2701 of the formed foam material 201 may be coated with a suitable outer coating 401, 2702 such as an epoxy, paint, vinyl or other UV inhibitor to (1) protect the foam from UV rays, (2) seal the foam from moisture, and/or (3) provide additional structural support. The coating 401, 2702 may be a material such as plastic or other polymer such as polyvinylchloride, metal such as aluminum, fiberglass, canvas or other material that is fused, or otherwise externally affixed to the formed foam material 201, 2601, or that may be fabric layered, thereby providing impact resistance to harsh weather. The coating may be applied by spraying, troweling, dipping, fusing or pouring the desired material onto the foam or alternatively, the plastic

material may be modified to allow for the appropriate protective outer coating to be included in, or combined with, the foam material itself.

4. Arc-shaped reflector (wing)

[00065] As shown in Fig. 5 and Fig. 28-30, there may be two or more symmetrical arc-shaped reflectors or wings 501, 2802. These wings 501, 2802 may be attached at the bottom of the parabolic arc with a fastener such as a clip, e.g. an H- or other shaped-clip 502, 2803 and 3701 and 3702 of Fig. 37A and 37B described in further detail below. The clip 502, 2803, 3701, 3702 may optionally have a provision for attaching a stanchion 503, 2808 described in further detail below, which supports the receiver tube 1301, 2801 also described in further detail below.

[00066] The wings 501, 2802 may also be independently rotated so they may close in upon each other in a clamshell like configuration 504 which allows for the protection or storage of the collector. Specifically, the wings may be attached pivotably to allow each wing to pivot and rotate on top of the other 504. This protects the inside of the panel and reduces the wind load profile. The wing is driven by a sprocket assembly that when reaching a certain point, engages the second half of the panel and drives it synchronously. The wings, also or instead may be decorative.

5. Reflective Panels

[00067] As shown in Fig. 6 and Fig. 26, the core supports reflective element panels or panel segments 601, 2602 that are placed onto the formed foam surface 602, 2603. One or more reflective panels 601, 2602 may form the reflective surface upon the support structure. The reflective element may be a flexible material such as polished aluminum, aluminum laminated with reflective Mylar, or other suitable material such as epoxy sputtered with silver or a glass mirror. Preferably, a flexible aluminum panel polished to a mirror finish is used as the reflective element. The reflective element may be flexible so that a flat sheet of the reflective element can be bent into the desired shape at room temperature and pressure, or the reflective element may be rigid at room temperature and pressure but capable of being deformed into the desired shape using heat and optionally pressure or vacuum.

[00068] One or more flat but flexible reflective panels 601, 2602 may be retained onto the formed foam surface 602, 2603 mechanically through the use of cowlings 702 (Fig.

7) and 2805 (Fig. 28-30) and end caps 703, 2804 discussed in further detail below, or through the use of adhesion using an adhesive such as 3M adhesive, or both. The formed foam material 602, 2601 beneath the reflective element provides the desired panel shape (such as parabolic shape, flat, or partially parabolic shape that a wing may take).

5 6. Top and Bottom Longitudinal Cowlings

[00069] As shown in Fig. 7 and 28-30, the formed foam material 701 and the reflective element 2807 may be mechanically held together using reinforcing cowlings 702, 2805 on each longitudinal edge of the parabola pieces. The cowlings 702, 2805 mechanically hold the reflective element in place and provide rigidity. The end caps 703, 2804 discussed in further detail below, may also serve to mechanically hold down the reflective element to the core 701.

[00070] The top and bottom cowlings 702, 2805 may be made of aluminum (polished or unpolished) or other metal such as stainless steel that has high rigidity or a plastic. The cowlings 702, 2805 may be applied by positioning inserts 704 or 3101 or 3201 of Fig. 31 and 32, discussed in further detail below, to allow fasteners to be placed into the core foam material 701, 3102, 3202. An alternative may include using glue to bond the cowlings 702, 2805 to the foam material 701, 3102, 3202 or using a band or cable to join the upper and lower cowlings 702, 2805 to prevent deflection under load.

[00071] The top and bottom cowlings 702, 2805 may also accommodate a variety of thicknesses of the combination of core, reflective element, and/or backing through the use of laterally opposed interlocking notches 706 to provide a cowling with variable opening size. This assembly 705 allows for the adjustability of the opening of the cowling assembly to accommodate varying thicknesses of the combination of the formed foam material, outer coating, and the reflective element. The adjustability of the opening may also accommodate the need to add, change, or remove the reflective material. This cowling assembly 705 also serves to lock the adjusted width in place because the cowlings legs rotate in towards the center as the width is adjusted, thereby providing increased holding pressure on the combination of the formed foam material, outer coating, and the reflective element. This may provide a significantly stronger and more secure attachment of the reflective material. Lastly, the top and bottom cowlings 702 are secured longitudinally with inserts 704 through the center to engage the edge of the panels and force the reflective material to form and maintain a parabolic shape.

[00072] The cowlings may be made of flat sheet stock that is bent into a shape to conform with the longitudinal edges of the core, or the cowlings may be rigid channels or conformal material that, alone or together with the core material, provide rigidity to the arc-shaped reflector formed from the core, reflector material, longitudinal cowlings, and optional end caps. The cowlings may themselves be polymeric (e.g. polycarbonate, solid rigid polystyrene), metallic (e.g. aluminum, stainless steel, or other material), ceramic, or other material that aids in protecting the core as well as providing additional rigidity.

7. Transverse End Caps

[00073] As shown in Fig. 8 and Fig. 28-30, a support structure may also have transverse end caps 801, 2804 which provide further rigidity to the assembly and resistance to flexure and/or torsion. The end caps 801, 2804 located at either end of the collector are identical and may be attached to an end arm 901 (Fig. 9), 2806 (Fig. 28-30) described below. The end caps 801, 2804 may be made of any suitable rigid material, preferably aluminum (polished or unpolished) or another metal, such as stainless steel, that has high rigidity. The end caps 801, 2804 may be used at both ends of the panels to further lock the reflective element in place, transfer load, retain the parabolic shape and provide additional structural strength to the panel design.

[00074] The end caps 801, 2804 may be a single piece of metal stamped, or otherwise cut, from a sheet and having a surface that has a shape which is generally parabolic or substantially arc-shaped to fit the profile of the formed foam material and provide a structural frame. The end caps 801, 2804 preferably may have a tab such as an outer perimeter tab to encase the edge of the formed foam material and to allow for points of attachment. The tab may therefore be configured to overlap the reflector and/or cowlings, and the tab may be configured to allow the core to insert within the tabbed portion of the end cap so that the assembled pieces may be secured. The tab may protect the edge of the panel, hold the reflective element in place, add a dimension to the end cap 801, 2804 for rigidity, and provide a finished look to the support structure.

[00075] One or more ribs may be used in place of or in addition to end caps. Ribs attach directly to the end arms and form arc-shaped members that make the end-arm a more rigid structure independently of whether reflector panels or wings are attached to the core and end-arms. A rib is therefore separate from a reflector panel or wing and end cap as discussed above.

8. End Arms

[00076] End arms help to support mirrored panels and transmit movement induced by a motor to the panels to track the sun's apparent movement. An end arm may be configured in a number of ways.

5 [00077] As shown in Fig. 9 and Fig. 33, the end arms 901, 3301 may be similar to the end arms described in prior patent applications incorporated by reference herein. The support structure may have transverse end arms 901, 3301 which provide further rigidity to the support structure and resistance to flexure and/or torsion. The end arms 901, 3301 located at either end of the collector, are identical and may be attached to a stand.
10 Additionally, the end arm 901, 3301 may rotate as one unit about the longitudinal axis.

[00078] An end arm 505 as illustrated in Fig. 5 may be formed by stamping or otherwise cutting the end arm from sheet-metal. An end arm can be a single piece of material such as metal stamped from sheet-stock, so that the end arm depicted in Fig. 5 has a generally "T"- or "Y"- shaped structure. Alternatively, an end arm may be formed using
15 two pieces as shown in Fig. 5 that each have a generally "L"- shaped structure. In this instance, the two stampings may be identical and positioned together during assembly to provide a generally "T- or "Y"- shaped structure when the support structure is viewed from the side. An end arm 505 may also be formed by superimposing two or more end pieces having a "T," "Y," or "L" shape and attaching them to one another directly or with or
20 without a cowling. An end arm need not be "T"- or "Y" shaped. It may be solid or perforated to which parts are attached, for instance.

[00079] An end arm 901 may be formed from individual fittings such as welded, die cast, or molded fittings that are formed to accept tubing, rods, or other fitting couplers and attach to the wings. As depicted in Fig. 33 and 34, the fittings may comprise a bottom fitting
25 3302 that engages with bottom cowling of adjacent arc-shaped reflectors, an end fitting 3303 that engages with an arc-shaped reflector 3305 (two of which are shown stacked awaiting assembly to the end arms), and a hub fitting 3304.

[00080] A bottom fitting 3302 may have a collar or shape 3308 that engages another depression or opening 3309 of the same or an adjacent panel. A bottom fitting may be
30 formed in one piece as shown so that the piece engages both of the reflective panels of adjacent panels to form a larger arc from the two panels. A bottom fitting may instead be formed in two or more pieces that are secured to one another. A bottom fitting may have

one or more collar portions 3313 that overlie an edge of the reflective layer or element and/or the cowling 3314 as well as the core. The collar portion 3313 may also or instead overlap a backing material 3315 applied to the core. The bottom fitting may also have holes that allow e.g. a bolt or screw to engage with a fastener or anchor in the core. A bottom
5 fitting may also have one or a plurality of holes 3316 that receive fitting couplers 3317 that engage with the hub fitting.

[00081] An end fitting 3303 may have a collar or shape 3306 that engages a recess or opening 3307 in the arcuate reflector panel 3305. Screws or bolts may be inserted through holes 3310, 3311 in the end and bottom fittings to secure an arc-shaped reflector to fittings
10 in the core by screwing into anchors in the foam or honeycomb beneath the optional end-caps. An end fitting may have one or more collar portions 3318 that overlie an edge of the reflective layer and/or the cowling as well as the core. The collar portion may also or instead overlap a backing material applied to the core. An end fitting may also have one or a plurality of holes 3319 that receive fitting couplers 3320 that engage with the hub fitting.
15 An end fitting may also optionally have a flat rectangularly-shaped surface 3322 along an edge of the end-fitting so that e.g. a flat bar 2901 (Fig. 29) can be attached upon the edge of adjacent collectors to gang the collectors together and therefore move multiple collectors simultaneously using a single motor and drive sprocket.

[00082] A hub fitting 3304 may have the locator tube collar mentioned previously, an
20 end of which is depicted as 3312 in Fig. 33 and the collar end of which is seen as 2809 in Fig. 28. As shown in these figures and in Fig. 23, a locator tube collar 2301, 2809 of the hub fitting 3304 may be used to connect the end arms 901 perpendicular to the locator tube 2201. The hub fitting may have means for mounting a drive sprocket 3001 as seen in Fig. 30. Such means include holes 2810 (Fig. 28) such as threaded holes for bolts, a
25 keyway and corresponding key (either as a separate piece or formed integrally with the hub fitting), screws, rivets, welding, adhesive, and any other known fastening arrangement for securing one piece to another. A hub fitting 3304 also may have holes 3321 extending radially from the hub and into which couplers 3317, 3320 insert to couple a plurality of end fittings and one or a plurality of bottom fittings. The locator tube 2201 (Fig. 22) inserts
30 through the locator tube collar 2301, 2809 of the hub fitting and engages with a bearing. The bearings may be roller, ball, plastic, or graphite bearings that are retained in the stand by screws in the stand and from a cap that mates with the stand. The hub fitting, made of

any suitable rigid material, preferably aluminum (polished or unpolished) or another metal such as stainless steel that has high rigidity, slides onto the locator tube 2201 and may be secured with bolts and/or a keyway 2202. The keyway may allow for accurate positioning of the locator tube collar 2301, 2809 on the locator tube 2201. The collar 2301 may consist
5 of one or more elements that allow each end arm 901, 3301 to rotate independently of the other so the wings may rotate together in a clamshell configuration as mentioned earlier.

[00083] Couplers 3317 and 3320 may run radially from the hub fitting 3304 on a locator tube collar and to the end 3303 and bottom 3302 fittings, thereby forming generally two “L” shapes or a “Y” shape. Various lengths of couplers may be used to adjust the shape
10 and length of the end arm 901, 3301 to allow forming collectors of varying aperture widths mentioned earlier. The fittings may be rods such as solid or tubular metal rods (e.g. aluminum), and the rods may be e.g. cylindrical, square, rectangular, regular, or irregular in cross-section.

[00084] The fittings and/or couplers may be formed of polymer (such as a rigid non-foamed polymer as discussed herein), metal such as aluminum, ceramic, or other suitable
15 material.

9. Corner End Panel Interconnect

[00085] As shown in Fig. 10, there may be a corner end panel interconnect 1001 that serves to tie the end caps 1102 to the cowlings 702 structurally, providing for extra strength
20 and support. The corner end panel interconnect 1001 may be made of any suitable rigid material, preferably aluminum (polished or unpolished) or a metal such as stainless steel that has high rigidity. It is either die cast or metal stamped into its desired shape.

[00086] The corner element 1001 may bridge one panel to another to maintain alignment and transfer torque to the next row of collectors. Potentially, multiple corner end
25 panel interconnect 1001 pieces may be used to tie the bottom cowlings together to form an I-beam type structural member. This member may also be a one piece extruded shape.

[00087] An interconnect may also be a section of flat bar 2901 (Fig. 29), for instance. And end fitting may have a flat rectangularly-shaped surface 3322 along an edge of the end-fitting so that e.g. flat bar 2901 can be attached to the edge of adjacent collectors to gang the
30 collectors together and therefore move multiple collectors simultaneously using a single motor and drive sprocket.

10. Inserts/anchors

[00088] As shown in Fig. 11, 31, and 32, inserts 1101, 3101 or embedded anchors 3201 may be used to attach the cowlings (e.g. Fig. 7 702, Fig. 28-30 2805) to the formed foam material 701, 3102, 3202. One insert or anchor 1101, 3101, 3201 may be used every
5 few feet. The inserts or embedded anchors may also be used to secure the end caps 1102 that maintain the parabolic shape and engage with the end arms 901, 2806 as a means of support.

[00089] An insert may be glued into foam or other polymer of a core, as shown in Fig. 31. The foam may be melted, and an insert may be anchored into the foam by heating
10 and embedding it and allowing the polymer to resolidify around the anchor. As shown in Fig. 32, a small hole may be formed in a surface of the foam by melting the surface, and the insert may be glued into the hole.

11. Fastener (e.g. clip)

[00090] As shown in the figures, a clip (502 (Fig. 5), 1201 (Fig. 12), 2803 (Fig. 28-
15 30)) such as an H-clip may be used to attach two arc-shaped reflectors 501, 2802 together at the bottom of a parabola by connecting the cowling of one arc-shaped reflector to the cowling of the opposite reflector. A clip such as an H-clip may therefore have two sets of arms, one set that engages one arc-shaped reflector and one set that engages the other arc-shaped reflector.

20 [00091] A clip 502, 1201, 2803 may also optionally have a provision for attaching a stanchion 1401, 2808 to support the receiver tube 1301 and glass envelope 2001. The stanchion 1401, 2808 may be positioned on top of the H-clip 1201 in the center of collector. This allows the stanchion 1401 to remain stationary and ensures the receiver tube 1301 is always centered at the focal point of the collector.

25 [00092] A clip as used in the collector depicted in Fig. 28-30 may not have the exact shape of an "H" as the H-clip of Fig. 12 has. A clip 3701, 3702 in this instance may have a cross-section similar to that depicted in Fig. 37A or 37B and be generally H-shaped.

[00093] The fastener need not be a clip. For instance, the fastener may be a screw that joins flat tabs from adjoining cowling together or a latch and receiving portion on
30 adjacent panels, for instance.

[00094] A clip may span some or all of the distance from one end cap to the other end cap. Since a clip need only provide an attachment point to improve rigidity of the assembly, a clip may be relatively short, being less than about 1/10 of the length of the cowling with which it engages. If further rigidity is desired, the clip can be made longer. The clip may be positioned at a midpoint along the longitudinally extending cowling for instance, or multiple clips may be positioned approximately equidistantly along the longitudinally extending cowling.

12. Longitudinal Collector Tube

[00095] As shown in Fig. 13 and Fig. 28-29, a longitudinal collector tube 1301, 2801 similar to that described in prior patent applications incorporated by reference above, may be positioned with the parabola to receive light and solar thermal energy reflected by a parabolically-shaped reflective panel of a solar energy collector.

[00096] The collector or receiver tube 1301, 2801 may have a working fluid, preferably an oil, Freon or water, working through the interior of the pipe. The receiver tube 1301 may connect to a joint or pass through a locator tube collar 2301 (Fig. 23) (3312 of hub 3304 in Fig. 33) and locator tube 2201 (Fig. 22) joined to a stand 2401 (Fig. 24) that supports the support structure. Each support structure may have its own receiver tube 1301, 2801 that joins to adjacent receiver tubes through joints, hoses, or other types of connectors typically used in joining tubes that will undergo thermal expansion and contraction.

Alternatively, a single receiver tube 1301, 2801 may be used for ganged support structures or for two or three adjacent support structures. A support structure may have one or more stanchions 1401, 2808 to support the receiver tube, as explained in further detail below. The receiver tube may be painted with black paint or coated with a coating that absorbs solar energy and transmits the resultant heat to the tube wall. If the trough solar energy collector has an axis of rotation coaxial with the collector tube, the collector tube may be configured to rotate with the trough solar energy collector, or the collector tube may be fixed in position so that the trough collector rotates about the stationary collector tube. If the axis of the collector tube does not coincide with the rotational axis of the trough solar energy collector, the collector tube may revolve about the axis of rotation of the trough solar energy collector.

13. Stanchion

[00097] As shown in Fig. 14 and Fig. 35, one or more stanchions 1401,3501 similar to those described in prior patent applications incorporated by reference above, may be used to support a longitudinal receiver tube 1301 by means of a bearing (Fig. 15 1501, Fig. 35 3502) and bearing attachment (Fig. 17 1702, Fig. 35 3503) as explained in further detail below, as well as to support the glass envelope 2001 described below. One or more two-leg stanchions and/or single-leg stanchions 1401 are positioned between transverse end arms 901 and may attach to the arc-shaped reflector panel. The stanchion 1401, 3501 may be positioned on top of or formed as part of a clip 1201, 3504 in the center of the collector to keep it stationary and ensure the receiver tube 1301 is always centered at the focal point. A stanchion 1401, 3501 may be made of any suitable rigid material, preferably aluminum, stainless steel, or the like, may have adjustment screws 1503 or bolts or plastic screws, explained below, which can be adjusted to provide better reflective focus across the collector.

[00098] Collector tube height can be adjusted by moving the plate 3506 on which the bearing rests up or down and then tightening the bearing attachment 3503 to secure the collector tube 3507 and bearing 3502 in place. An additional cap (not shown for sake of clarity) engages with bolt-holes 3508 onto the stanchion to retain an insulating glass envelope (discussed below).

14. U-Bolt Assembly

[00099] As shown in Figs. 15-18, a U-bolt assembly may be used to fasten the receiver tube bearing 1501, described below, to the stanchion 1401, thereby allowing for adjustability of the receiver tube 1301. The U-bolt assembly shown in Figs. 15-18, which is secured by nuts, extends in a “U” shape through the bottom of the stanchion 1401, around the receiver tube bearing 1501, and back through the other side of the stanchion. Additionally, there may be a bolt extending through the bottom of a bracket where the “U” bolt is attached. This allows for height adjustments of the receiver tube bearing 1501 centering the receiver tube 1301.

15. Receiver Bearing Adjustment Screw

[000100] As shown in Figs. 15 and 16, stanchions may have adjustment screws 1503 and 1601 or bolts or plastic screws that can be adjusted to provide better reflective focus

across the collector. Adjustment screws 1503 and 1601 may adjust the height of the receiver tube bearing 1602 to provide optimal reflective focus across the length of the collector, thereby increasing collector efficiency.

16. Receiver Tube Bearing Attachment

5 [000101] As shown in Fig. 17, a receiver tube bearing attachment 1701 may be used to accommodate the thermal expansion and contraction of the receiver tube 1301. The bearing attachment 1701 permits the panels to rotate around the receiver tube 1301 and position the receiver tube 1301 to ensure maximum reflective focus and collector efficiency. This allows the receiver tube 1301 to slide longitudinally as the receiver tube 1301 expands and
10 contracts.

17. Stanchion Bracket

[000102] As shown in Fig. 18 and 33, stanchion brackets 1801, 3303, 3305 may be used to support the glass envelope 2001, described below. The brackets 1801, 3303, 3305 may be made of any suitable rigid material, preferably aluminum, stainless steel, or
15 otherwise, clamp together to compress against the glass and provide support across the length of the glass envelope 2001. An additional cap (not shown for sake of clarity) engages with bolt-holes 3508 on the stanchion bracket 3505 to retain an insulating glass envelope.

18. Gaskets

[000103] As shown in Fig. 19, silicone 1901, preferably, or another resilient polymer, organic or inorganic gel, ceramic or metals able to withstand high temperatures as described
20 in prior patent applications incorporated by reference above, may be used to support the glass envelope 2001 and serve as an end seal. The silicone foam gaskets 1901 are placed at the ends of the glass envelope 2001 between the receiver tube 1301 and the glass and are clamped down by a bracket secured with bolts.

25 [000104] The seal created contains the ambient atmosphere within the chamber of the glass envelope 2001 when a cover, described below, is placed on or in the opening of the glass envelope 2001 housing. The silicone end seals 1901 may be pliable and movable to allow thermal expansion without undue stress being created on the ends of the glass envelope 2001 or the receiver tube 1301.

19. Glass Envelope

[000105] As shown in Fig. 20, the glass envelope 2001, a transparent tubular housing similar to those described in prior patent applications incorporated by reference above, may be used to enclose the receiver tube 1301 to provide an insulating layer and reduce heat loss.

5 The glass envelope 2001 may vary in thickness, preferably around 2 millimeters thick and may have a chamber that is sufficiently large to contain the receiver tube 1301 positioned within the glass chamber. The glass envelope 2001 may be transparent to UV, visible, and/or infrared light. Preferably, the glass envelope 2001 is transparent to at least the sun's visible and infrared radiation. The envelope 2001 may be formed from borosilicate glass
10 such as Pyrex. Alternatively, the envelope 2001 may be formed of an acrylic polymer such as polymethacrylate, a butyrate, a polycarbonate, or other polymer that admits at least 70% of the sunlight 14 incident upon it. The glass envelope 2001 may contain air, other gases, or be evacuated or partially evacuated in some variations.

[000106] Additionally, the glass envelope 2001 may be sliced to shape leaving at least
15 one opening to allow easy access to the chamber, so the envelope 2001 may be placed over the receiver tube 1301 without having to slide it on and risk breakage. This opening allows for convenient and easy installation, assembly, replacement, and cleaning. The one or more openings may run the entire length of the glass envelope 2001 and may be as wide as or wider than the receiver tube 1301 that is to reside within the chamber of the envelope 2001.
20 Once placed over the receiver tube 1301, the glass envelope 2001 opening may be filled with an inner and outer reflective cover 2101 described below, and an insulating material 2102, all of which are sealed by the silicone foam gaskets 1901.

[000107] A glass envelope may be a telescoping envelope as illustrated in Fig. 36. One glass tube 3601 nests within a second glass tube 3602 around a collector tube 3603.
25 During collector assembly, the nested tubes are placed over the collector tube, and subsequently the outer glass tube is slid along the inner glass tube so that one of the tubes can be secured to a side of the stanchion and the other of the glass tubes can be secured to or in the vicinity of the locator tube collar 3312 of the hub 3304 of Fig. 33.

20. Inner and Outer Reflective Cover

30 [000108] As shown in Fig. 21, a cover assembly, similar to that described in prior patent applications incorporated by reference above, may be placed on or in the glass envelope 2001 opening, and may or may not be retractable. The cover assembly may consist

of an inner and outer cover 2101, as well as insulating material 2102. The cover assembly may be attached in a manner to allow the cover be retractable for venting and cleaning of the glass envelope 2001.

[000109] The inner and outer covers 2101 are often movable and may fit within or
5 upon the one or more openings of the glass envelope 2001. The inner and outer covers 2101 may be made of any suitable rigid material, preferably aluminum (polished or unpolished), may be formed of a metal such as stainless steel that has high rigidity, or may be silvered to make a reflective surface. The outer cover 2104 may provide a protective backing for the glass envelope 2001. The inner cover 2103 acts as a lens to better direct solar radiation onto
10 the receiver tube 1301. The inner cover 2103 focuses solar energy upon the receiver tube 1301 when it is seated in the glass envelope 2001 and reflects any solar radiation that is not reflected directly onto the receiver tube 1301. The inner cover's 2103 surface may reflect at least 50% of the radiation incident upon it, and preferably the surface reflects greater than 80% or 90% of the radiation incident upon it. Inserted in between the inner and outer cover
15 2101 is a thermally insulating material 2102 able to withstand high temperatures, preferably a rigid polymer like polycarbonate, polyamide, or polyimide that may have a mirrored coating to reflect light. The insulating material 2102 and the inner and outer covers 2101 may be clamped together by a bolt, screw, rivet, or any other suitable fastener.

21. Locator Tube

20 [000110] As shown in Fig. 22, a locator tube 2201, similar to that described in prior patent applications incorporated by reference above, may be used to support a solar collector, as well as to join two solar collectors together. The tube 2201, which extends through an end arm 901, may be made of any suitable rigid material, preferably aluminum (polished or unpolished) or a metal such as stainless steel that has high rigidity. In addition,
25 the locator tube 2201 rests on a stand 2401, described below, allowing it to rotate around the receiver tube 1301. The locator tube 2201 may also contain a keyway or a key which allows it to drive the locator tube collar 2301 described below.

[000111] The locator tube 2201 and locator tube collar 2301 may each have holes through which bolts or adjusting screws, for example, extend. The bolts or screws secure the
30 locator tube collar 2301 and locator tube 2201 so that they rotate in unison. Additionally, the bolts or screws may extend through the holes to support the receiver tube 1301 and the

locator tube may be used as a race for the bearing to allow the receiver tube 1301 to pass through.

22. Stand

[000112] As shown in Fig. 24, a support structure is typically secured to stands 2401
5 containing bearings, similar to those described in prior patent applications incorporated by
reference above, to allow the support structure to pivot along an axis defined by the
bearings. The stand 2401 may be made of aluminum (polished or unpolished) or a metal
such as stainless steel that has high rigidity. The stand 2401 may have a locator tube 2201
extending through the bearing at either or both ends of the bearing and extending into a
10 locator tube collar 2301 of the support structure, thereby providing a more rigid structure.

23. Torsion Cables

[000113] As shown in Fig. 25, the support structure 2502 may have optional torsion
cables 2501, similar to those described in prior patent applications incorporated by reference
above, that may extend diagonally from one end arm to the opposite end arm of the support
15 structure 2502. The torsion cables 2501 may therefore cross in an "X"- shaped
configuration, for instance. The torsion cables 2501 help provide a rigid structure that resists
torsion without adding significant weight to the support structure or shading to the solar
panels or reflective element.

What is Claimed:

1. A trough solar energy collector having a rotational axis comprising
 - (a) a collector tube,
 - 5 (b) a first reflective panel and a second reflective panel,
 - (i) each of said first and second reflective panels comprising
 - (1) a honeycomb or polymeric core having an arc-shaped surface
 - (2) a reflector on the arc-shaped surface of the polymeric core
 - (3) cowling along a longitudinal edge extending along the
 - 10 polymeric core and extending parallel to the rotational axis of the solar collector
 - (ii) the first reflective panel being positioned to illuminate a first side of the collector tube,
 - (iii) the second reflective panel being positioned to illuminate a second
 - 15 side of the collector tube.
2. A collector according to claim 1 wherein the core is polymeric and comprises expanded polystyrene, extruded polystyrene, or expanded extruded polystyrene.
3. A collector according claim 1 or claim 2 wherein the core is polymeric and the polymeric core is skinless.
- 20 4. A collector according to any of claims 1-3 wherein the core is polymeric and the polymeric core is uniform in compression and tension.
5. A collector according to any of claims 1-4 wherein the core is polymeric and an outer surface of the polymeric core is coated with a UV inhibitor or an externally affixed material such as metal, plastic, fiberglass, or canvas which provides impact resistance
- 25 and/or durability against harsh weather.
6. A collector according to any of claims 1-5 wherein the collector tube is coincident with the rotational axis of the solar collector,
7. A collector according to any of claims 1-6 wherein a portion of the cowling overlies an edge of the reflector to aid in securing the reflector to the core.
- 30 8. A collector according to any of claims 1-7 and further comprising a fastener, said fastener being positioned between the first reflective panel and the second reflective panel

such that the fastener engages an edge of the cowling of the first reflective panel and an edge of the cowling of the second reflective panel.

9. A collector according to claim 8 wherein said fastener is a clip having first and second sets of arms and positioned between the first reflective panel and the second

5 reflective panel such that the first set of arms engages an edge of the cowling of the first reflective panel and the second set of arms engages an edge of the cowling of the second reflective panel.

10. A collector according to claim 9 wherein the clip further comprises a stanchion that supports the collector tube.

10 11. A collector according to any of claims 1-10 and further comprising an end arm comprising

(a) a hub fitting having an opening through which the collector tube passes,

(b) a plurality of top fittings configured to engage with top portions of respective ones of the first reflective panel and the second reflective panel,

15 (c) a bottom fitting configured to engage with bottom portions of each of the first reflective panel and the second reflective panel, and

(d) a plurality of fitting couplers securing the plurality of top fittings and the bottom fitting to the hub fitting.

12. A collector according to claim 11 wherein the hub fitting has a collar at said opening
20 to engage with a locator tube of the collector and means for securing the collar to the locator tube.

13. A collector according to claim 12 wherein at least one of the locator tube and the hub fitting has a keyway for engagement of the locator tube and the hub fitting.

14. A collector according to any of claims 11-13 wherein the hub fitting has additional
25 means for mounting a drive sprocket to the hub fitting.

15. A collector according to any of claims 11-14 wherein the hub fitting has holes extending radially from the hub fitting to engage ends of the fitting couplers.

16. A collector according to any of claims 11-15 wherein the top fittings have collar portions into which edges of the first and second reflective panels insert.

30 17. A collector according to any of claims 11-16 wherein the top fittings or the reflective panels have openings and the other of the top fittings or the reflective panels have shapes that insert into the openings to engage the top fittings with the reflective panels.

18. A collector according to any of claims 11-17 wherein the bottom fitting or the reflective panels have openings and the other of the bottom fitting or the reflective panels have shapes that insert into the openings to engage the bottom fitting with the reflective panels.
- 5 19. A collector according to any of claims 11-18 wherein the bottom fitting has a collar portion into which edges of the first and second reflective panels insert.
20. A collector according to any of claims 11-19 wherein the fitting couplers are rods and insert into the holes of the hub fitting and additionally holes of the top and bottom fittings to form the end arm.
- 10 21. A collector according to any of claims 11-20 wherein a plurality of the fitting couplers interconnect the hub fitting with the bottom fitting.
22. A collector according to any claim above wherein the polymeric core has a convex arcuate profile in addition to a concave arcuate profile.
23. A collector according to any claim above and wherein the first and second reflective
15 panels further comprise end caps.
24. A collector according to claim 23 wherein the end caps have perimeter encasing tabs that engage the reflectors and the polymeric cores.
25. A collector according to claim 24 wherein the encasing tabs overlie the reflectors, the polymeric cores, and the longitudinally-extending cowling.
- 20 26. A collector according to any claim above and wherein the collector tube does not rotate or revolve about the rotational axis of the collector.
27. A collector according to any claim above wherein the reflective panels are flexible at room temperature.
28. A collector according to claim 27 wherein the reflective panels comprise polished
25 aluminum.
29. An end arm in assembled or disassembled form comprising
- (a) a hub fitting having an opening,
 - (b) a plurality of top fittings configured to engage with top portions of respective ones of a first reflective panel and a second reflective panel,
 - 30 (c) a bottom fitting configured to engage with bottom portions of each of the first reflective panel and the second reflective panel, and
 - (d) a plurality of fitting couplers securing the plurality of top fittings and the bottom fitting to the hub fitting.

30. An end arm according to claim 29 wherein the hub fitting has a collar at said opening to engage with a locator tube and means for securing the collar to the locator tube.

31. An end arm according to claim 30 wherein at least one of the locator tube and the hub fitting has a keyway for engagement of the locator tube and the hub fitting.

5 32. An end arm according to any of claims 29-31 wherein the hub fitting has additional means for mounting a drive sprocket to the hub fitting.

33. An end arm according to any of claims 29-32 wherein the hub fitting has holes extending radially from the hub fitting to engage ends of the fitting couplers.

10 34. An end arm according to any of claims 29-33 wherein the top fittings have collar portions into which edges of first and second reflective panels insert.

35. An end arm according to any of claims 29-34 wherein the top fittings have openings or shapes to engage with corresponding shapes or openings on reflective panels to allow engaging the top fittings with the reflective panels.

15 36. An end arm according to any of claims 29-35 wherein the bottom fitting has openings or shapes to engage with corresponding shapes or openings on reflective panels to allow engaging the bottom fitting with the reflective panels.

37. An end arm according to any of claims 29-36 wherein the bottom fitting has a collar portion into which edges of reflective panels insert.

20 38. An end arm according to any of claims 29-37 wherein the fitting couplers are cylindrical and insert into the holes of the hub fitting and additionally holes of the top and bottom fittings to form the end arm.

39. An end arm according to any of claims 29-38 wherein a plurality of the fitting couplers interconnect the hub fitting with the bottom fitting.

40. A method comprising

- 25 (a) simultaneously slicing a plurality of arcuate reflector cores from a polymer blank
- (b) placing reflective surfaces on concave portions of the arcuate reflector cores
- (c) affixing cowling along edges of the arcuate reflector cores to form arc-shaped reflectors.

30 41. A method according to claim 40 and further comprising affixing a first and second reflector selected from said first plurality of arc-shaped reflectors and said second plurality of arc-shaped reflectors along an adjacent edge of each of said first and second arc-shaped

reflectors at a mid-point between a larger arc formed by the first and second arc-shaped reflectors and distant from ends of the first and second arc-shaped reflectors.

42. A method comprising

- 5 (a) using a first set of sliced polymeric cores to form a first plurality of arc-shaped reflectors;
- (b) using a second set of sliced polymeric cores to form a second plurality of arc-shaped reflectors;
- 10 (c) affixing a first and second reflector selected from said first plurality of arc-shaped reflectors and said second plurality of arc-shaped reflectors along an adjacent edge of each of said first and second arc-shaped reflectors at a mid-point between a larger arc formed by the first and second arc-shaped reflectors and distant from ends of the first and second arc-shaped reflectors.

43. A method according to claim 42 and further comprising affixing cowling along edges of the polymeric cores.

15 44. A method according to any of claims 40-43 and further comprising affixing end caps onto the polymeric cores.

45. A method according to claim 44 wherein the end caps have perimeter encasing tabs that engage the polymeric cores and the longitudinally-extending cowling.

20 46. A method according to any claim of claims 40-45 wherein the polymer comprises polystyrene.

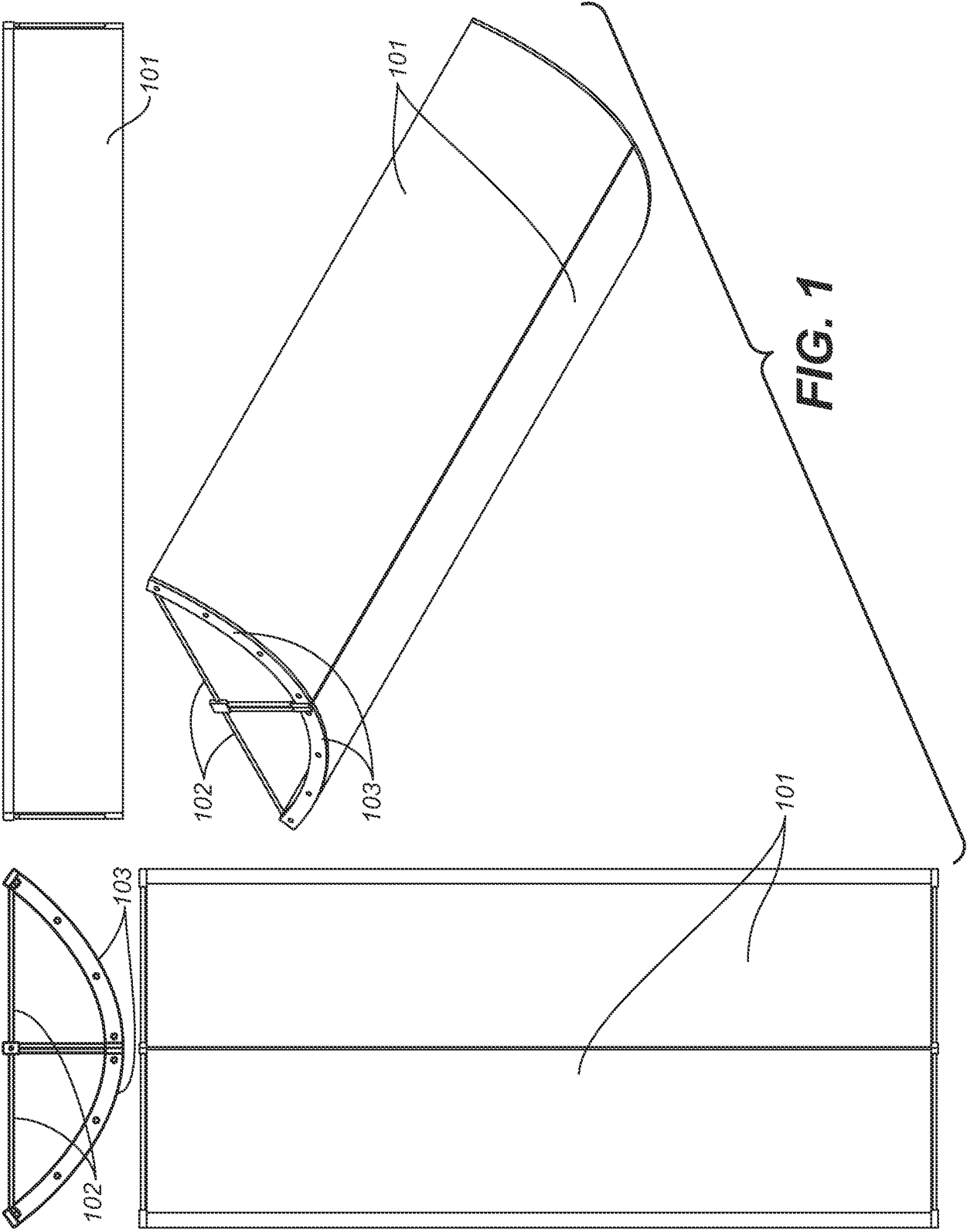
47. A method according to claim 46 wherein the polystyrene comprises at least one selected from expanded polystyrene, extruded polystyrene, and extruded expanded polystyrene.

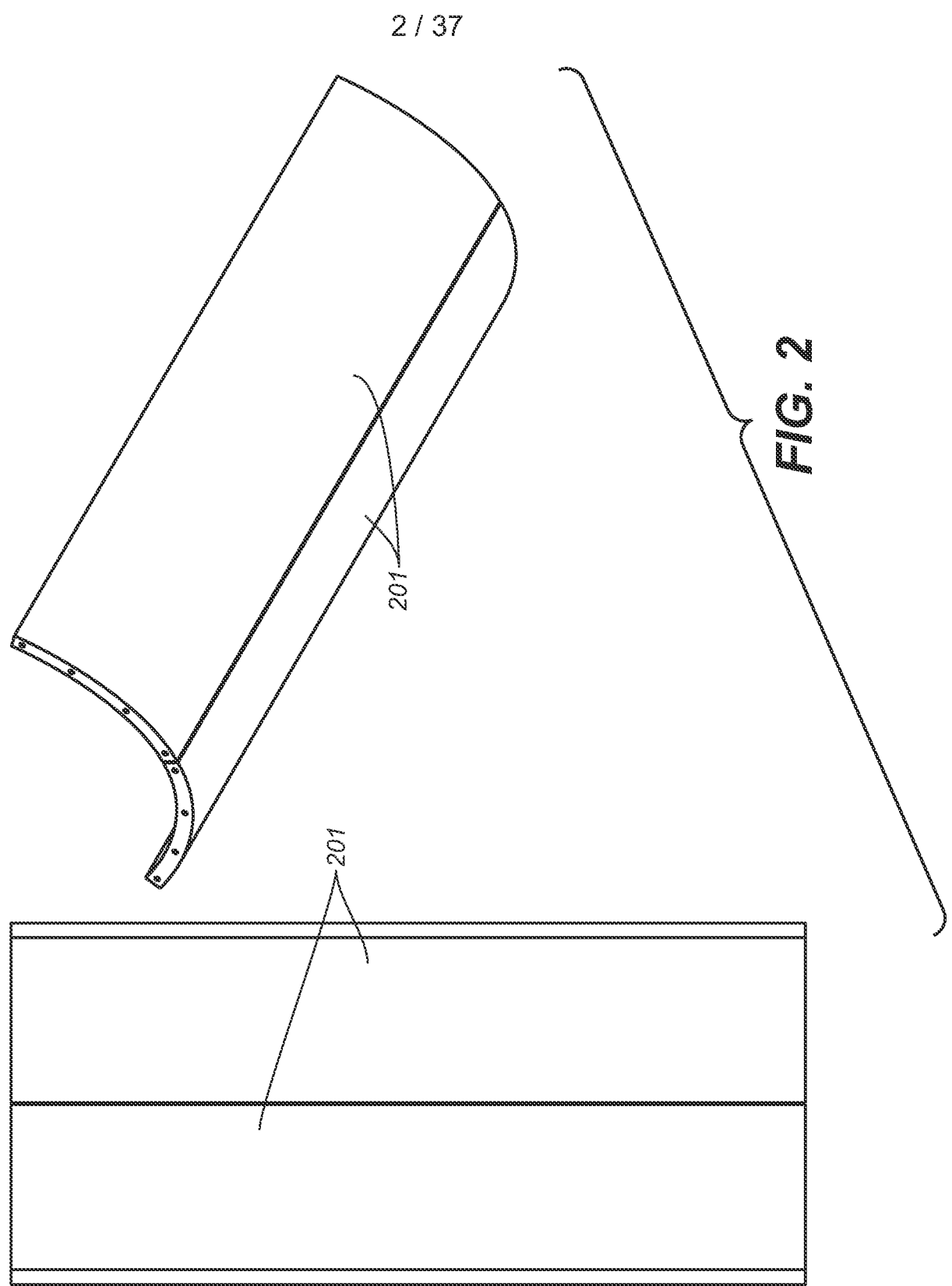
25 48. A method according to any claim of claims 40-47 wherein the act of affixing the first and second reflector comprises joining the first and second reflector at a longitudinal mid-point with a clip.

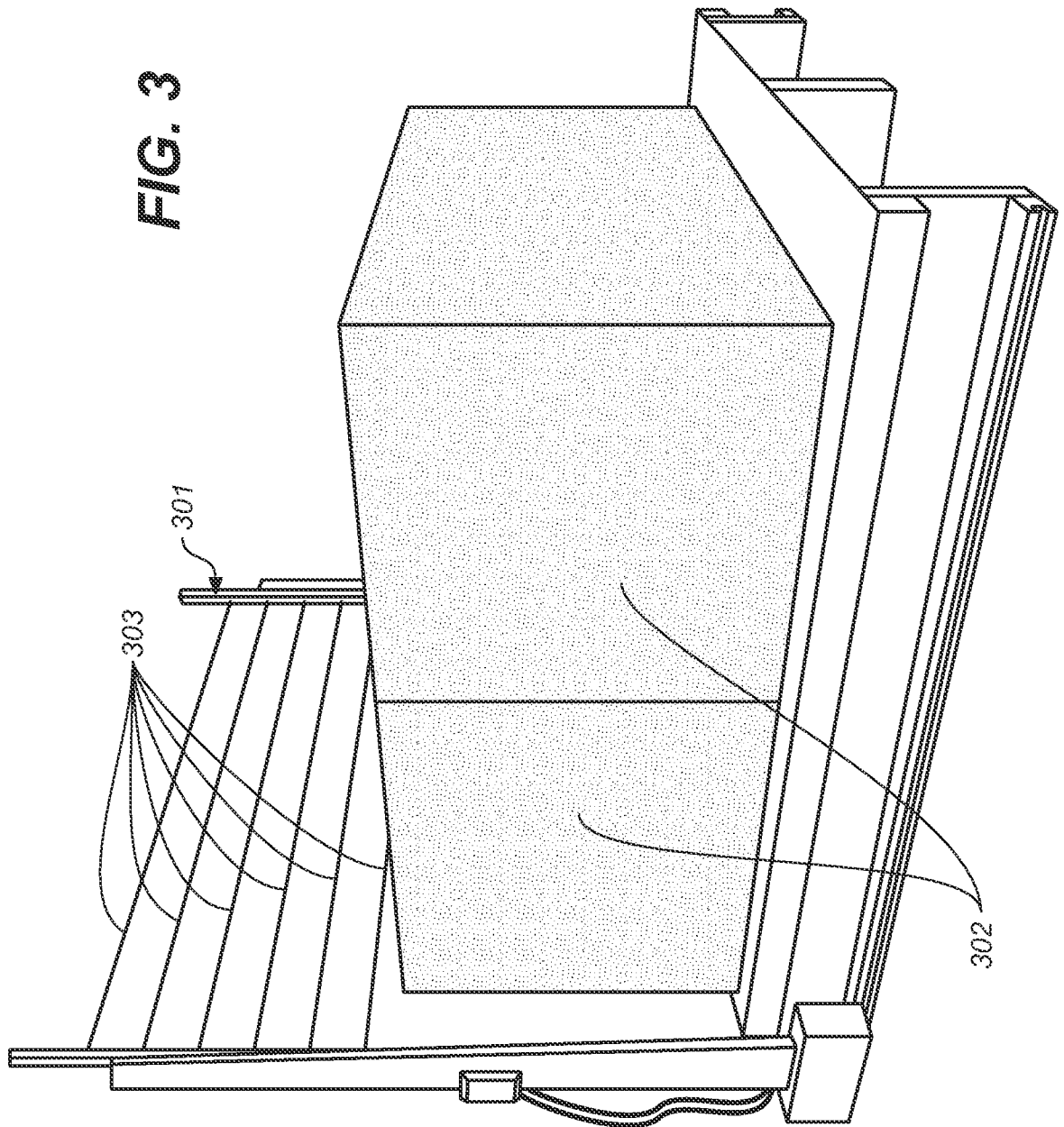
49. A method according to claim 48 wherein arms of the clip are secured to the first and second reflector.

30 50. A method according to any of claims 40-49 and further comprising affixing end arms of any of claims 29-39 to said arc-shaped reflectors.

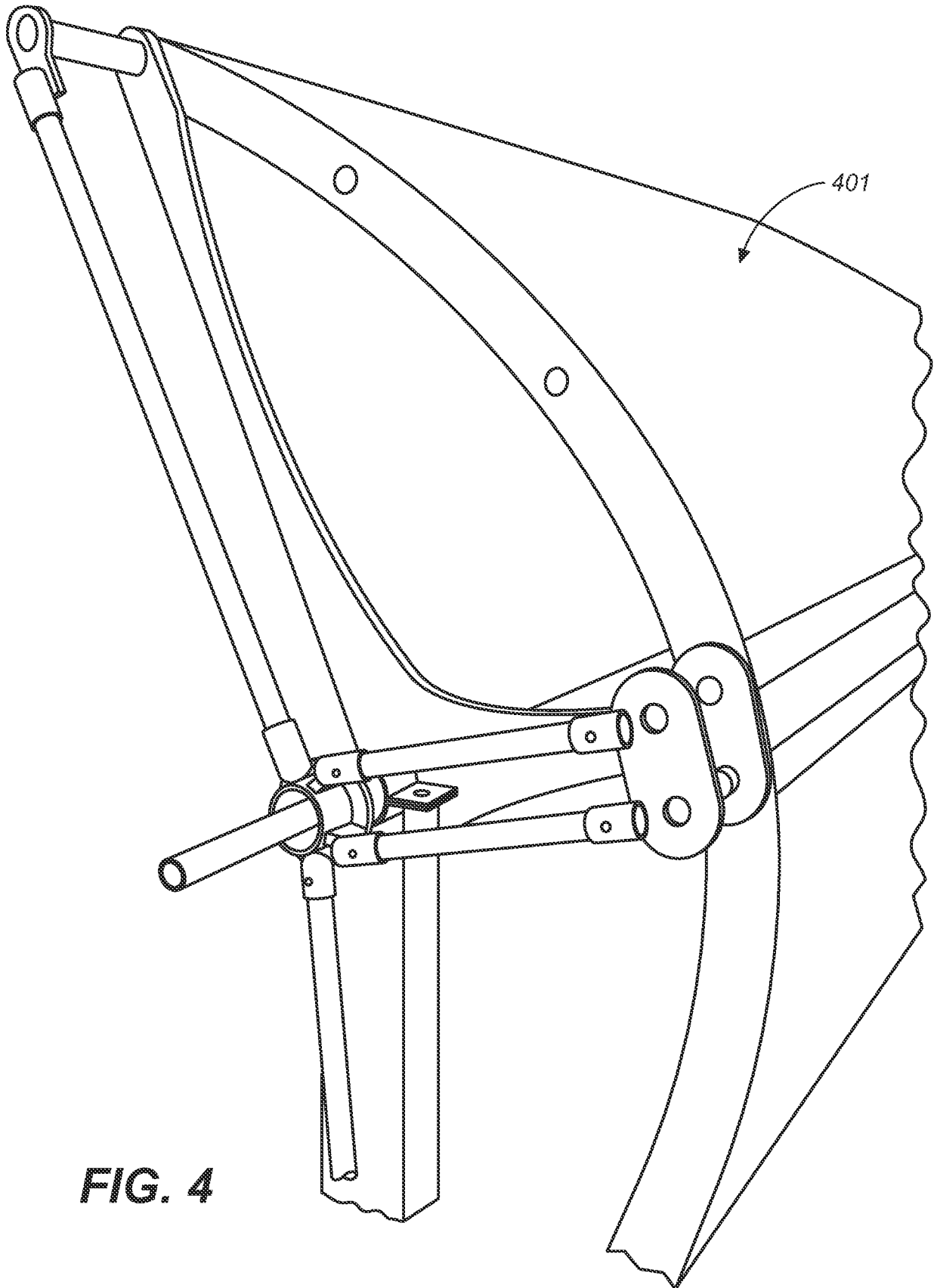
51. A collector made according to a method of any of claims 40-50.

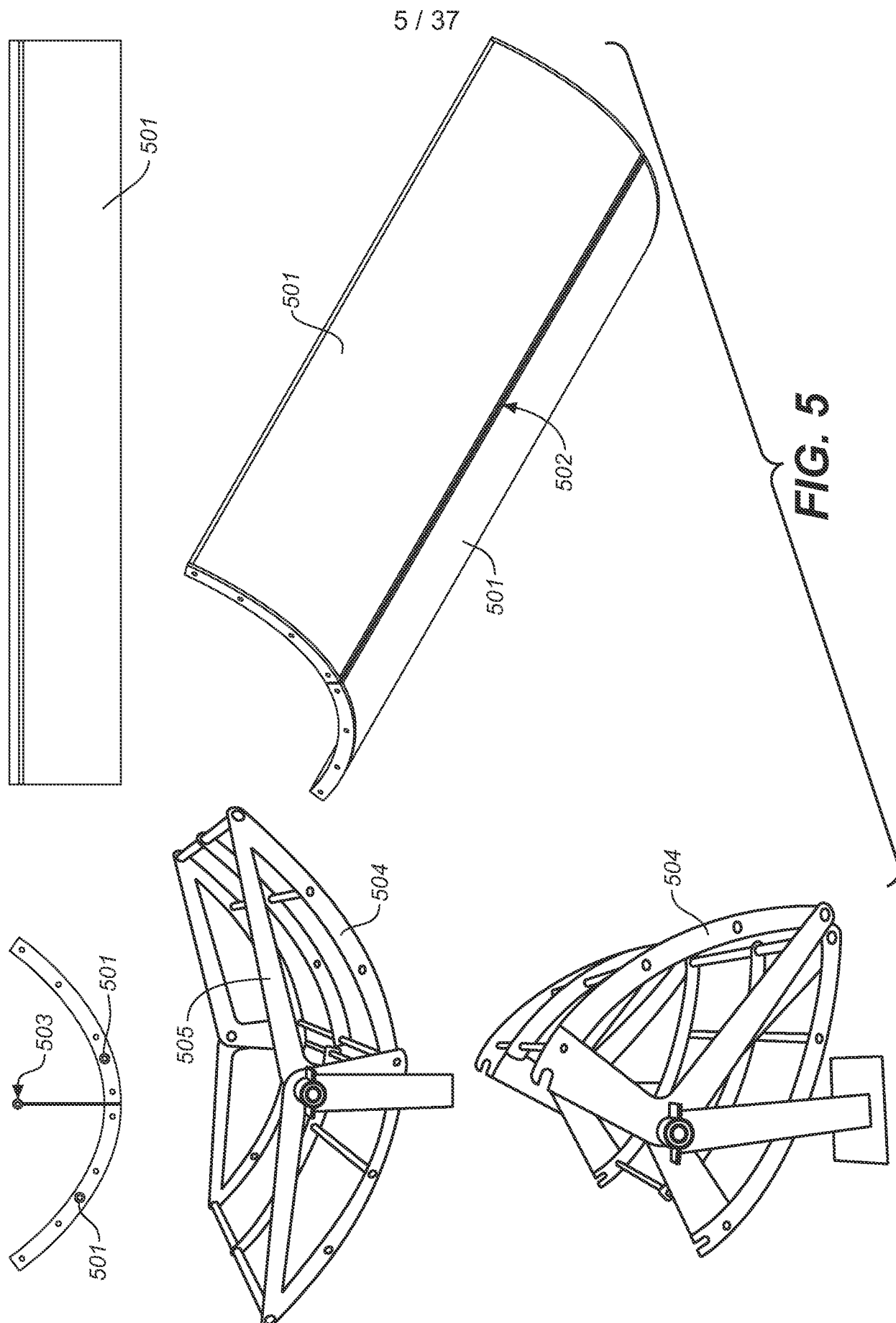


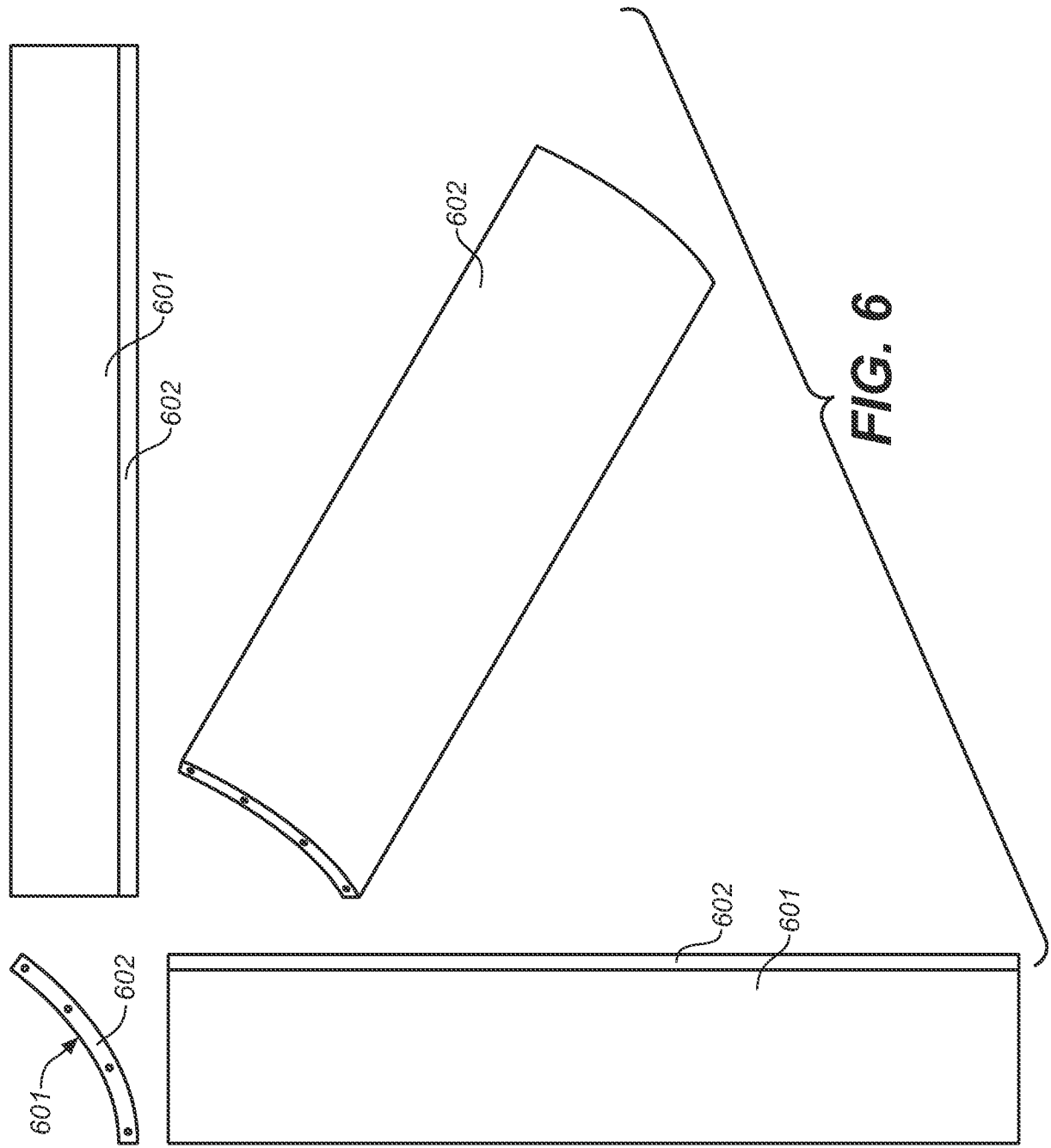




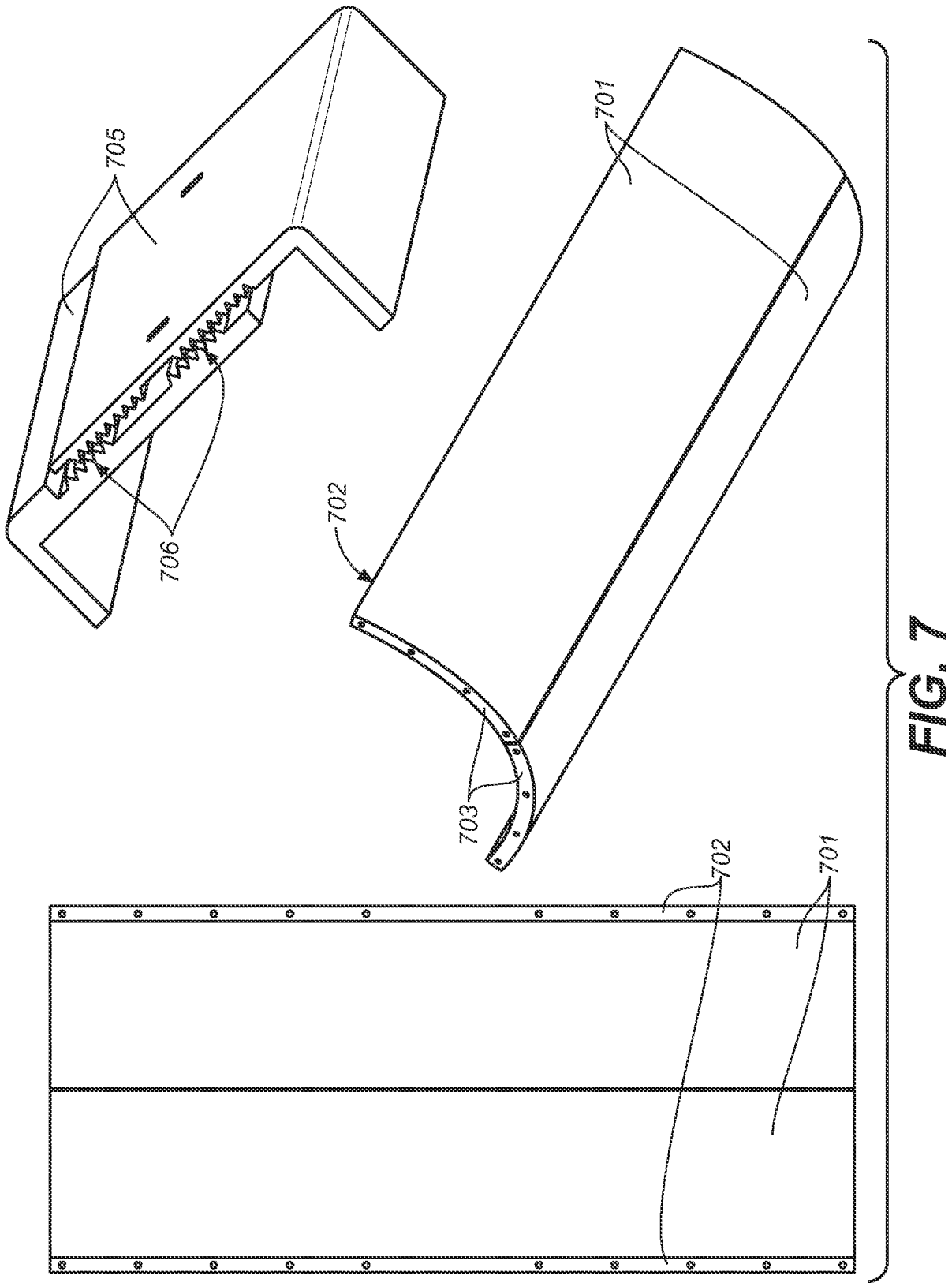
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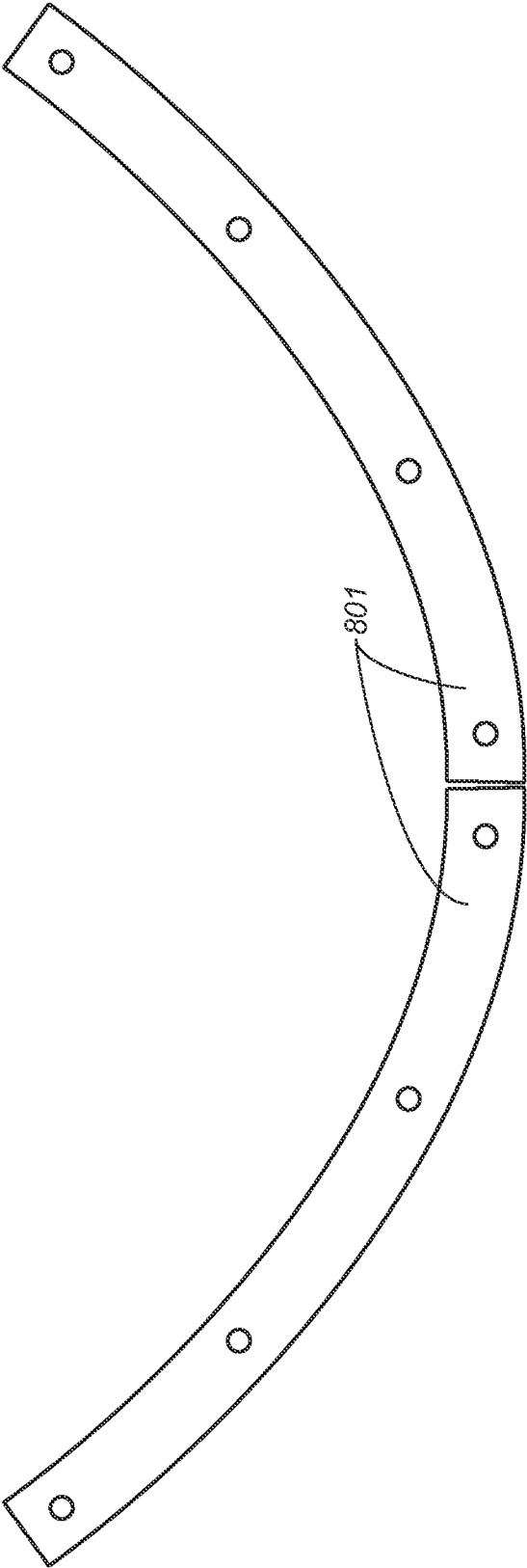
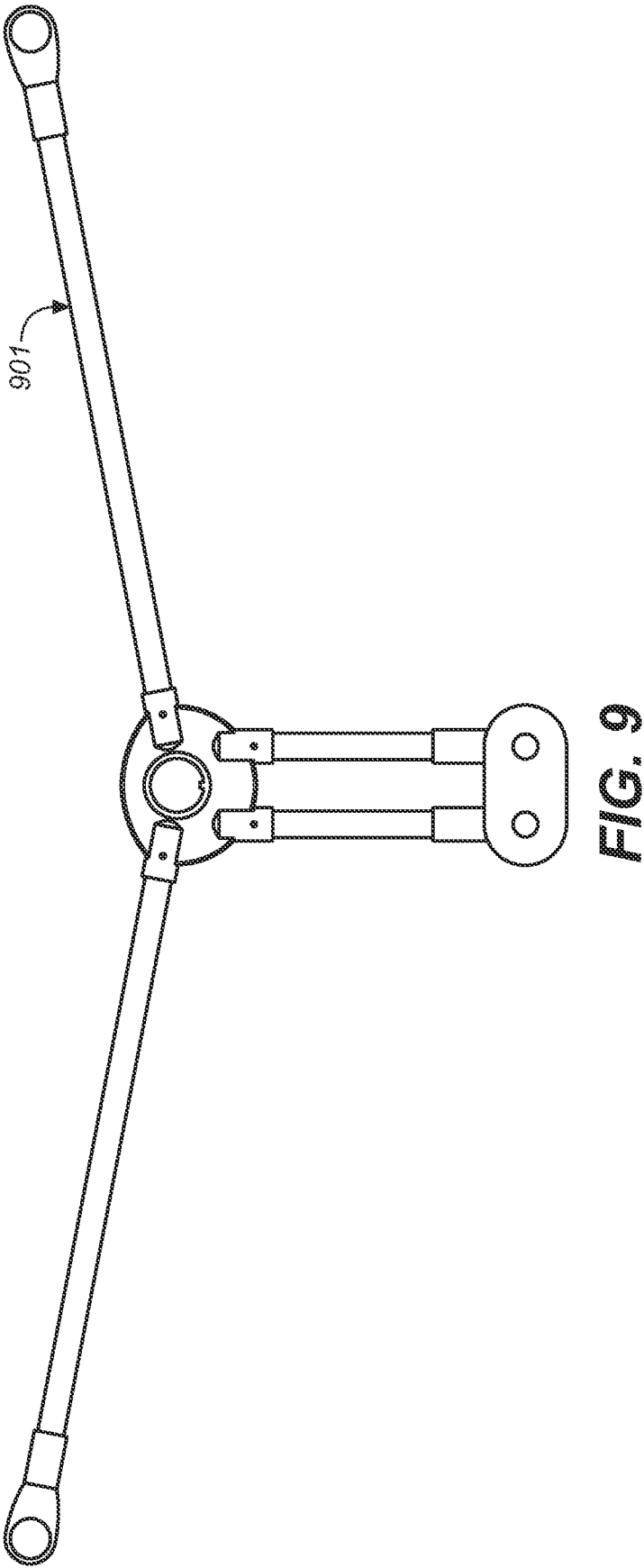
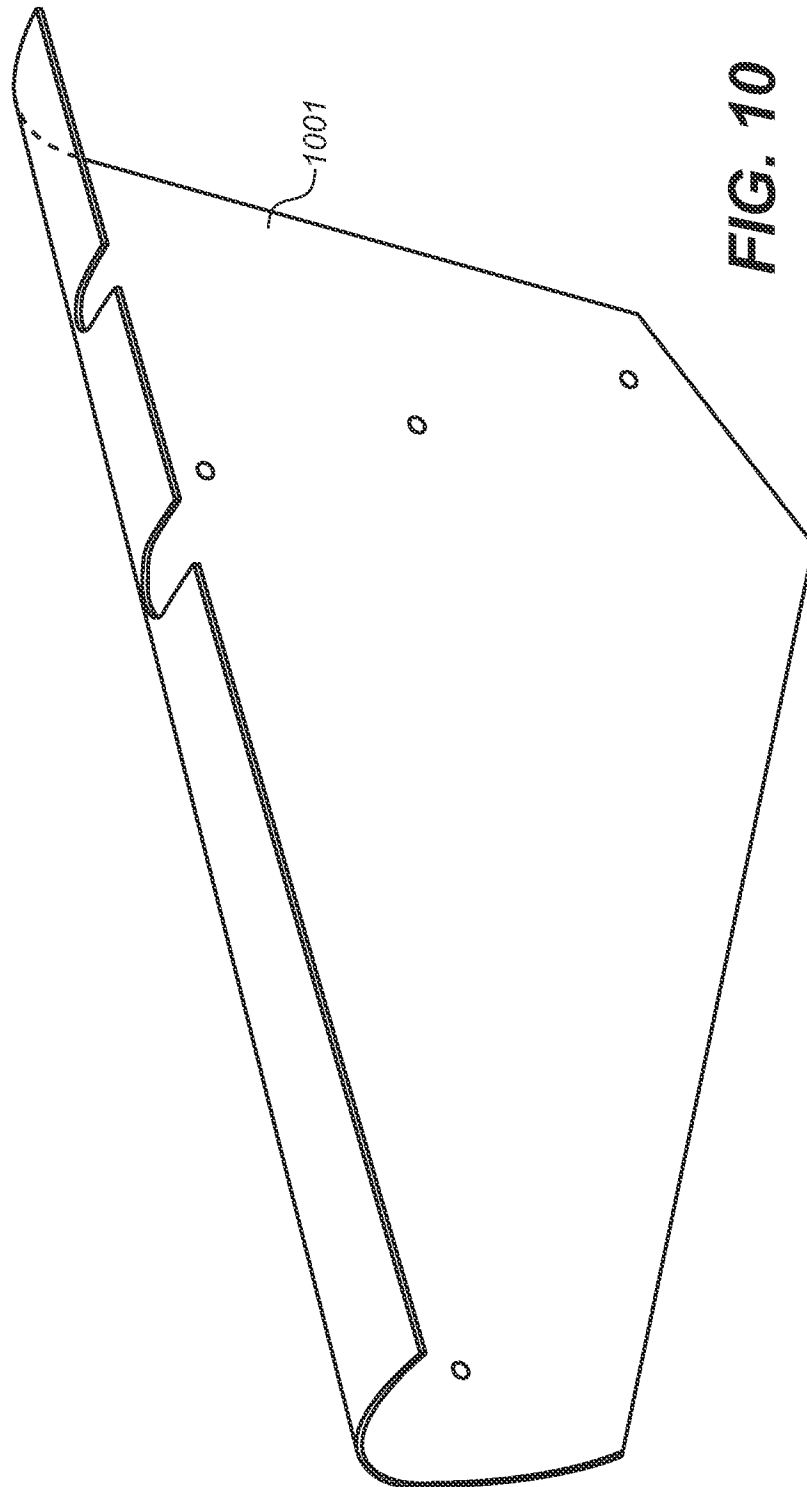


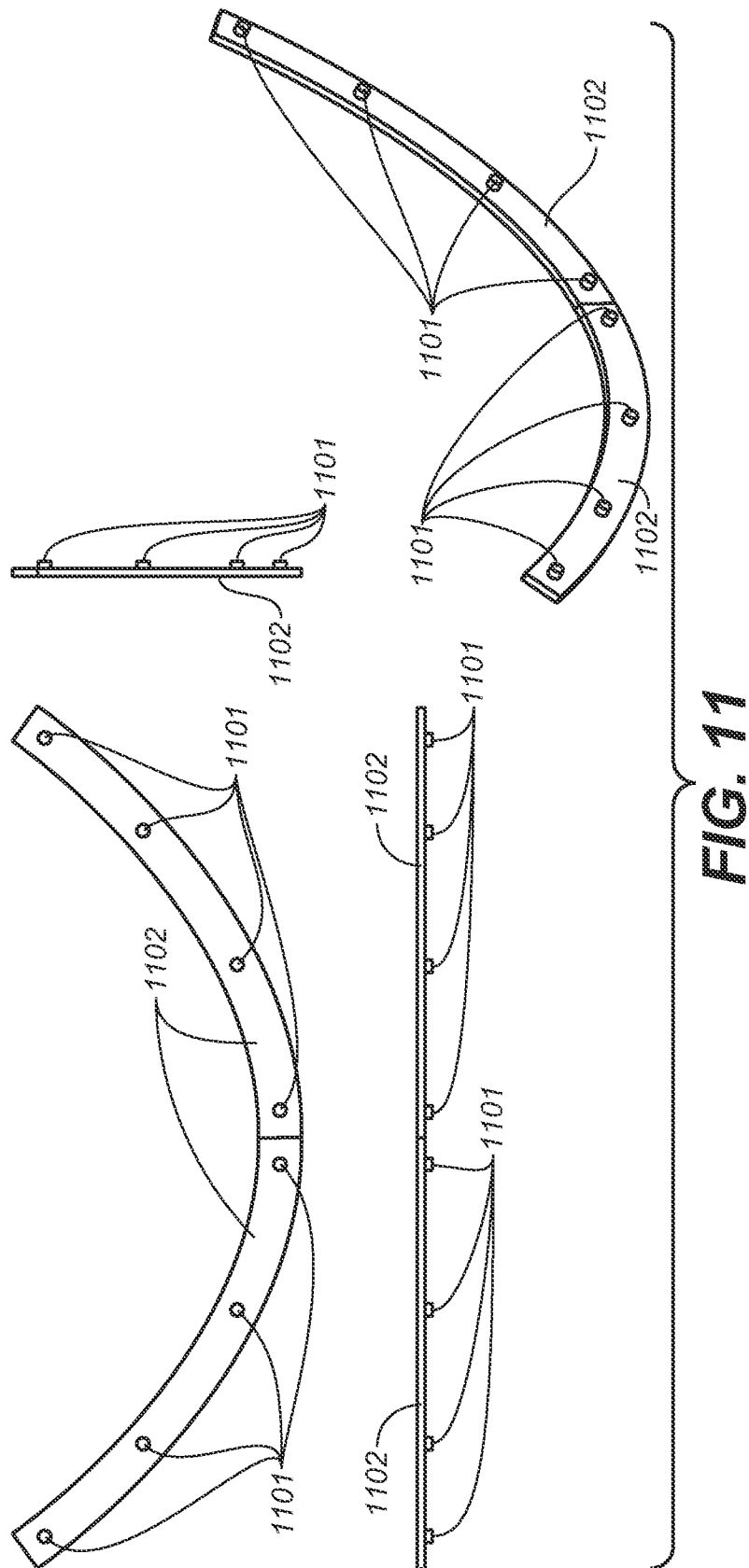
FIG. 8



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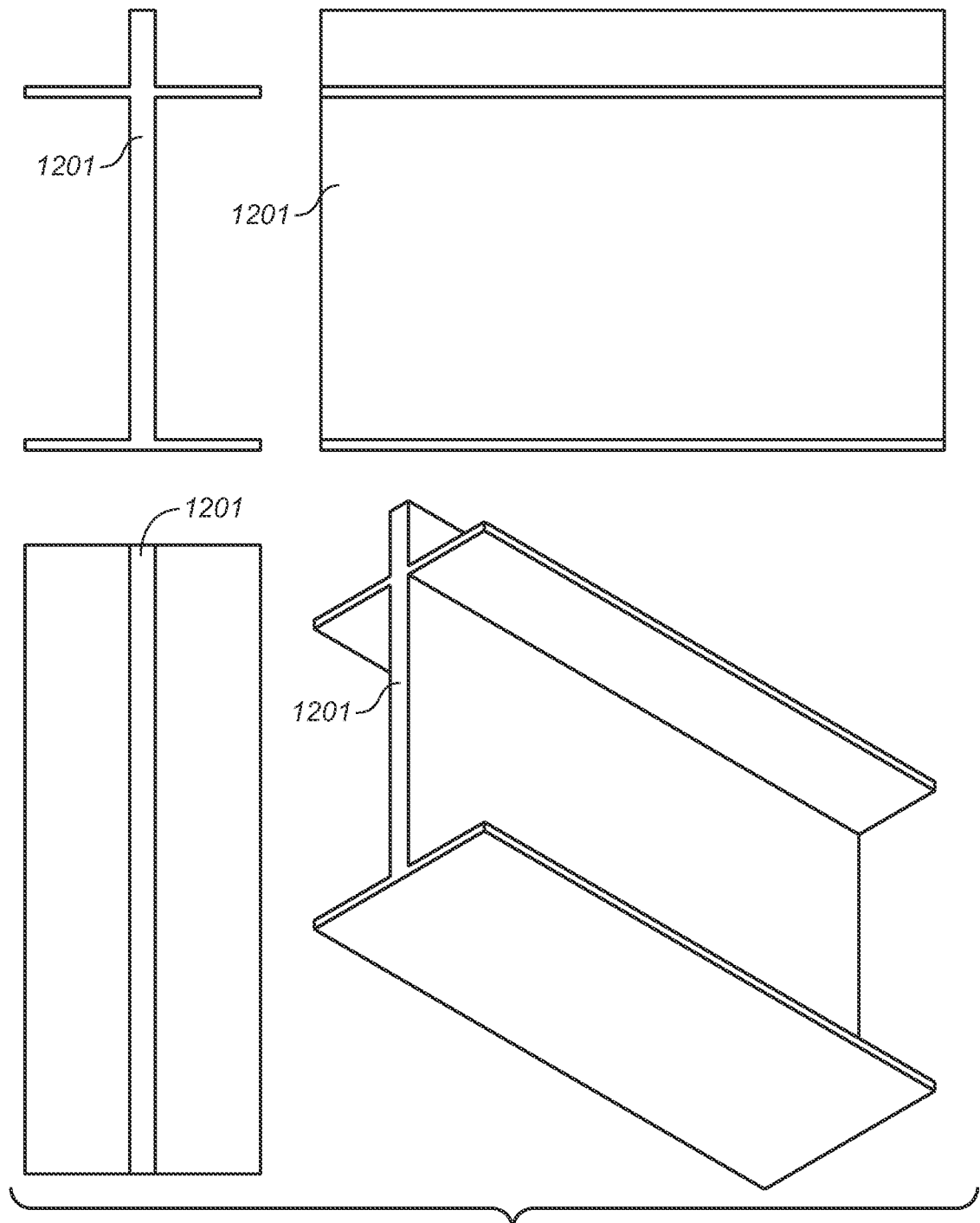


FIG. 12

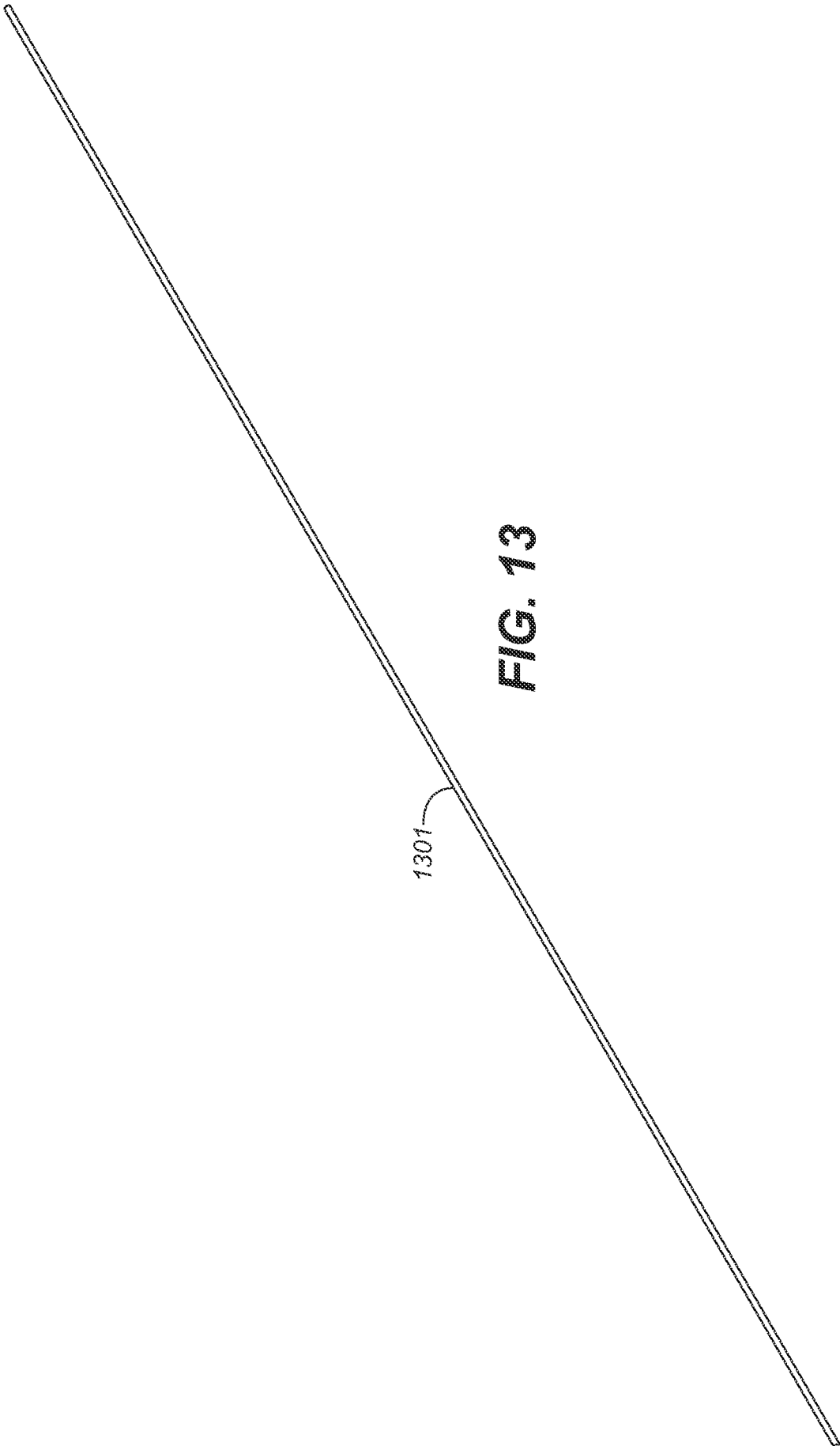


FIG. 13

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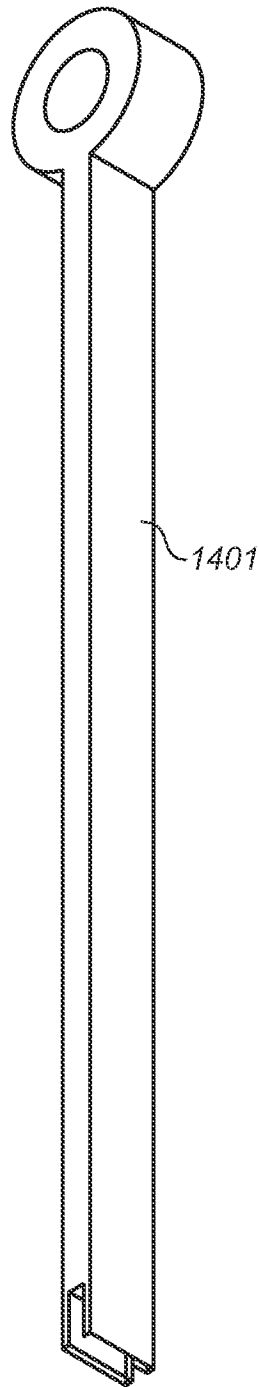


FIG. 14

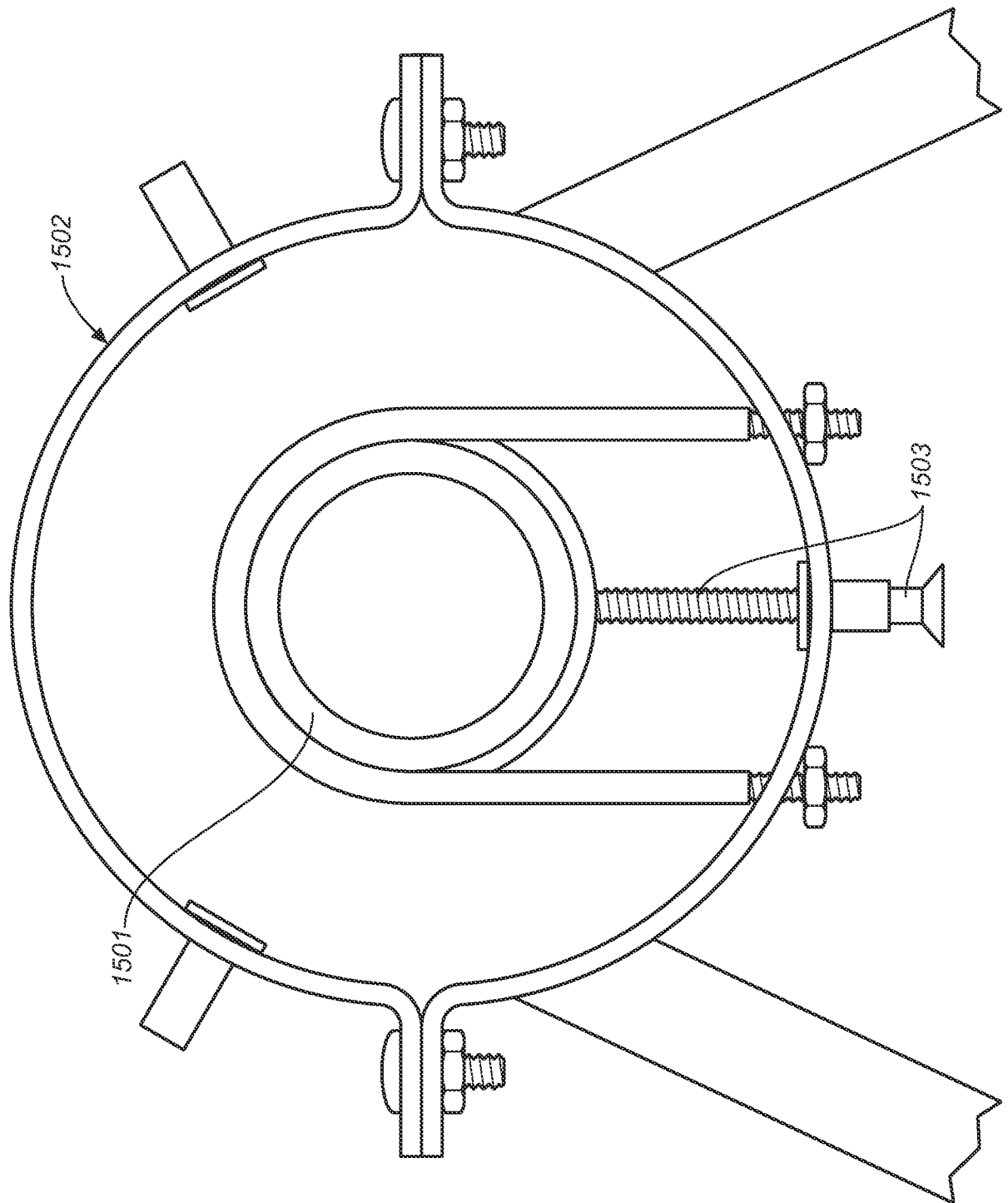


FIG. 15

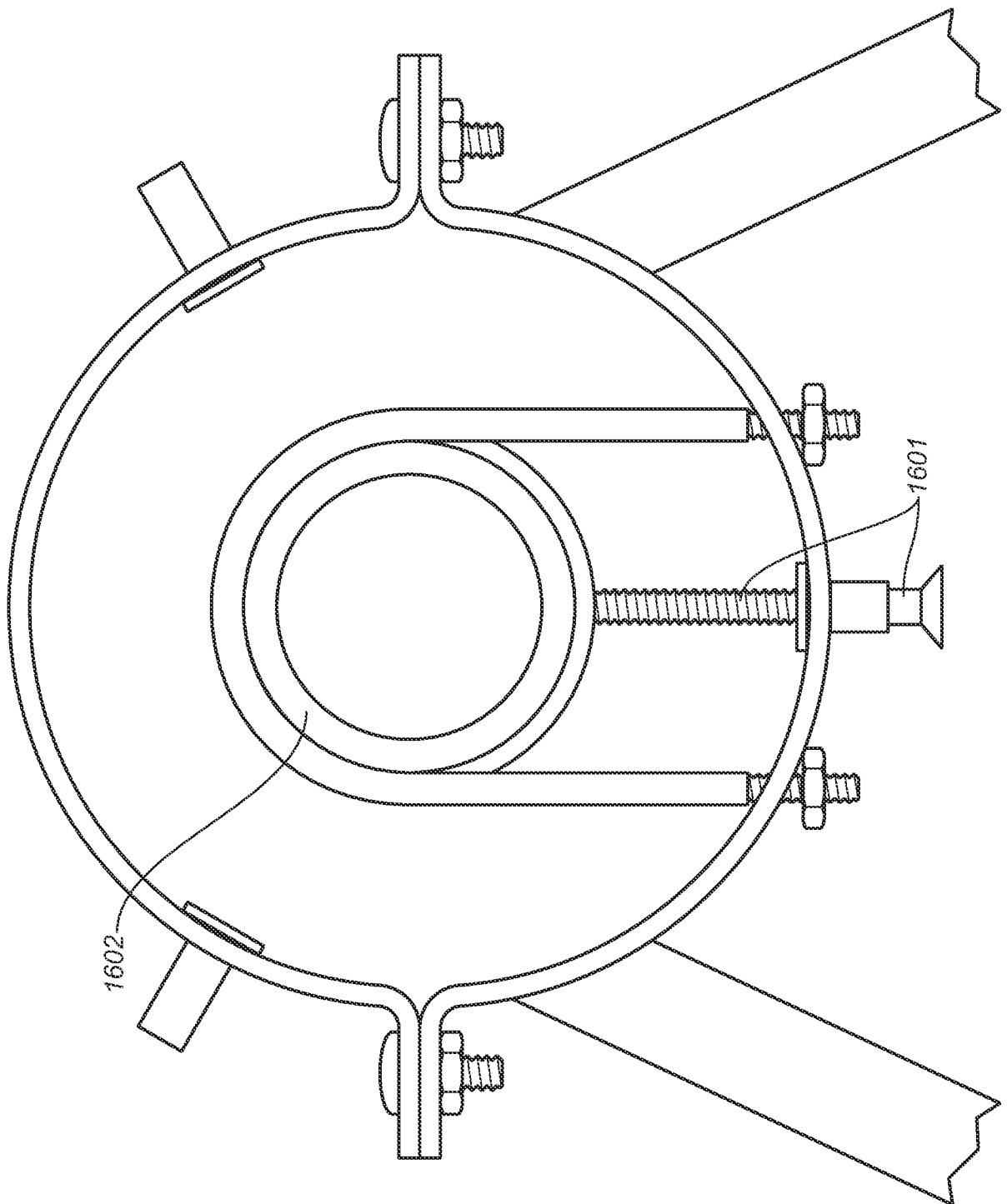


FIG. 16

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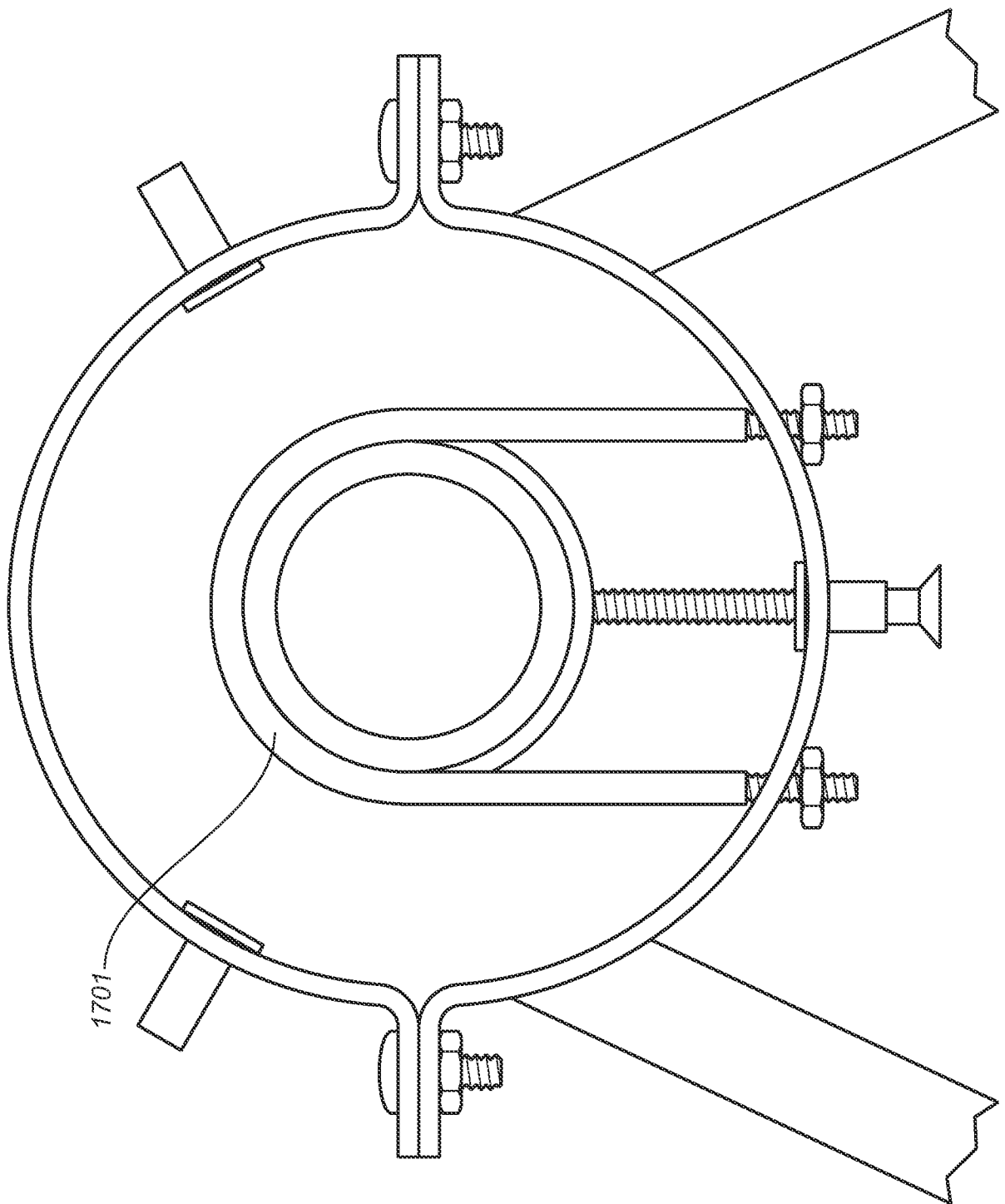


FIG. 17

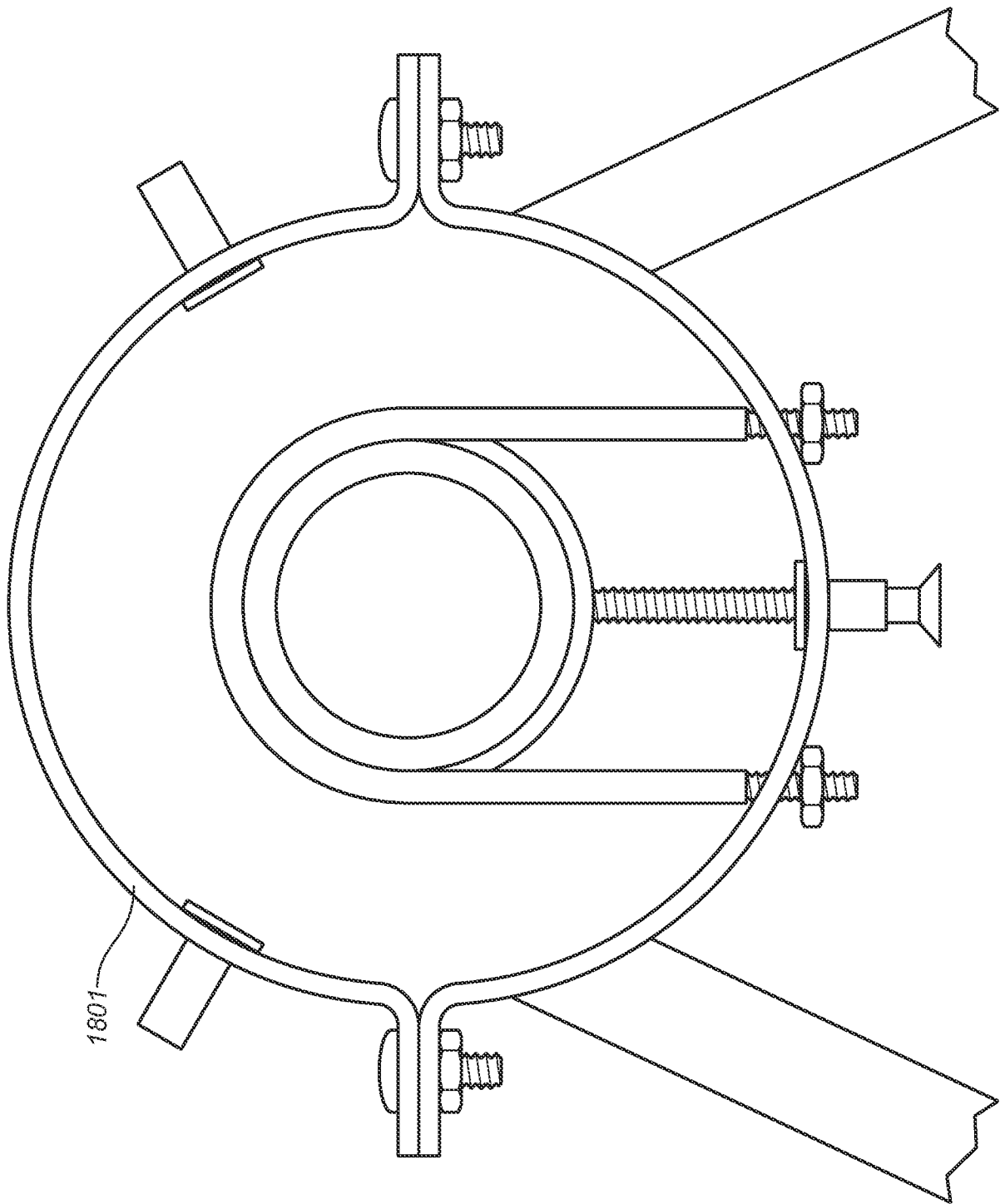


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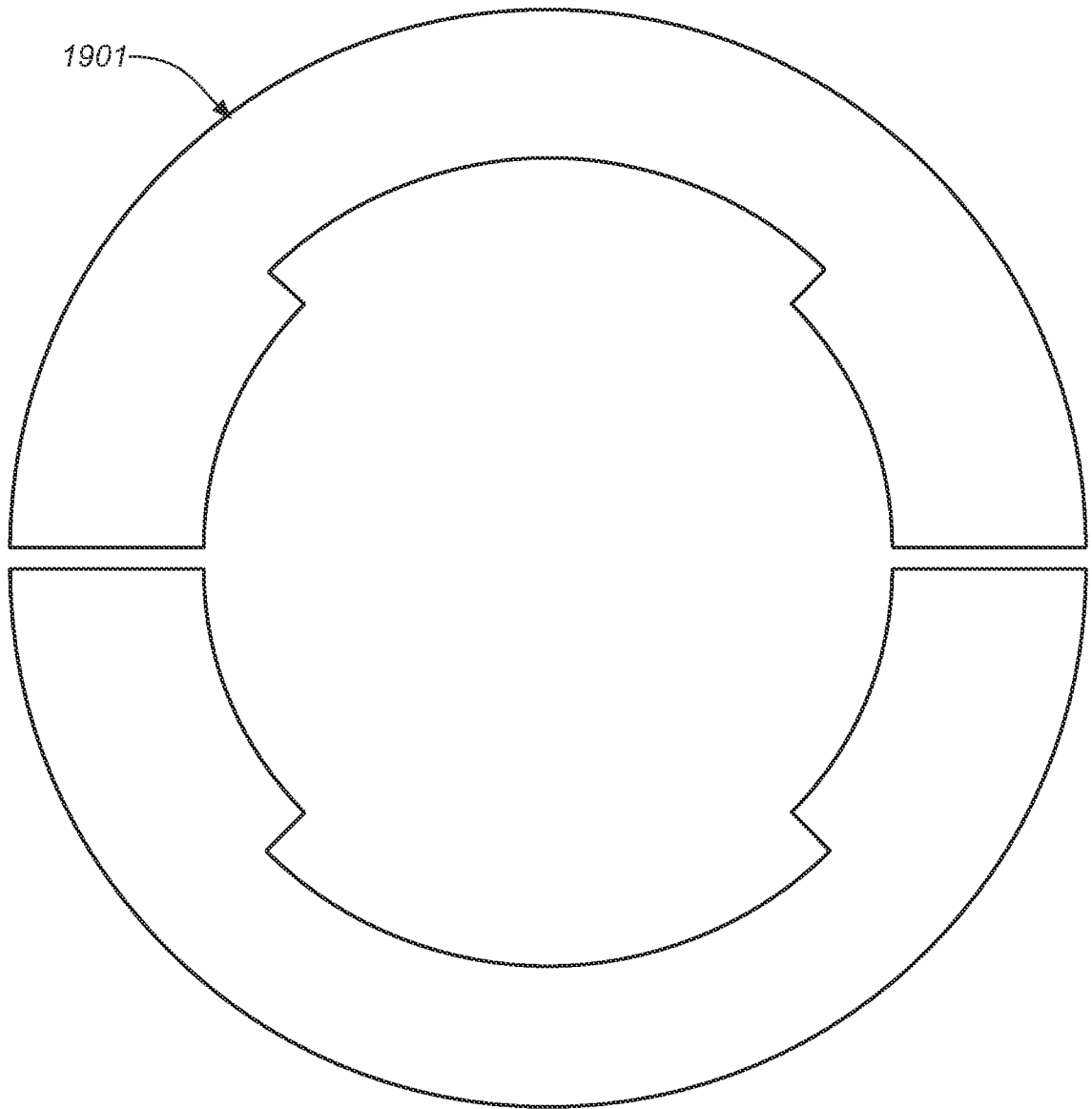
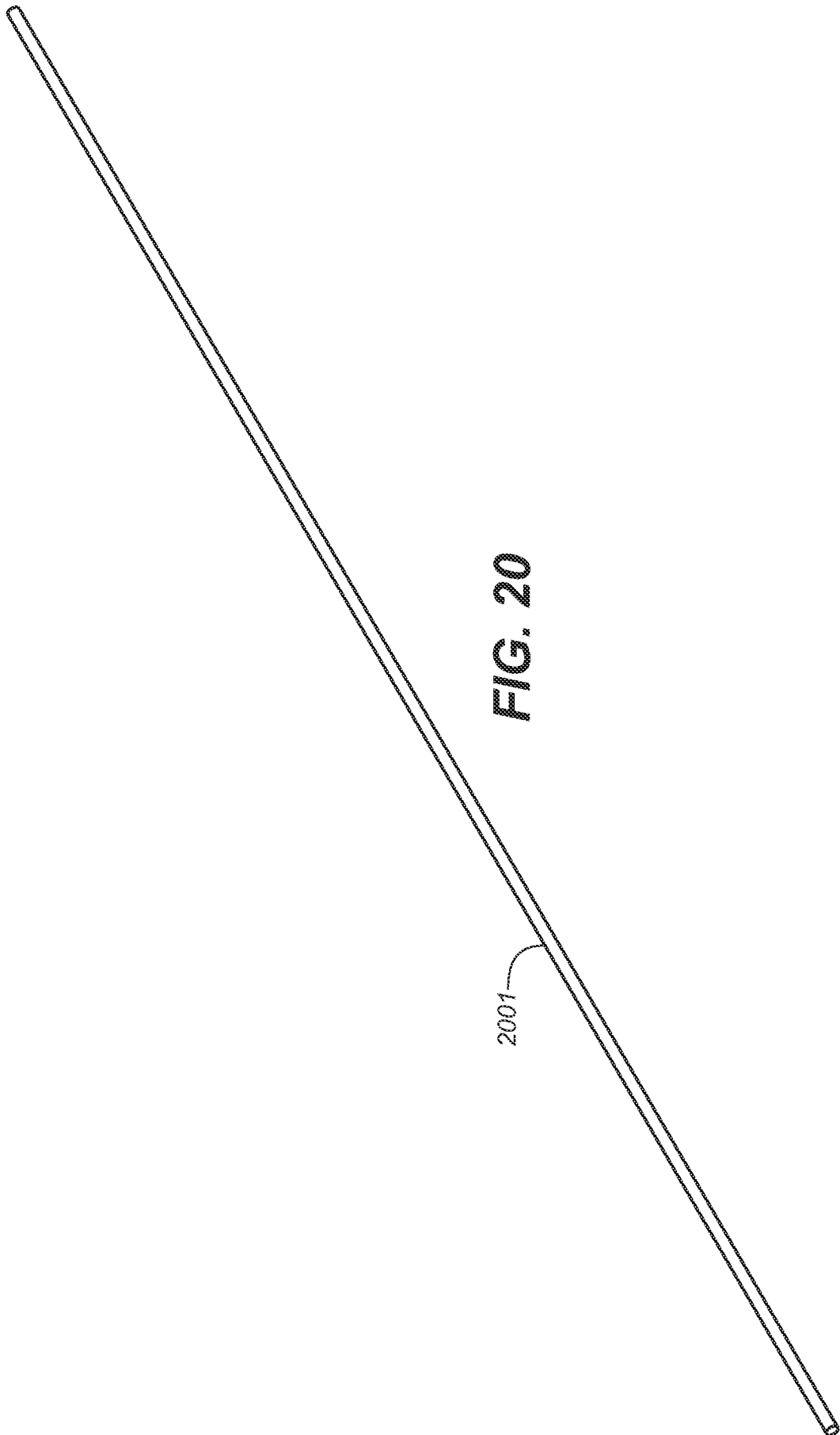


FIG. 19

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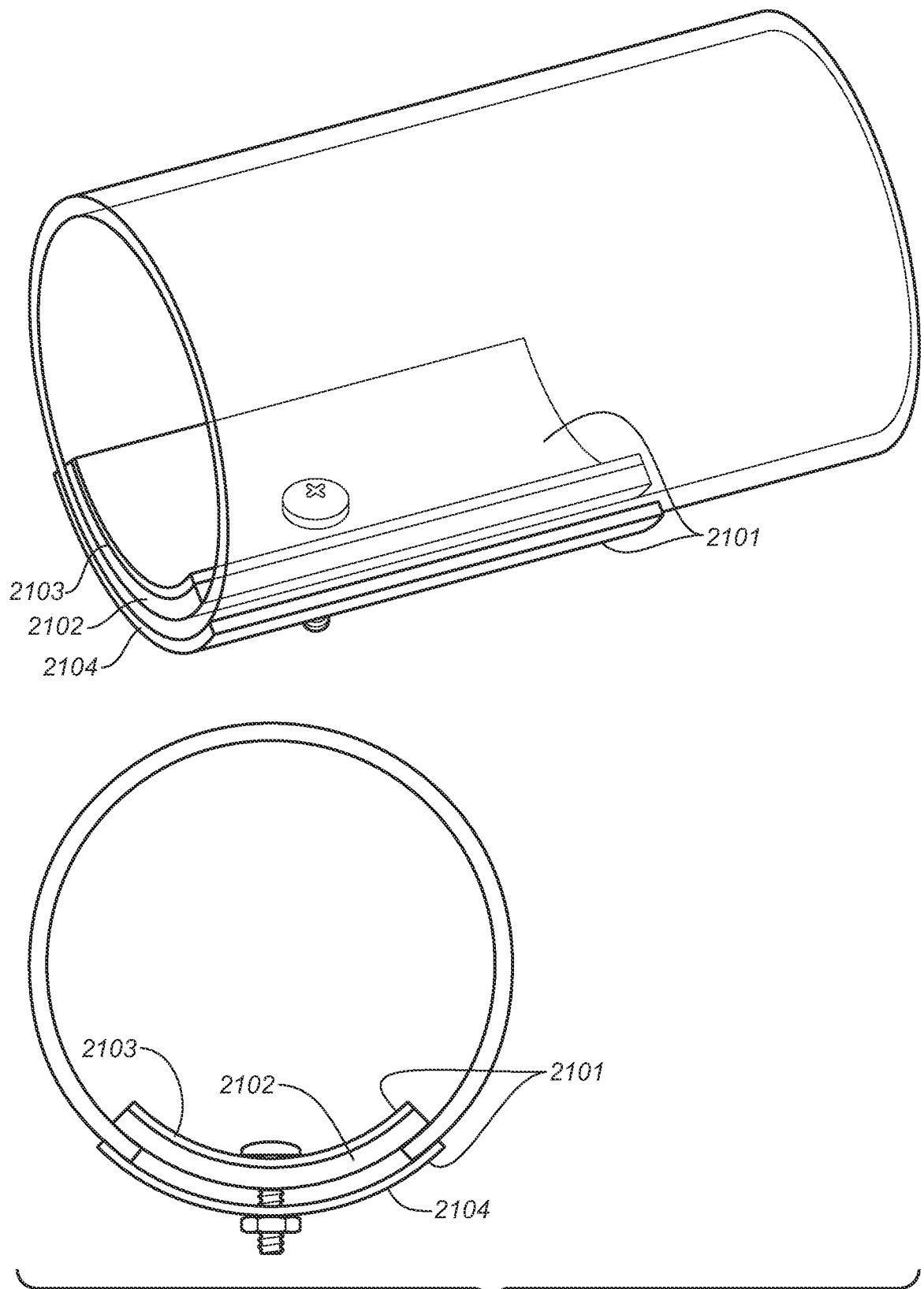


FIG. 21

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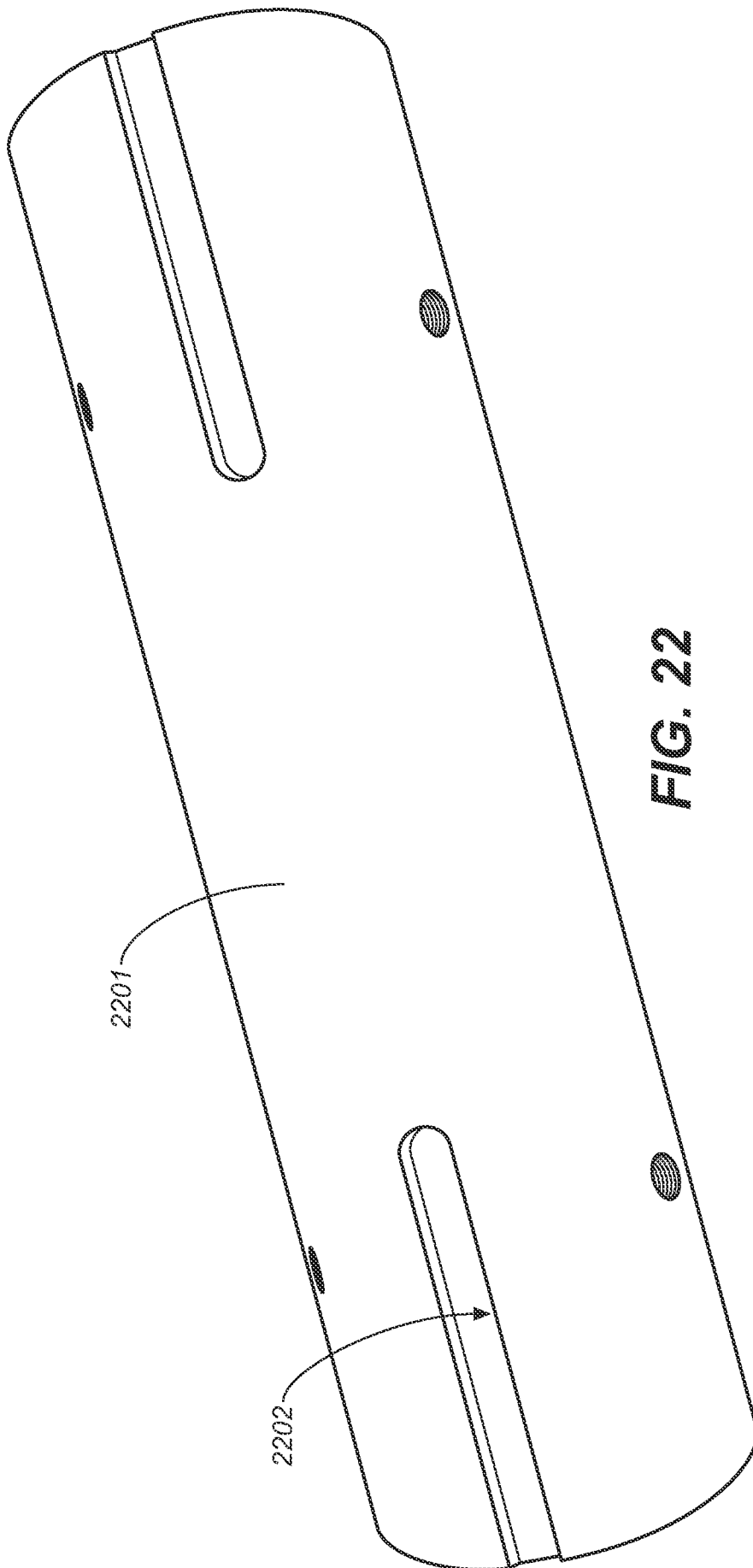


FIG. 22

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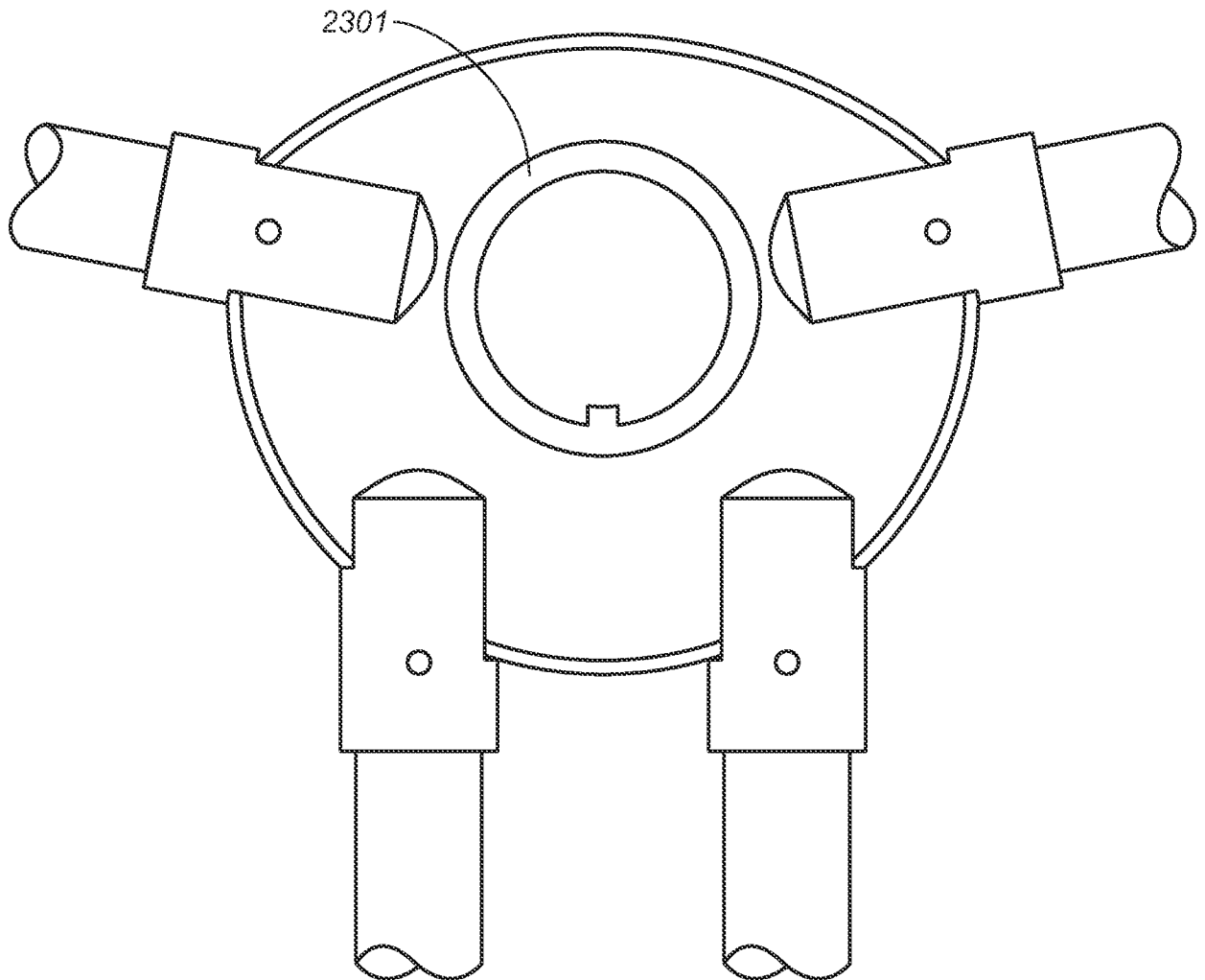
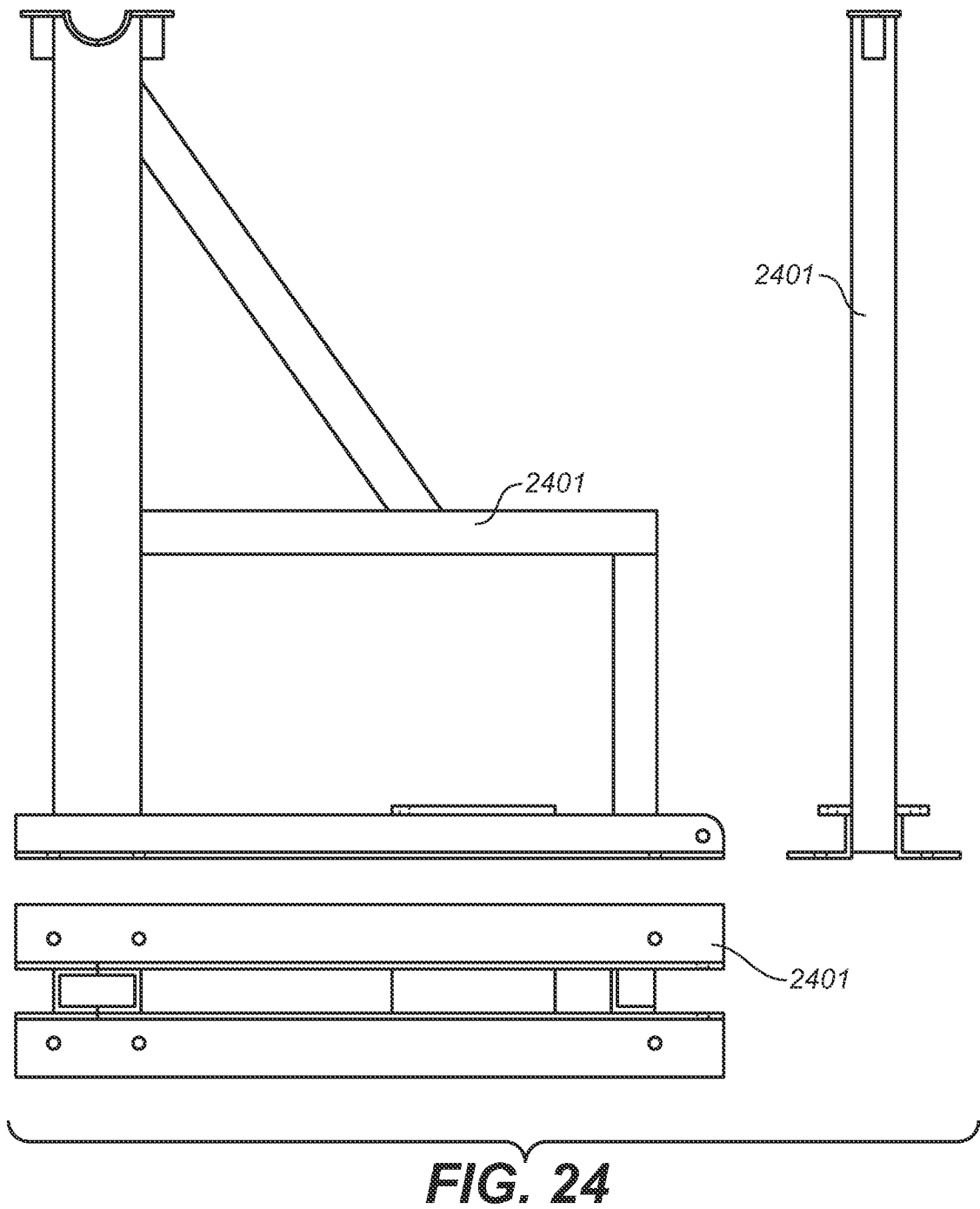


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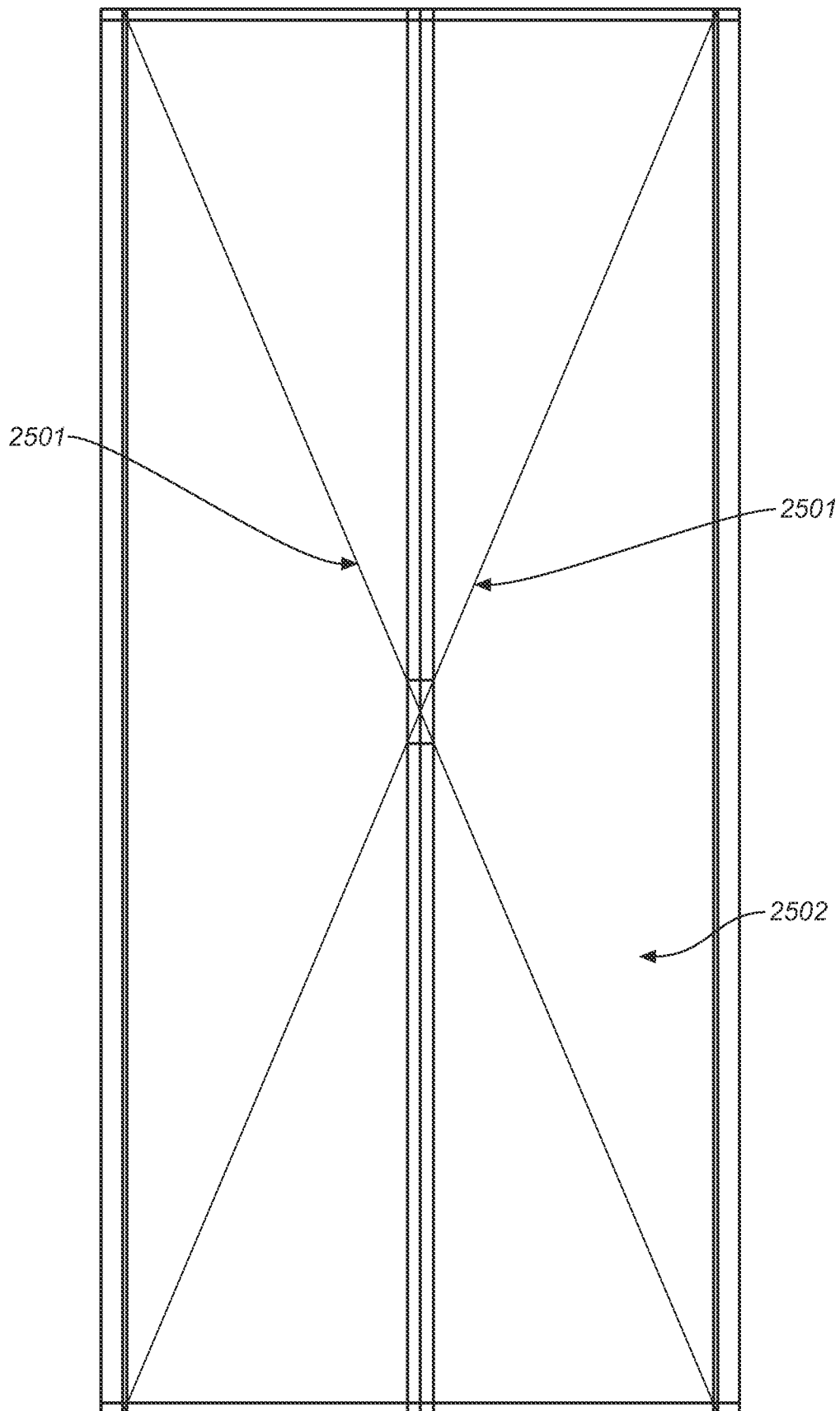


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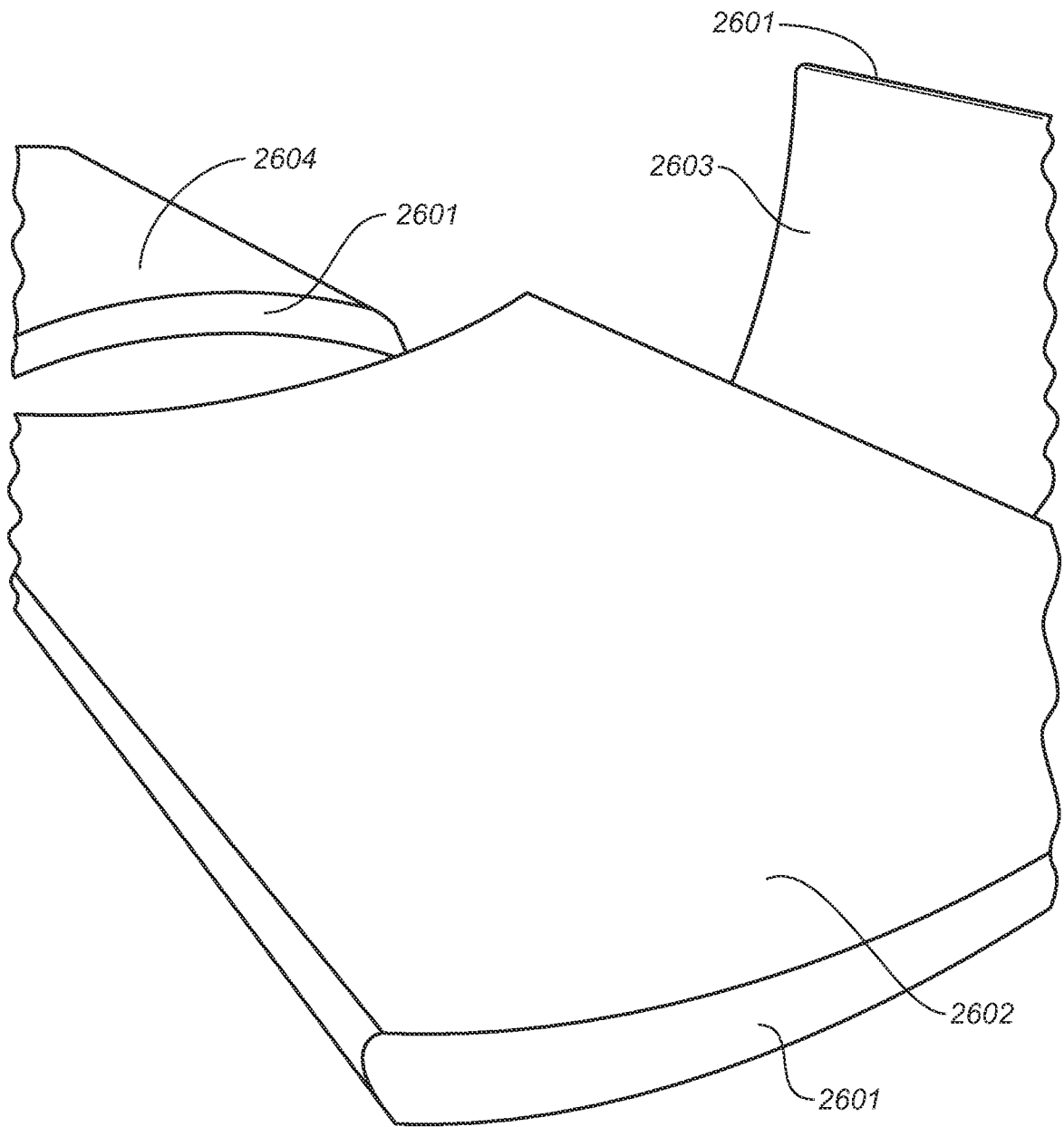
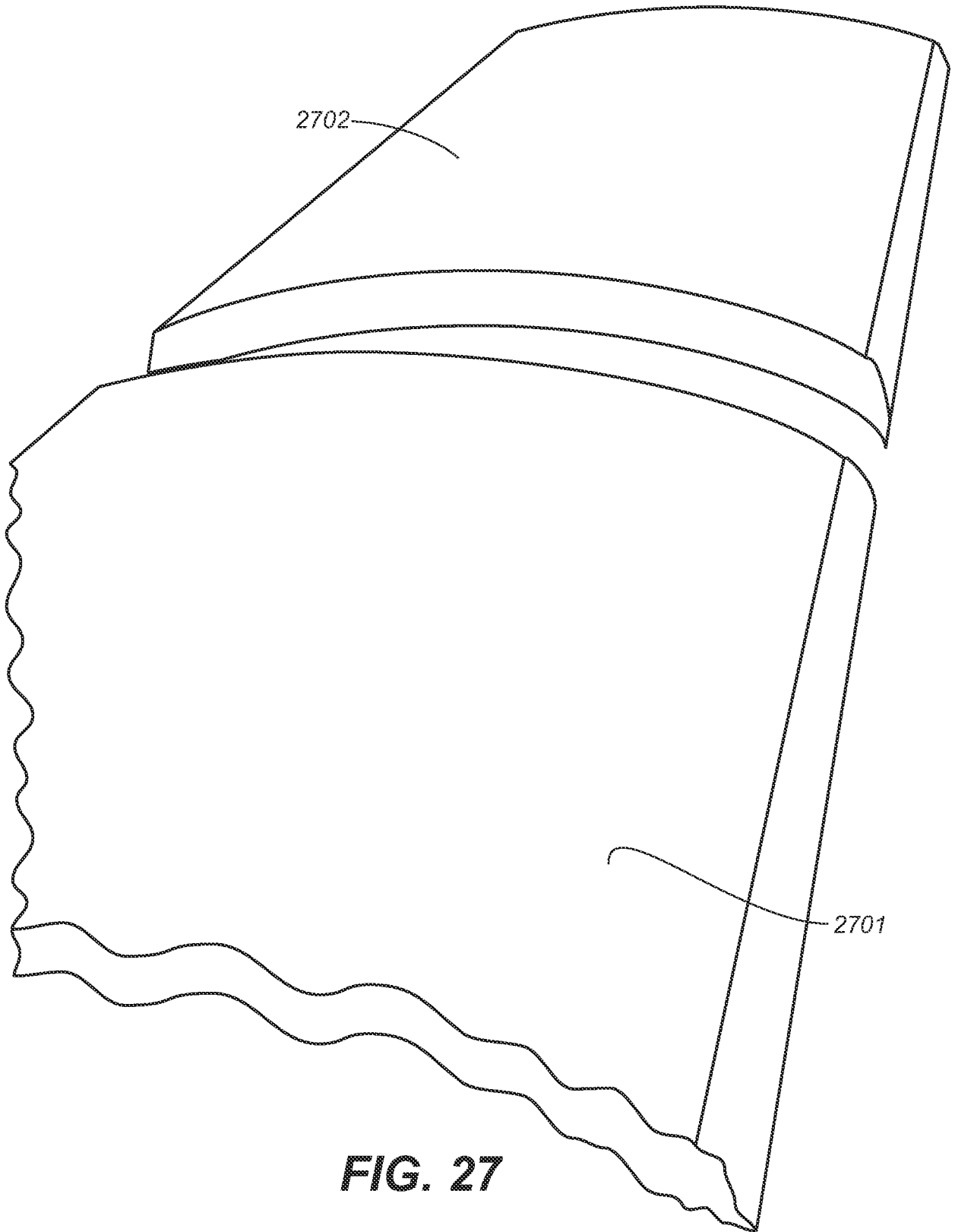
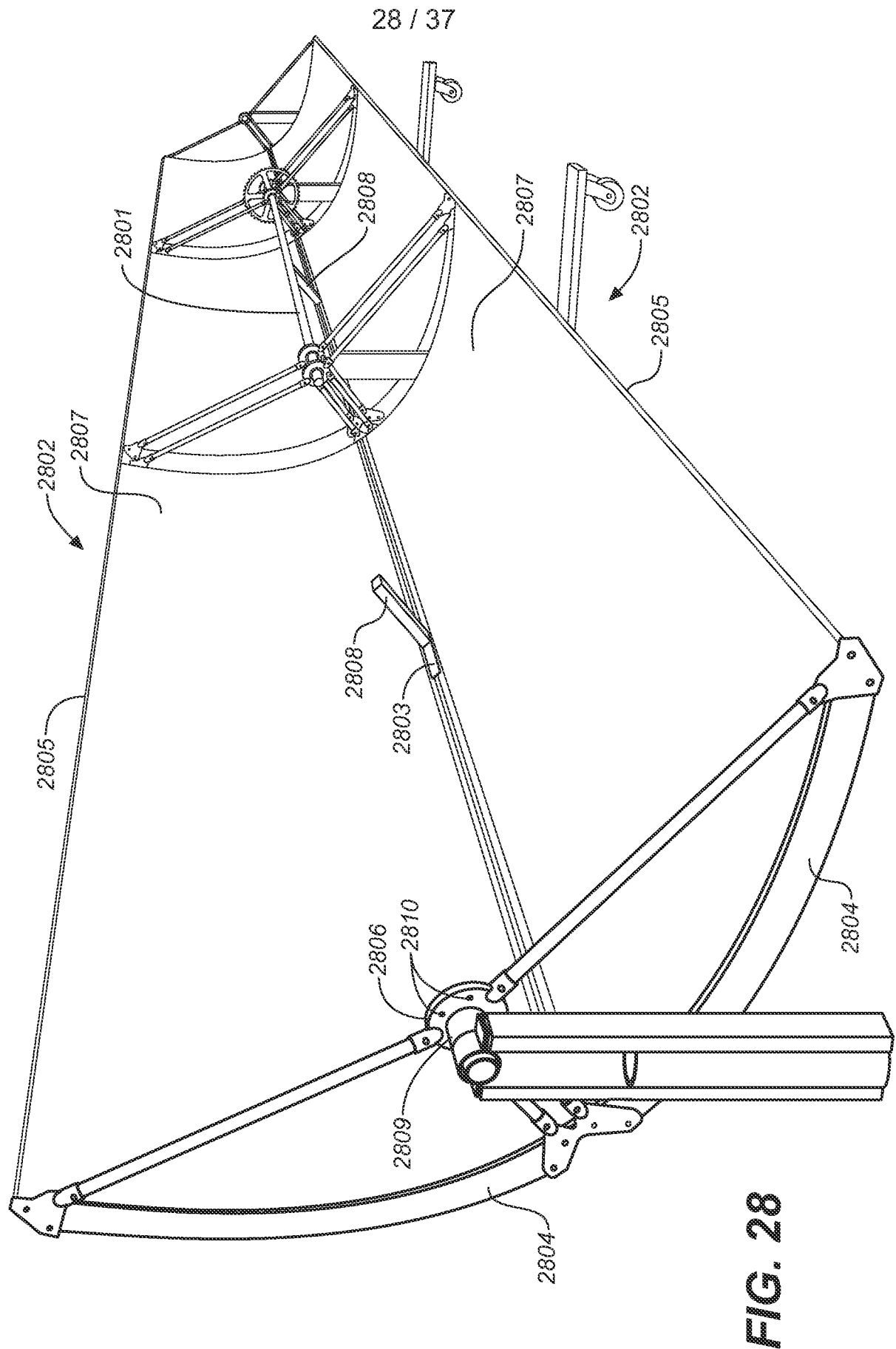


FIG. 26

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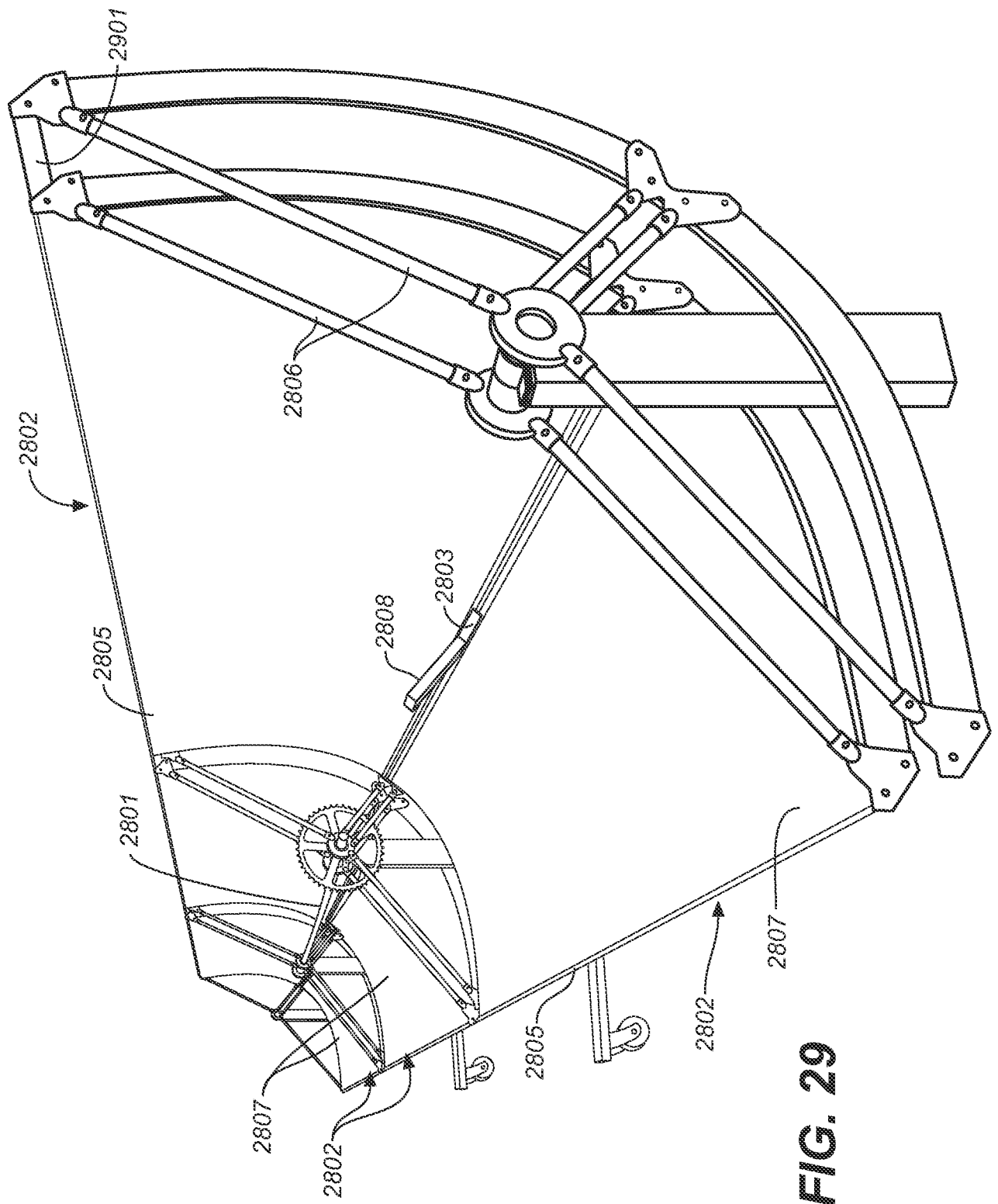


FIG. 29

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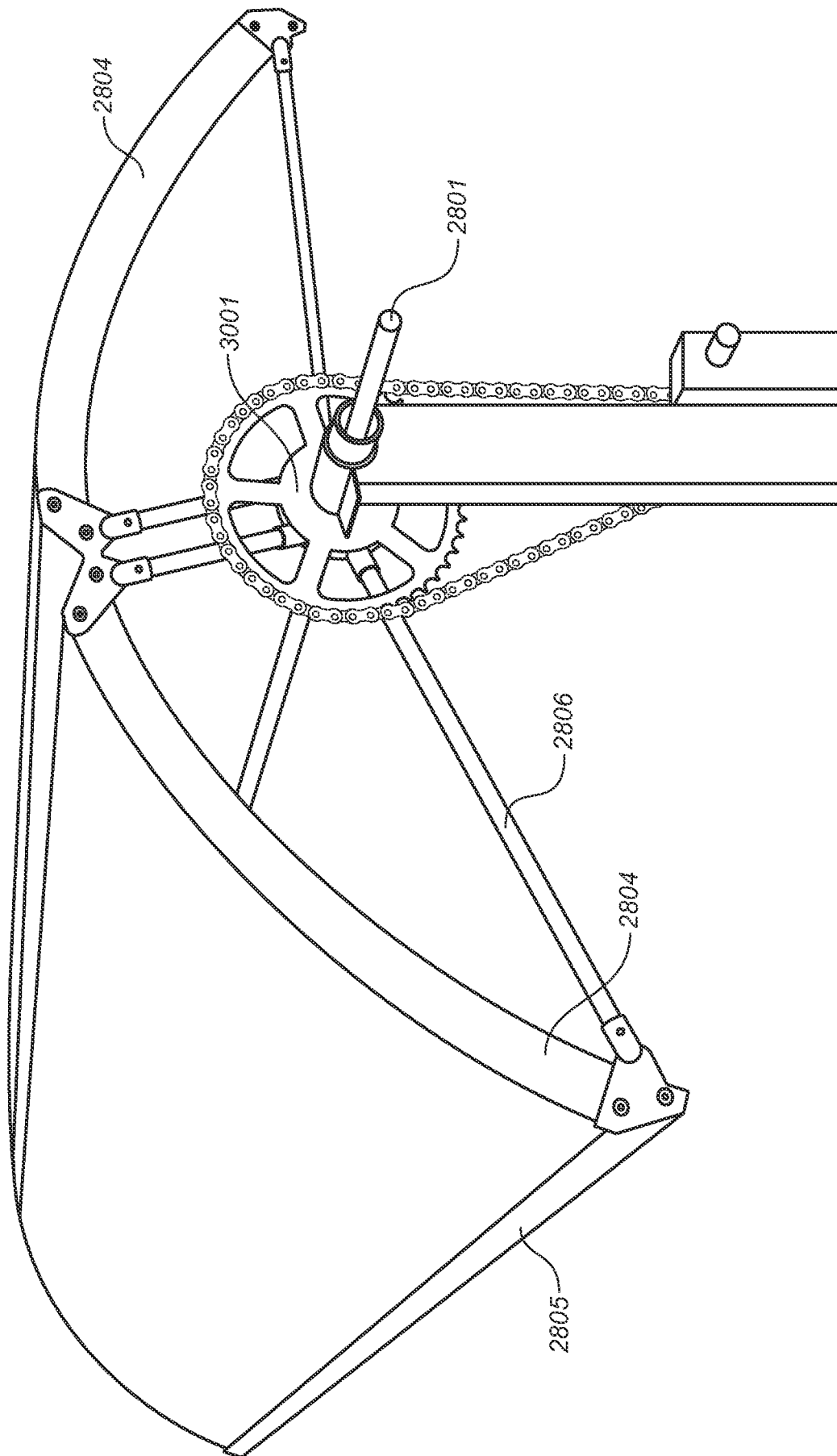


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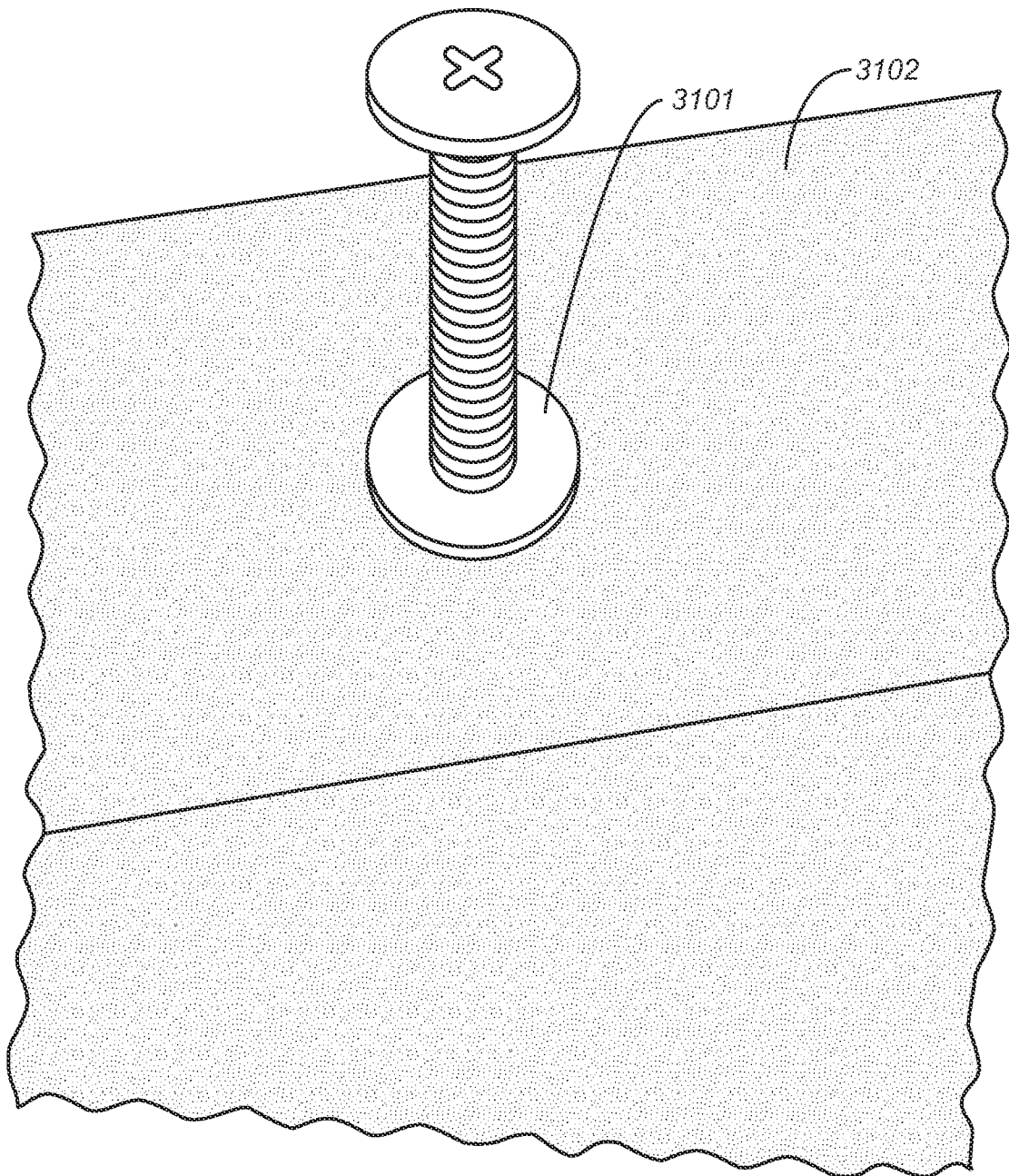


FIG. 31

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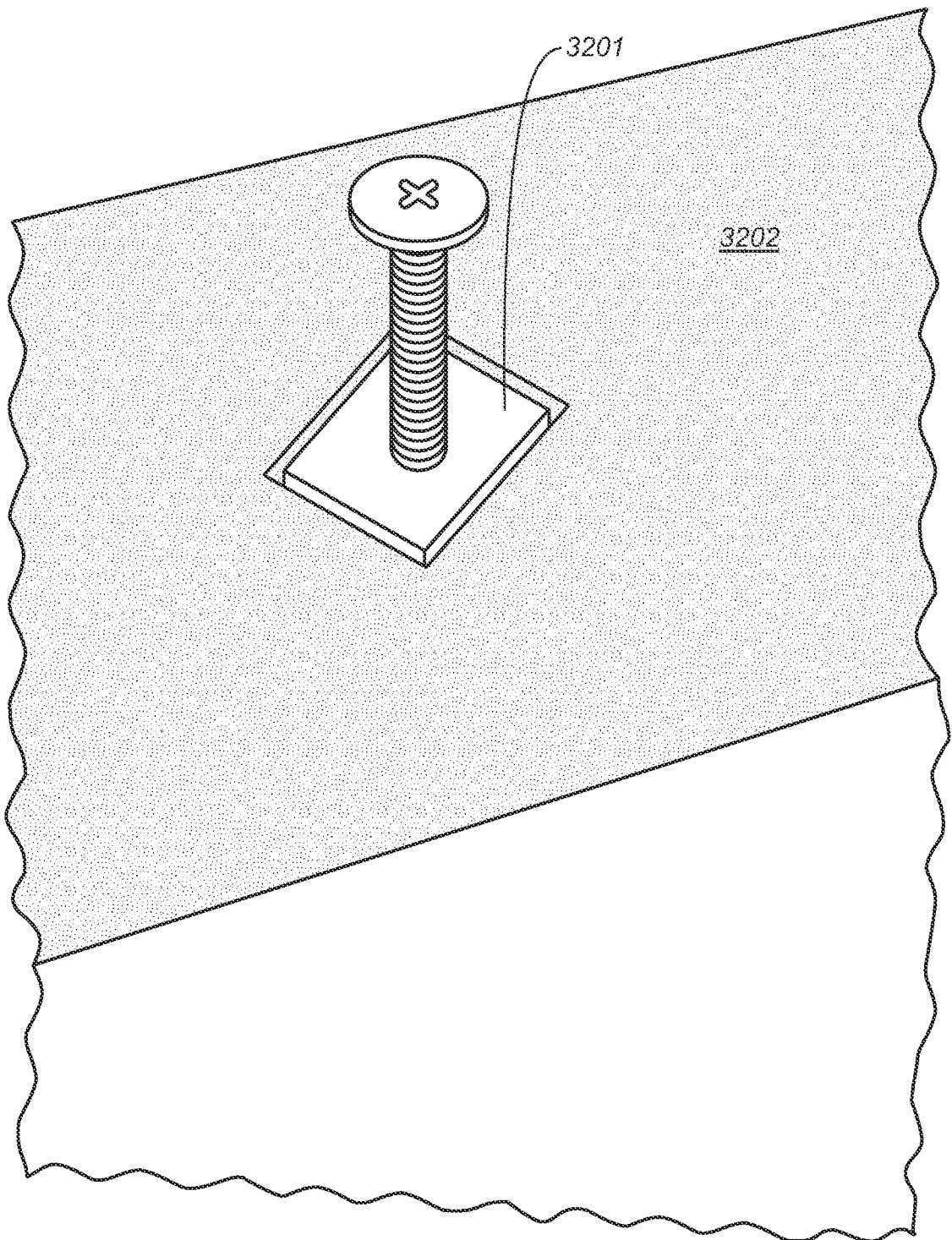


FIG. 32

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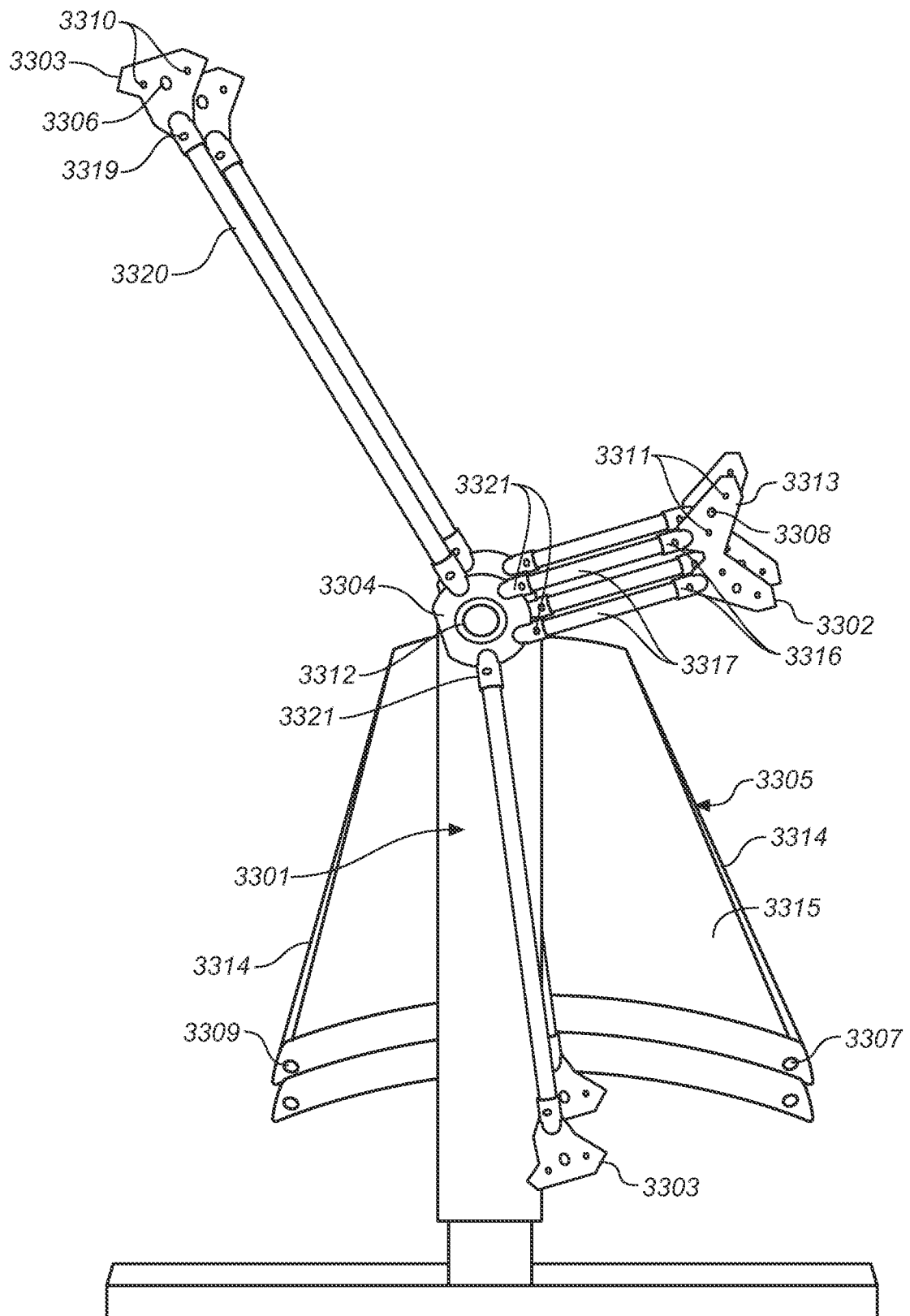


FIG. 33

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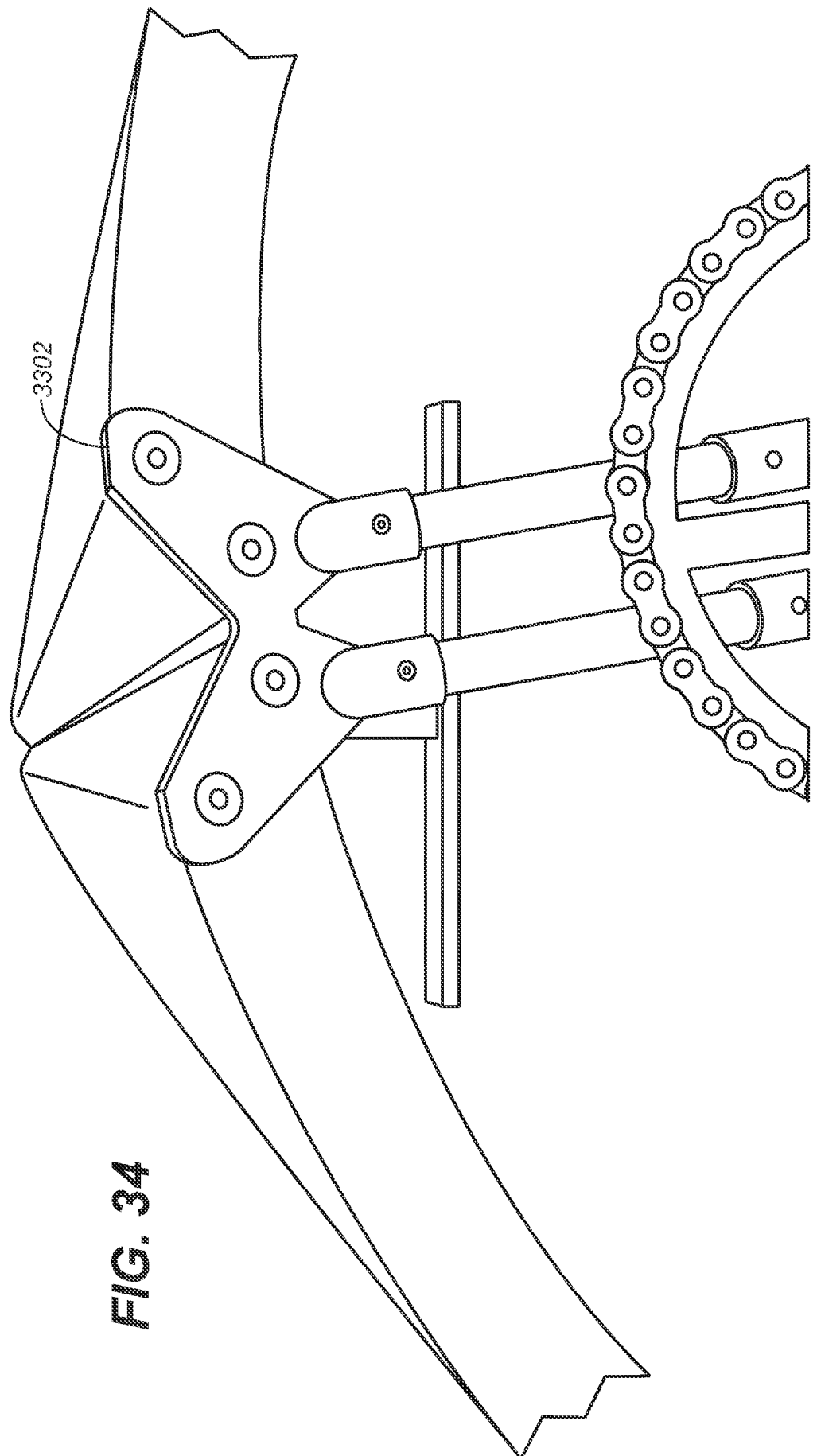


FIG. 34

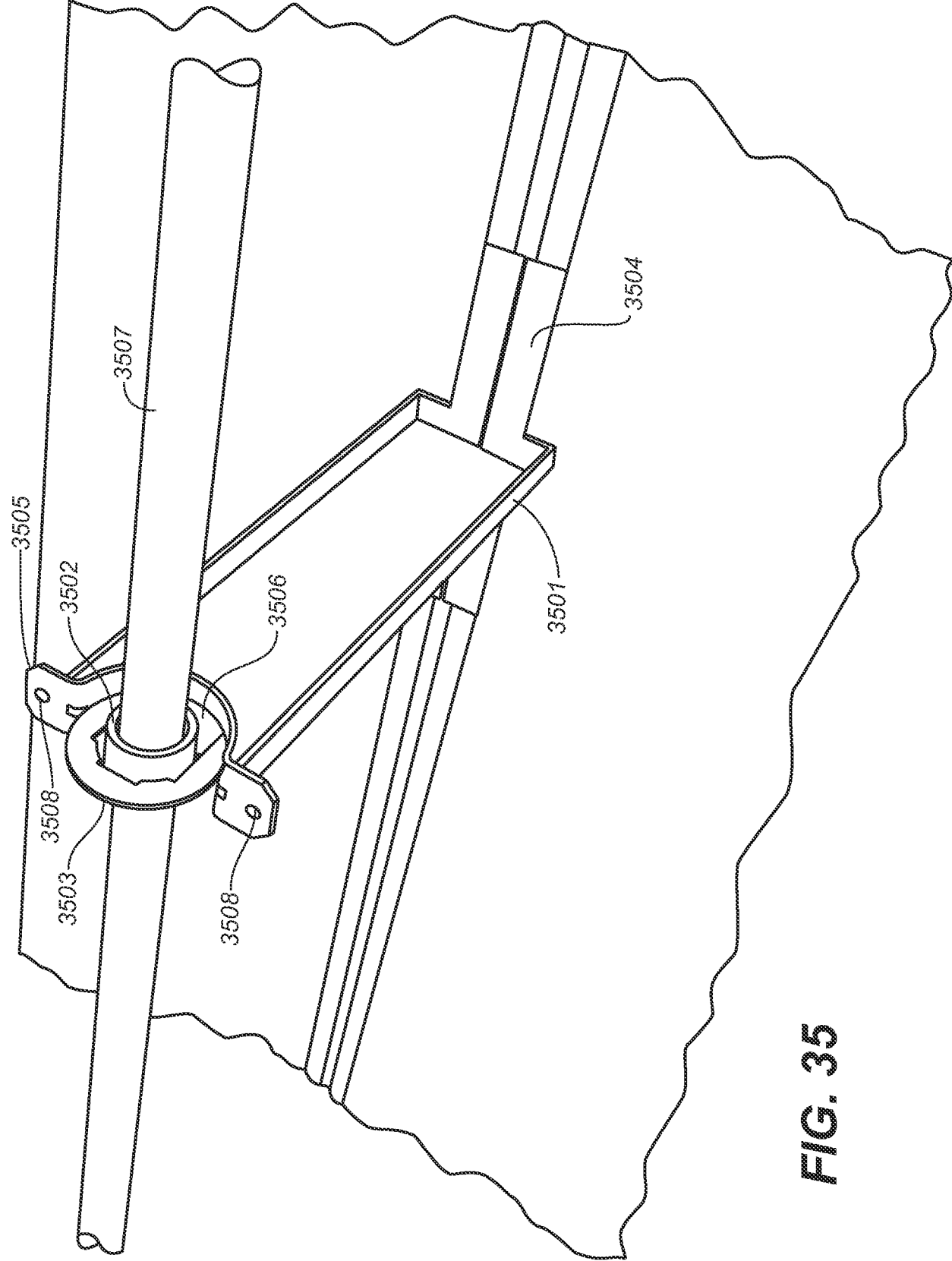


FIG. 35

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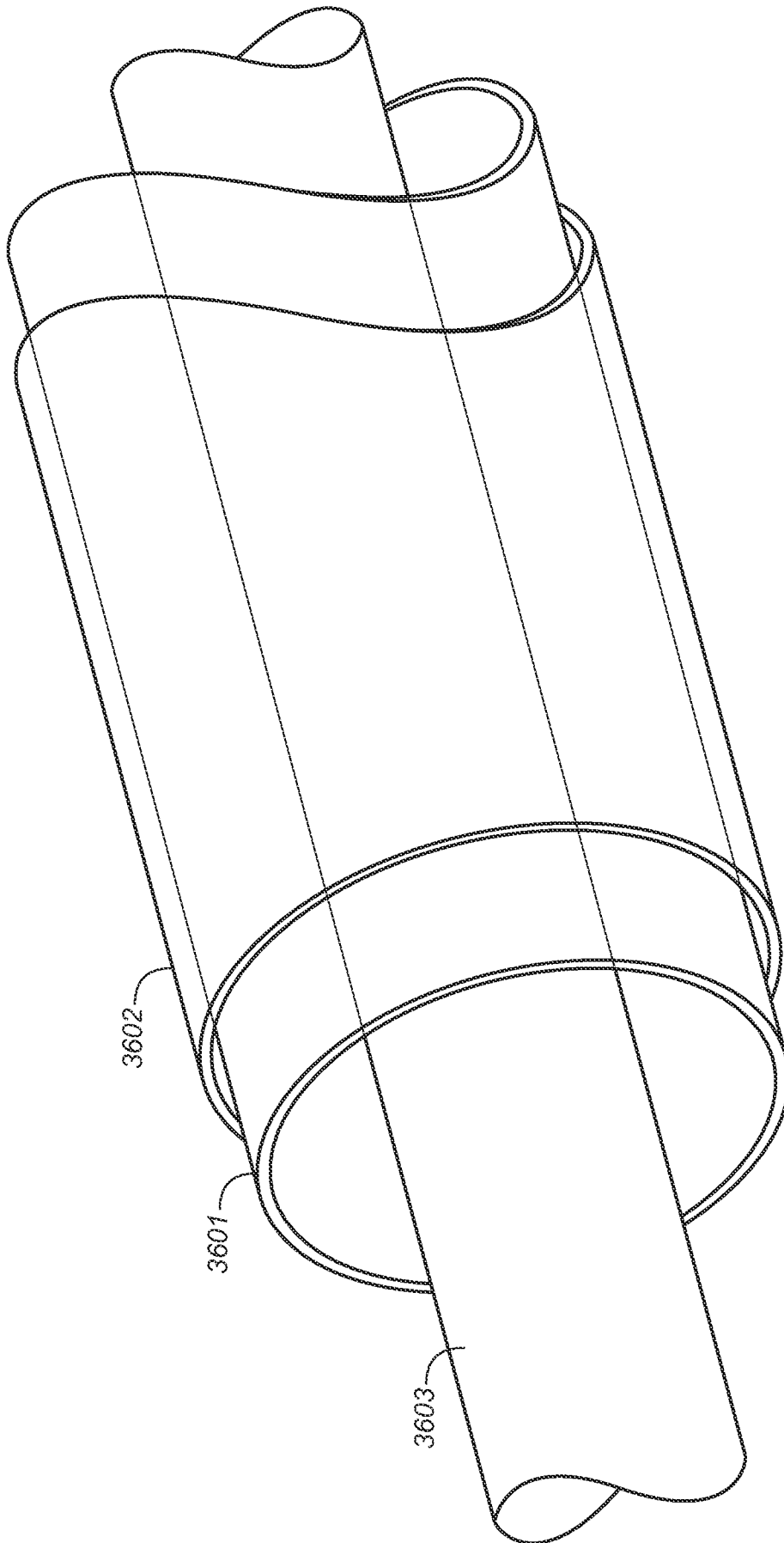


FIG. 36

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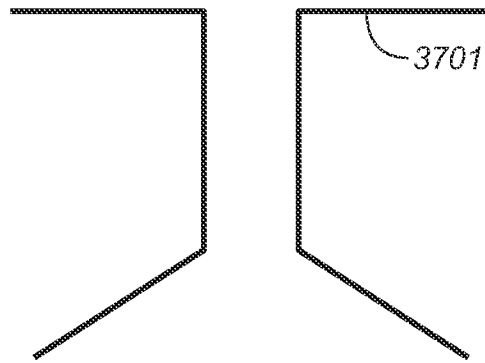


FIG. 37A

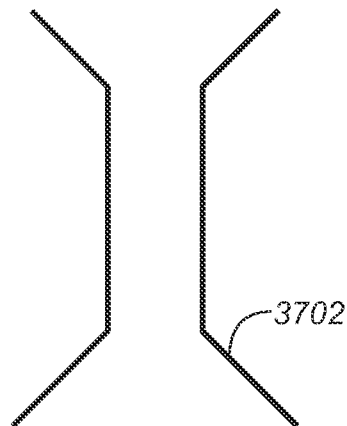


FIG. 37B