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(54) **MECHANICAL PHOTOVOLTAIC MODULE CARTRIDGE AND METHOD OF CONSTRUCTION**

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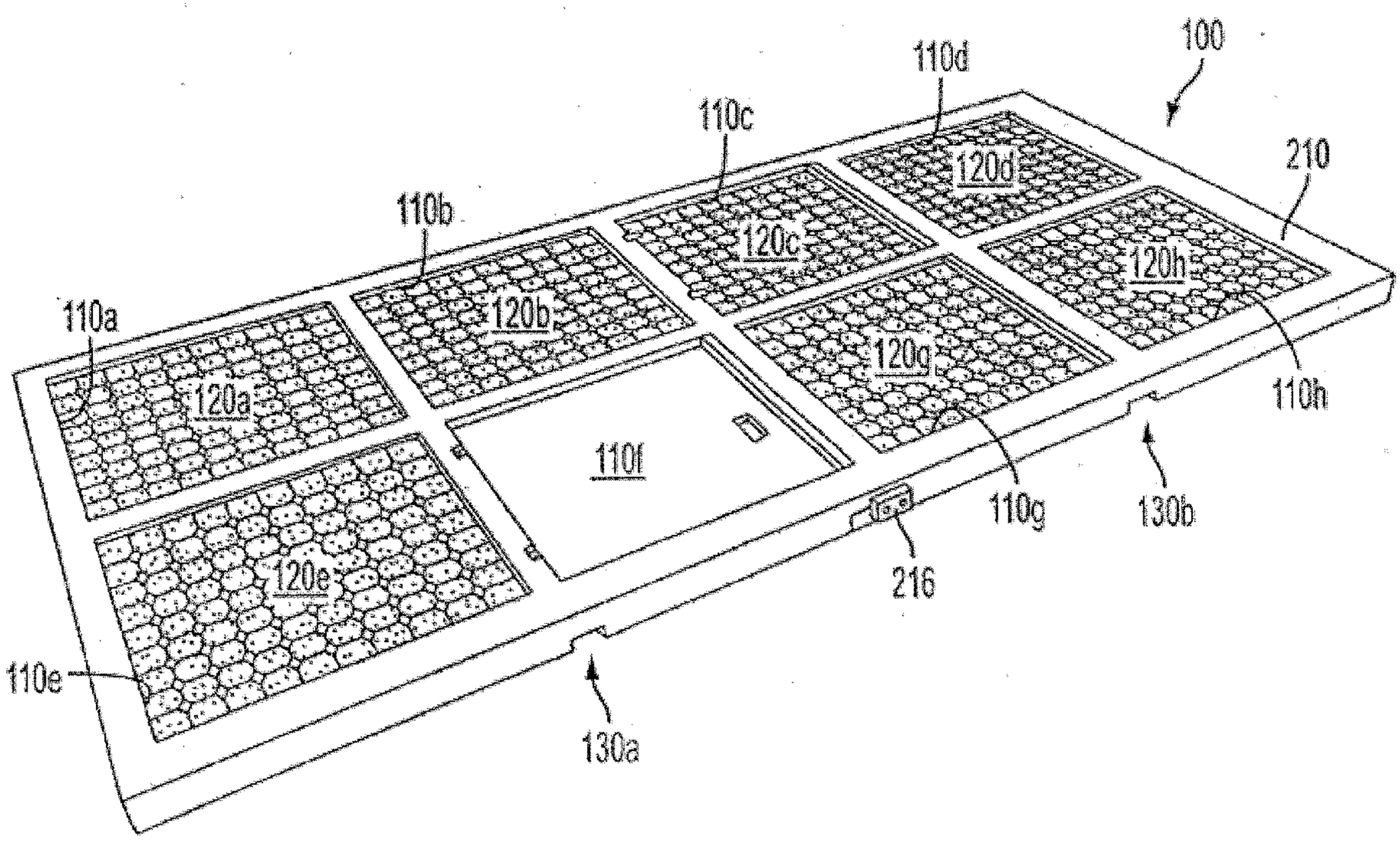
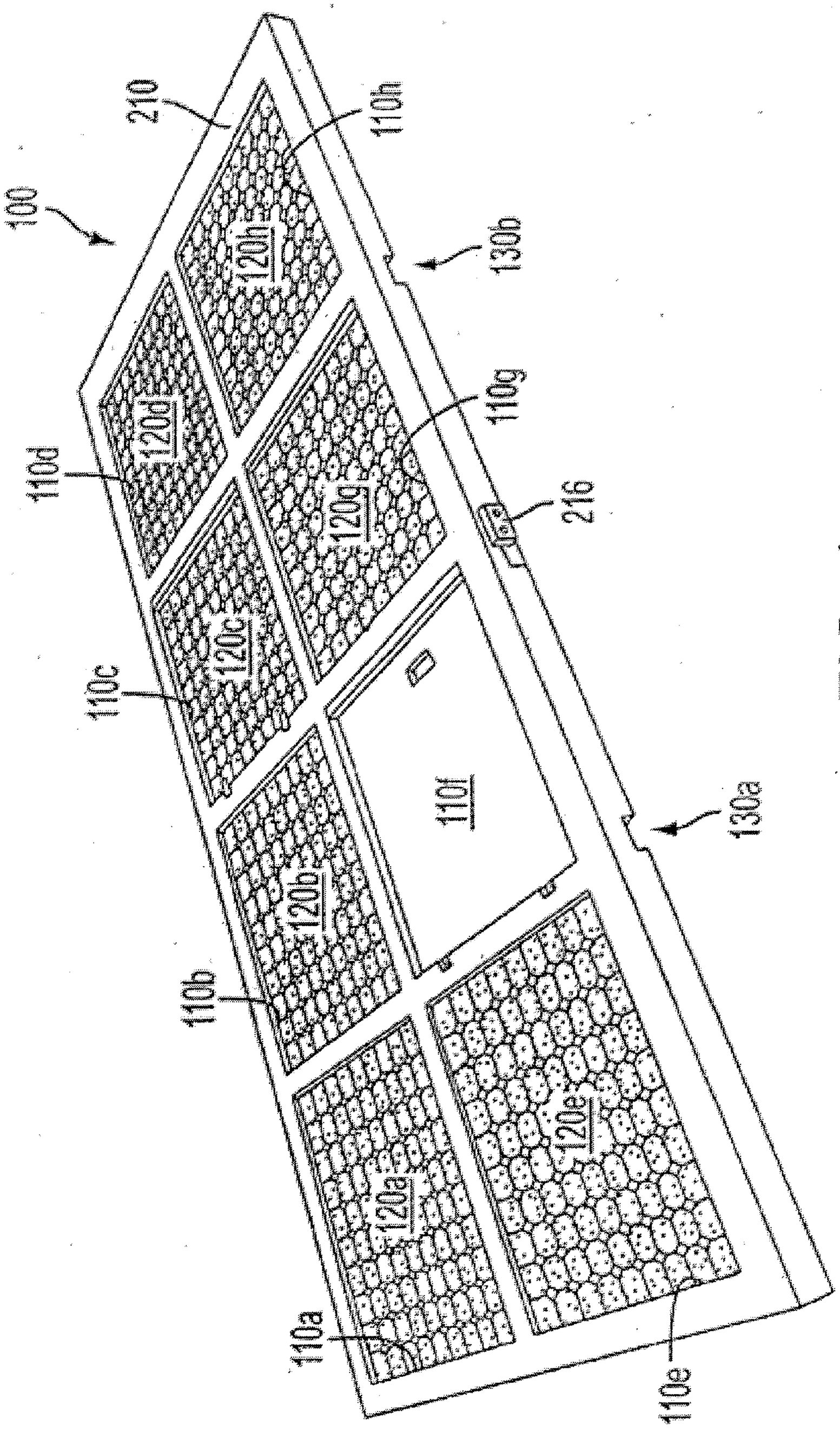
(52) **U.S. Cl.** **52/173.3**; 52/745.19; 52/745.2

(57) **ABSTRACT**

A photovoltaic panel cartridge for mounting a plurality of photovoltaic panels and method of its construction are described. The photovoltaic panel cartridge is formed from a unitary frame with internal beams and struts for stability. The photovoltaic panels are inserted into channels within the frame, struts, and/or the internal beams in order to be mounted to the photovoltaic panel cartridge and secured to mounting regions on a different one of the frame, struts, and/or internal beams. The photovoltaic panel cartridge is configured to be stacked upon similarly configured photovoltaic panel cartridges for ease in transport and to reduce damage to the photovoltaic panels during transport. The photovoltaic panel cartridge may be slidably mounted to rails of a support structure.

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110a
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FIG. 1

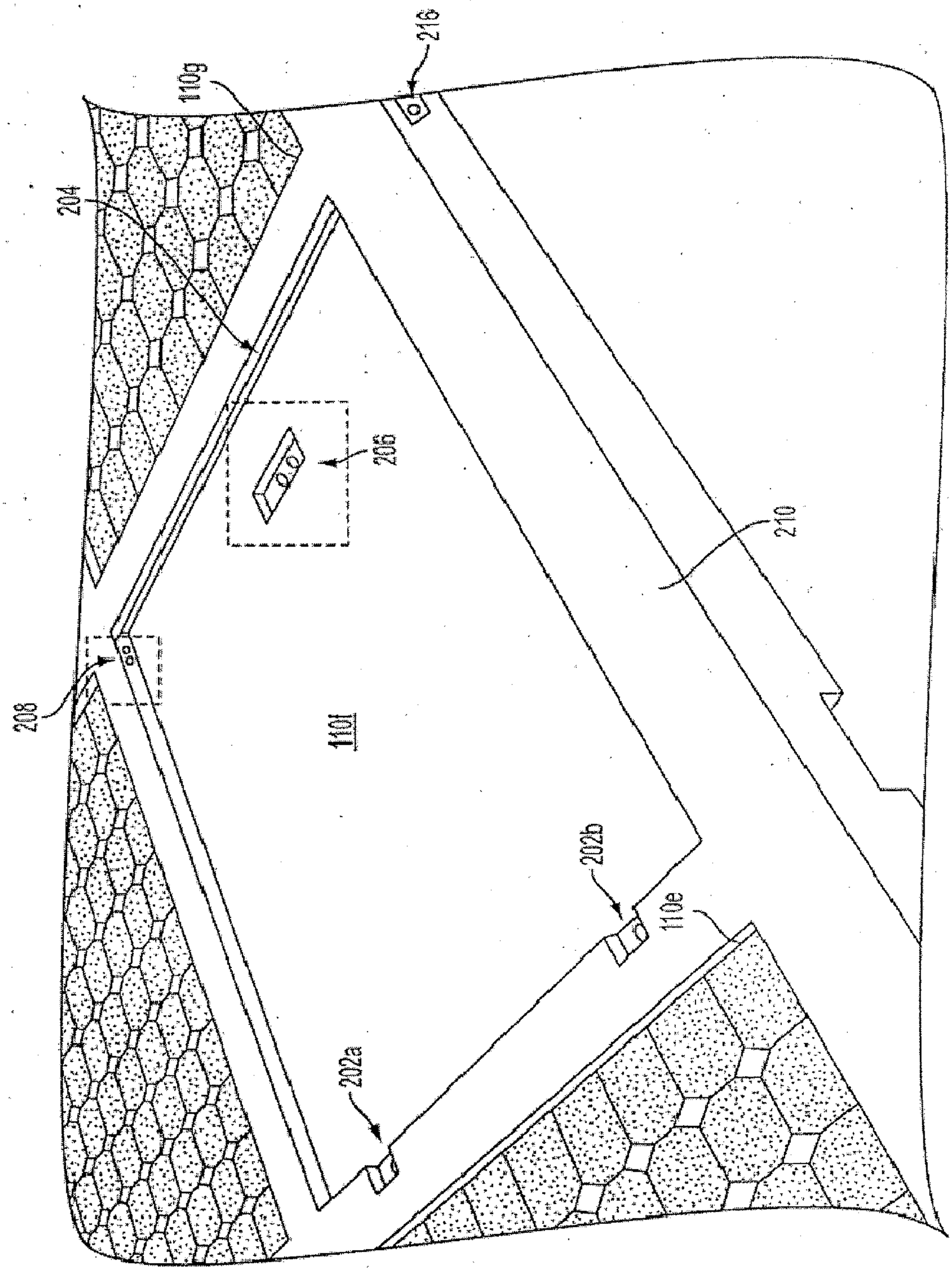


FIG. 2

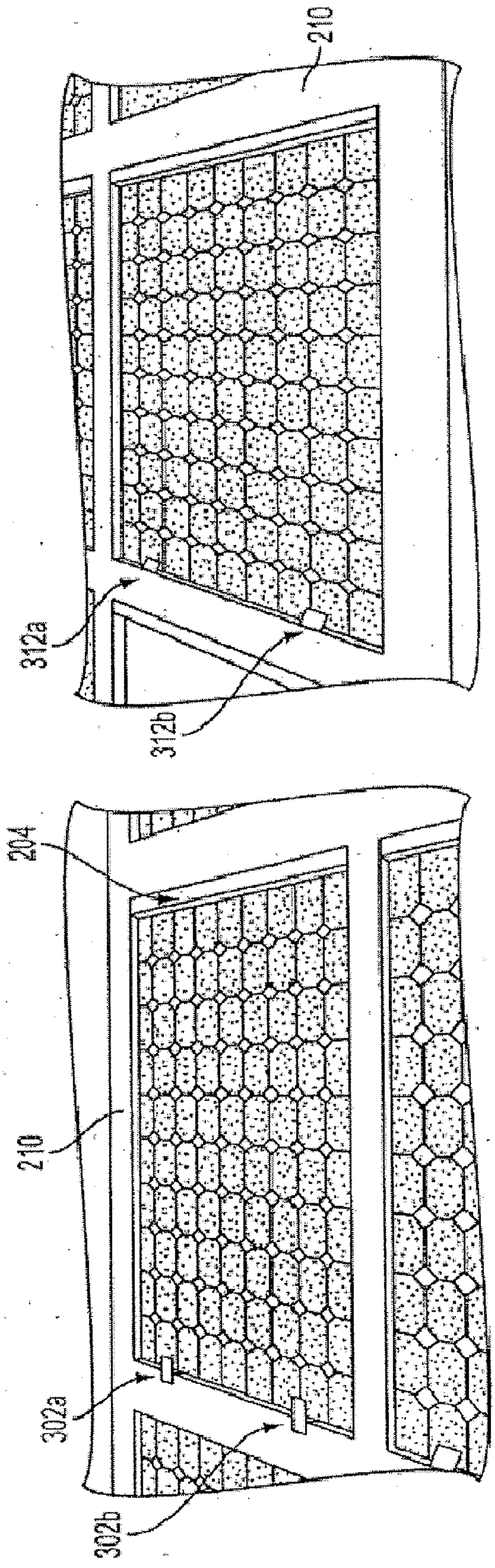


FIG. 3A

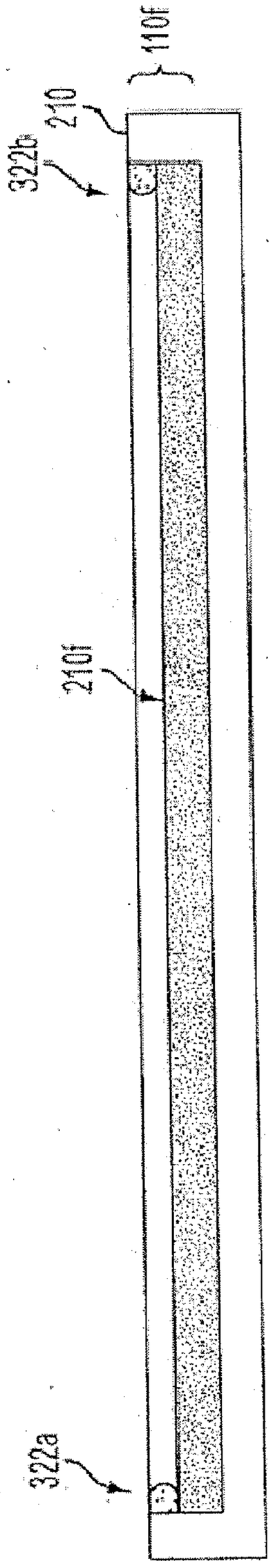


FIG. 3B

FIG. 3C

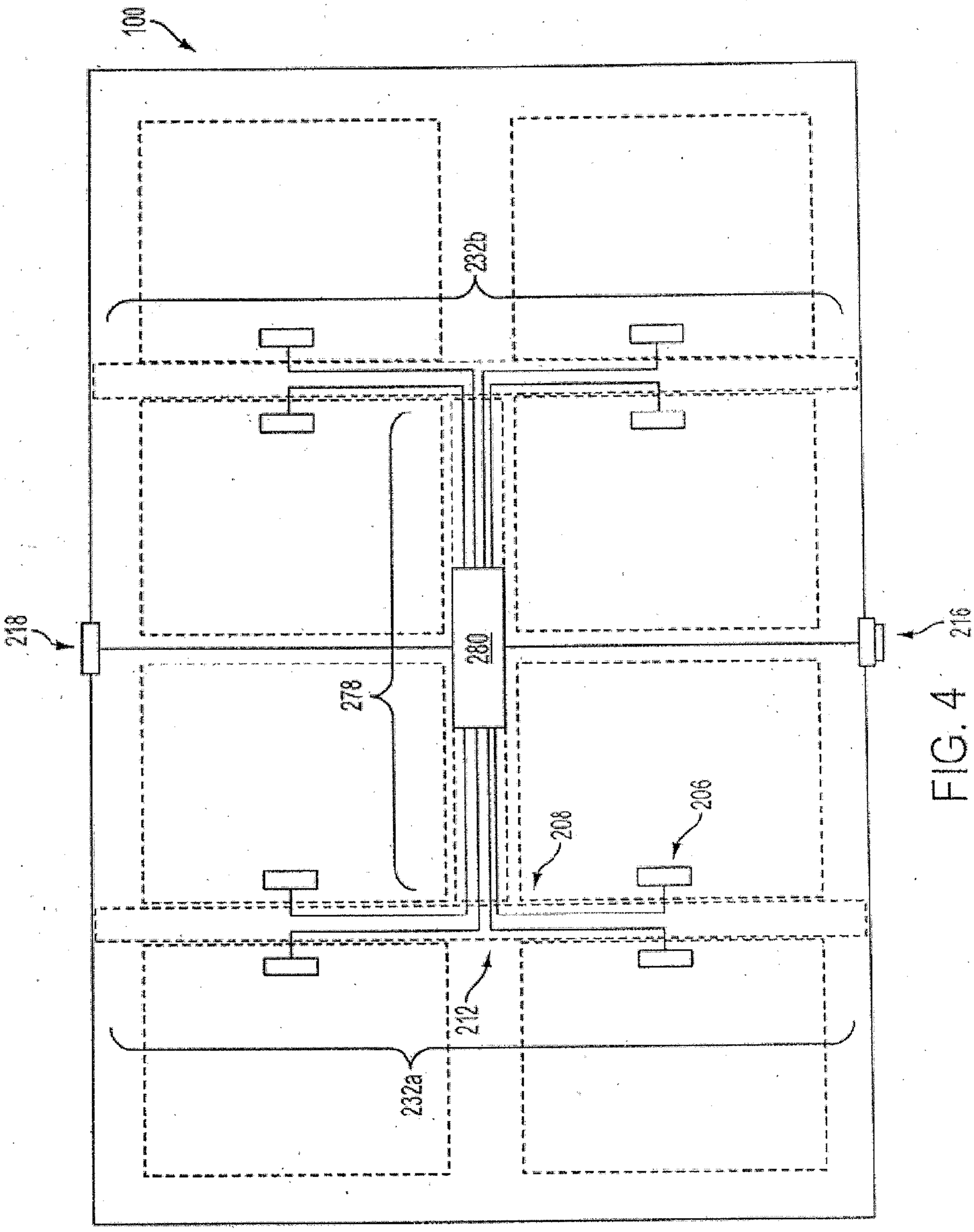


FIG. 4

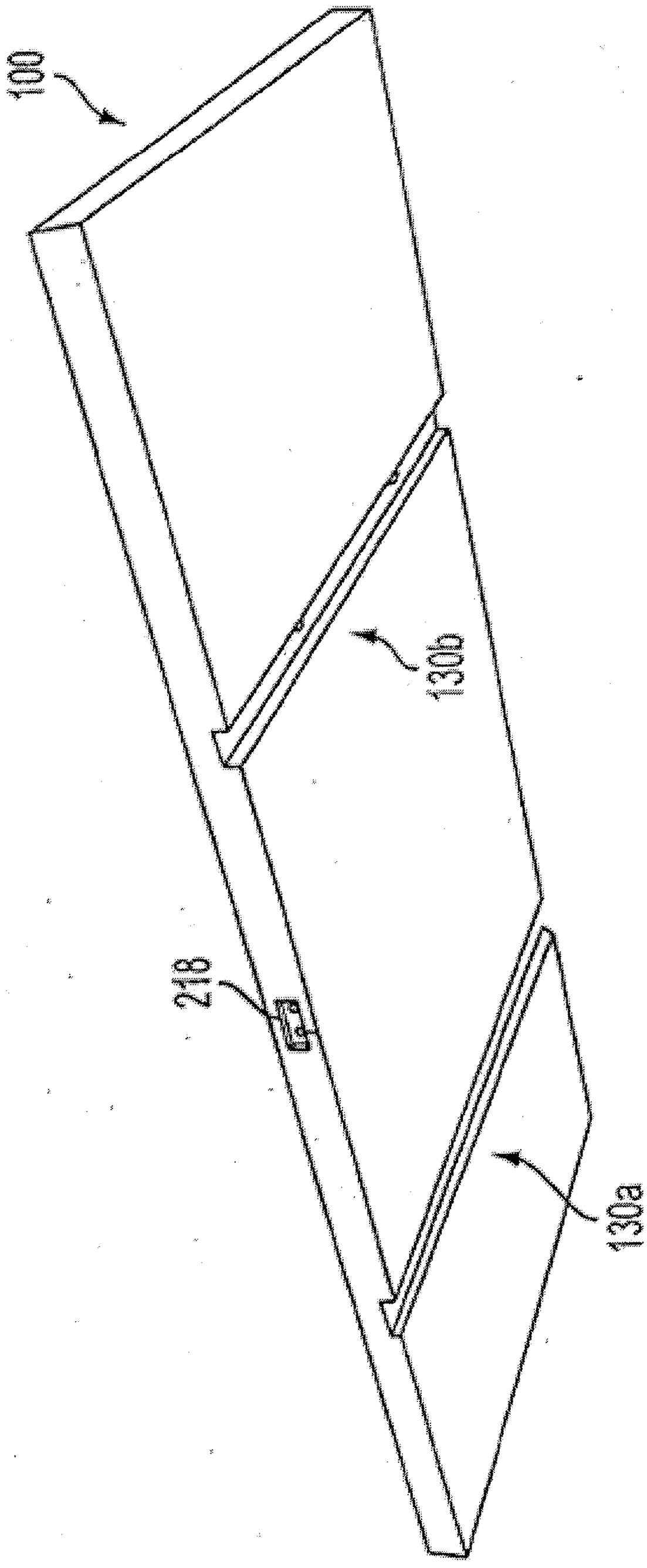


FIG. 5

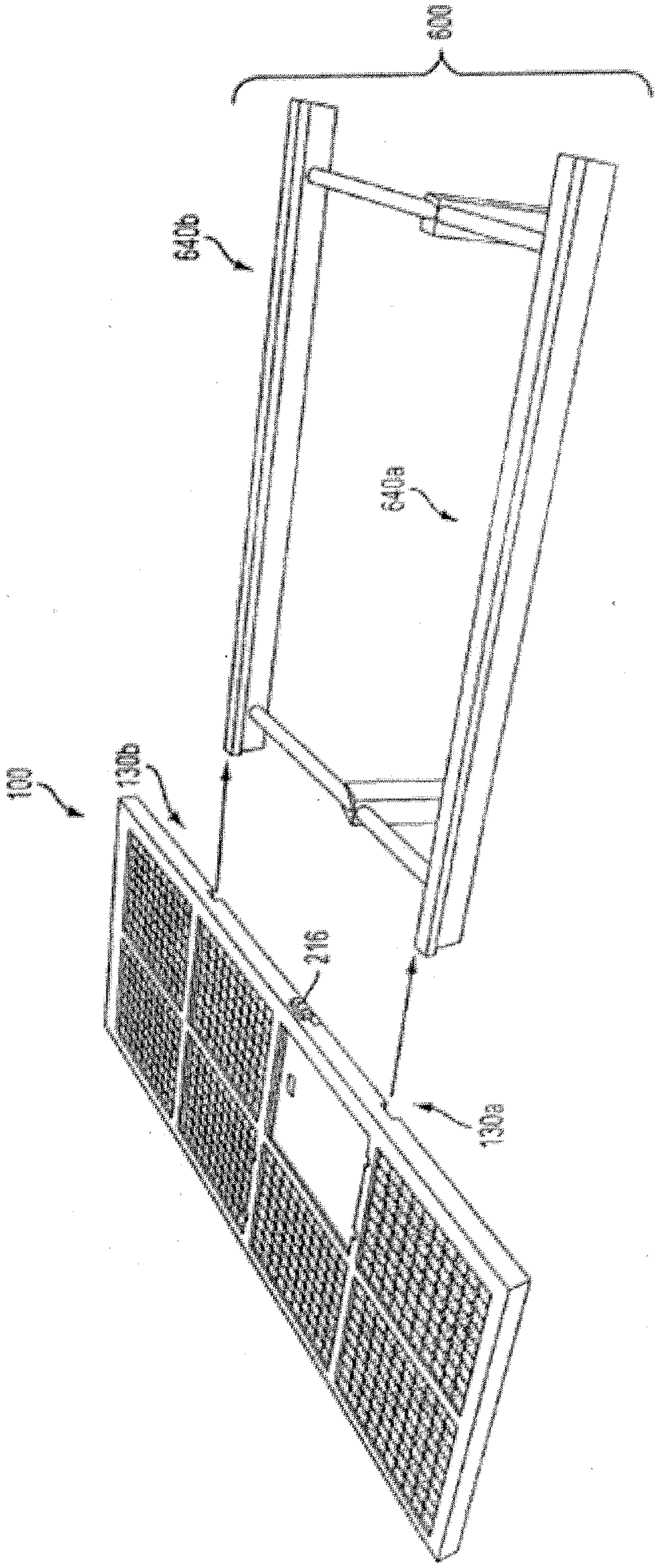


FIG. 6A

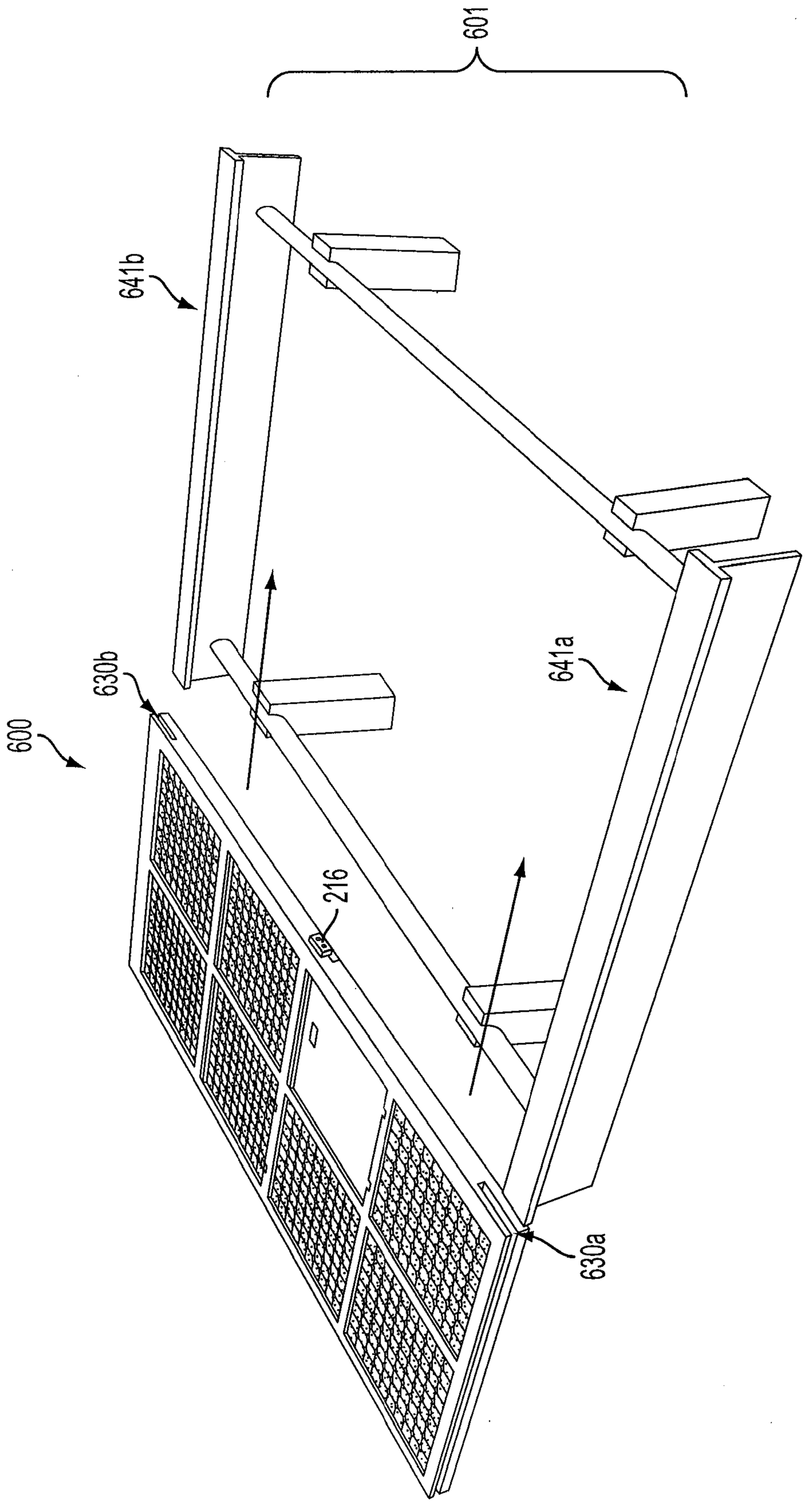


FIG. 6B

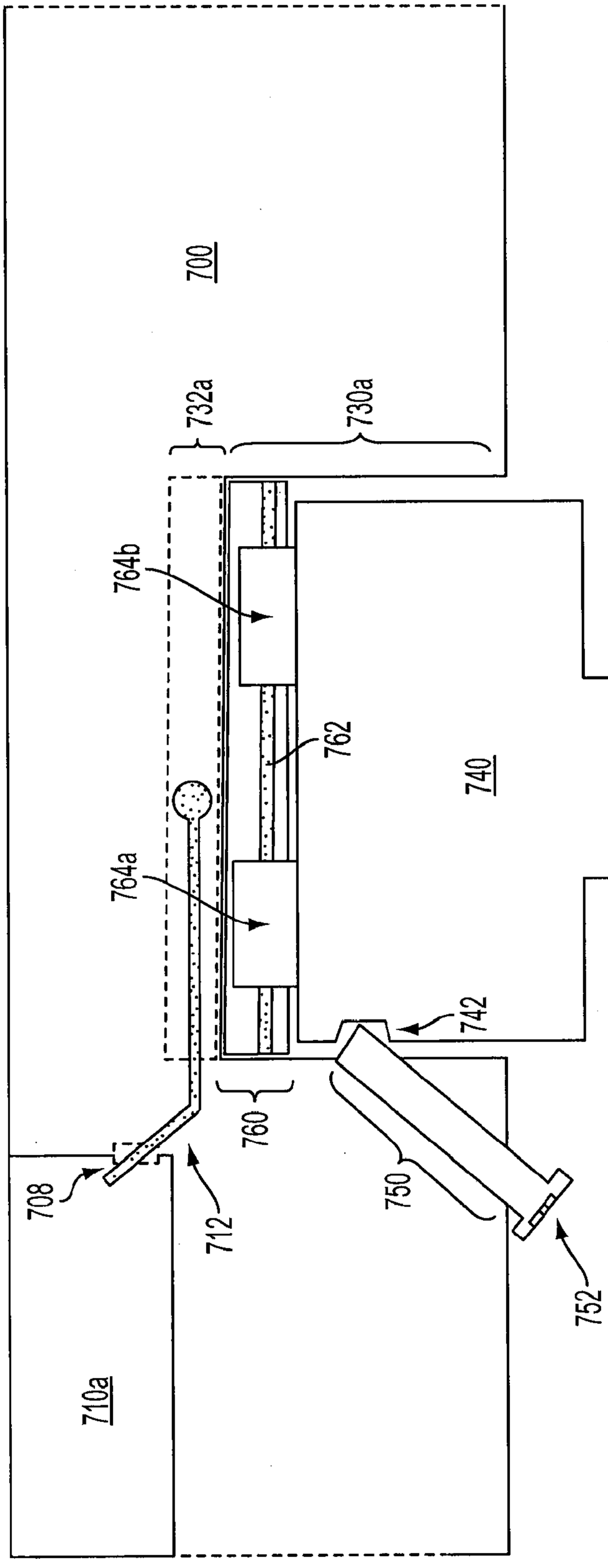
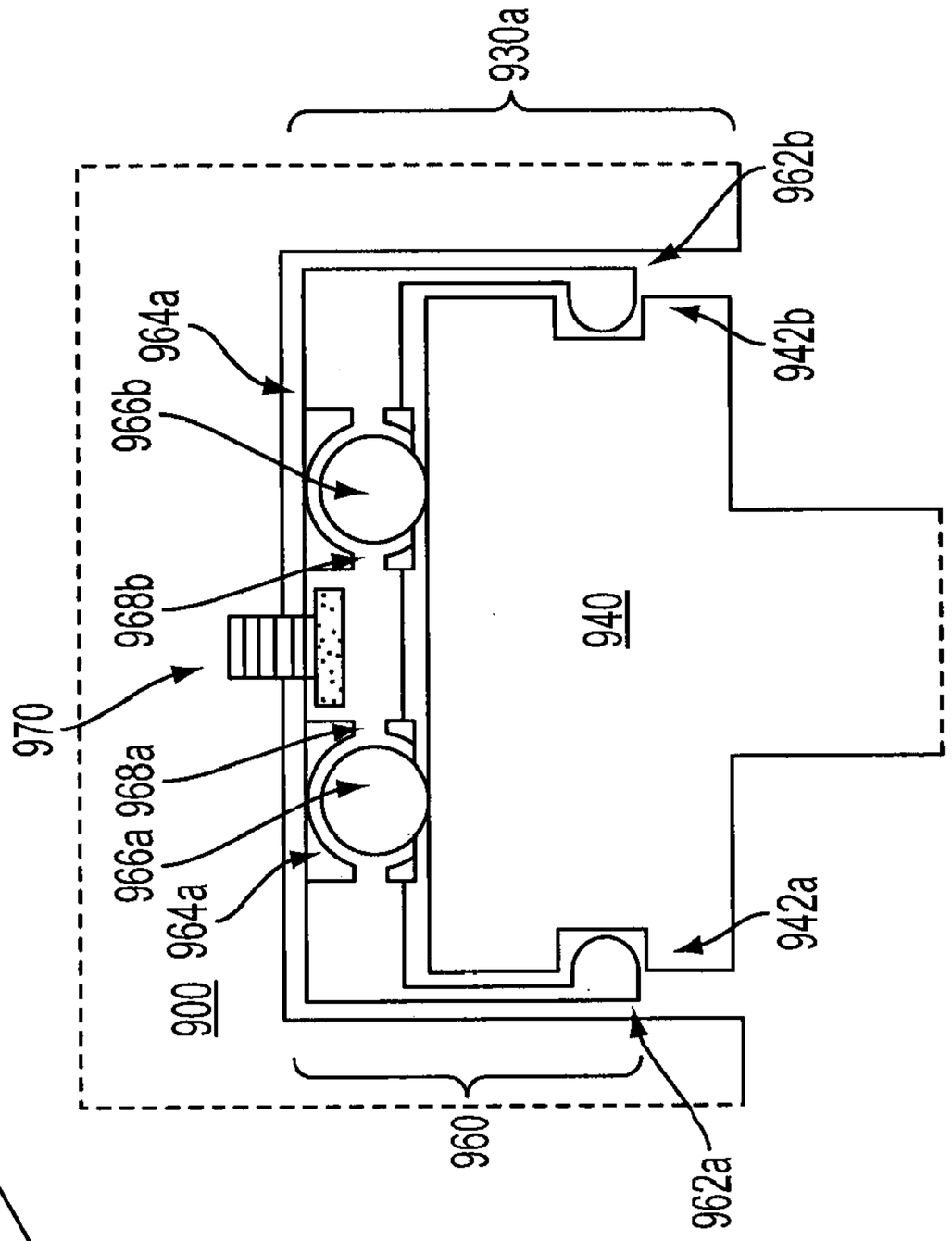


FIG. 7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942b
942a
960
962a

FIG. 9

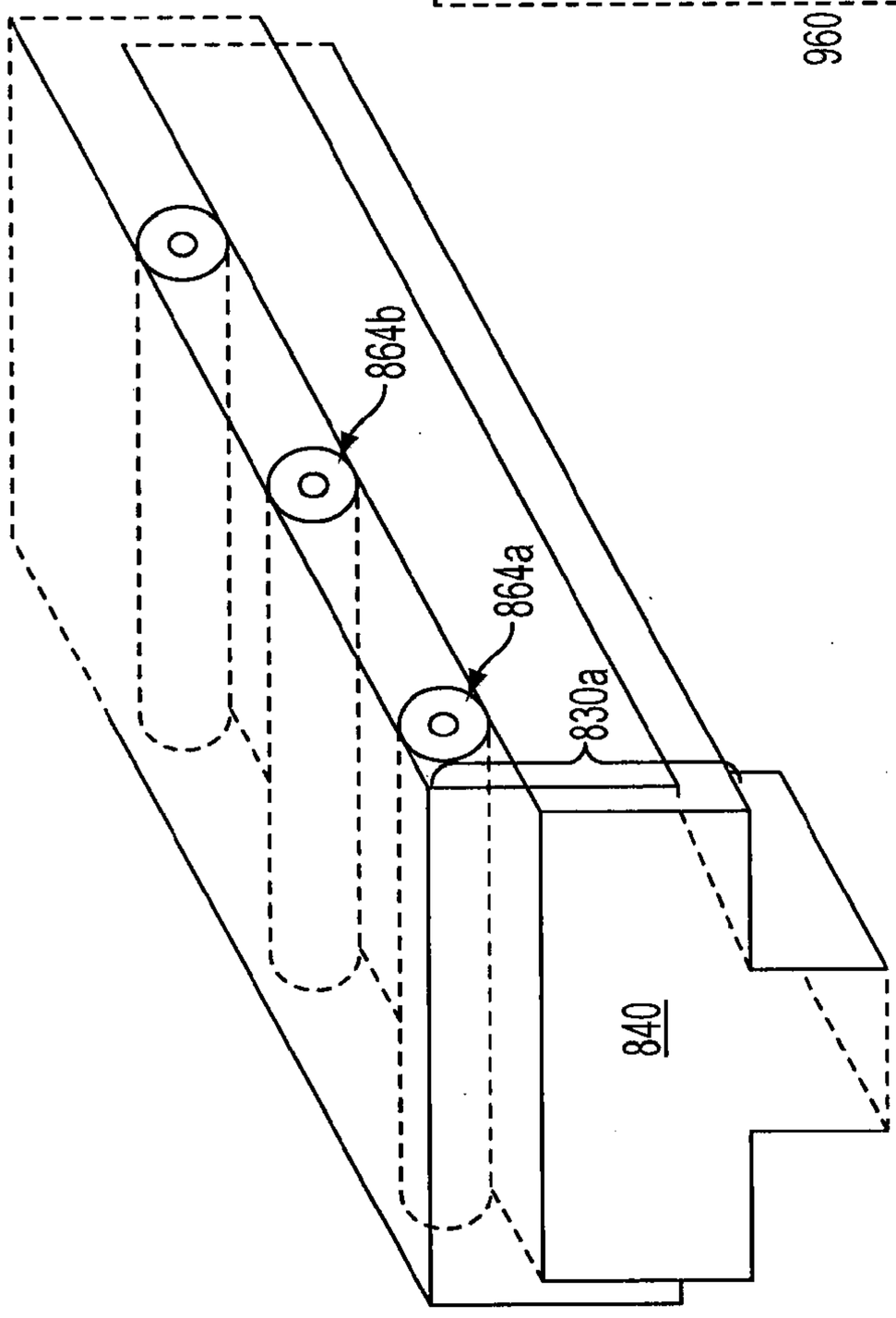
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FIG. 8

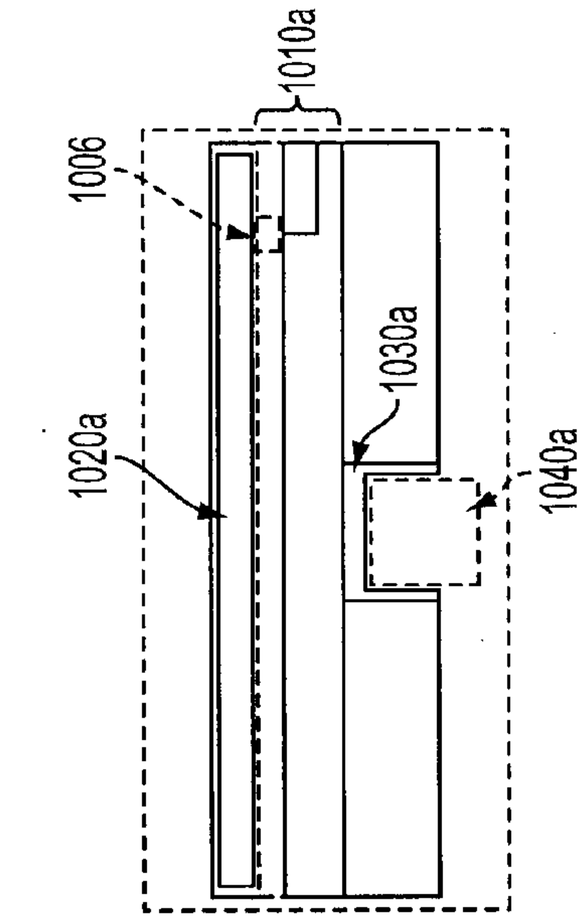


FIG. 10B

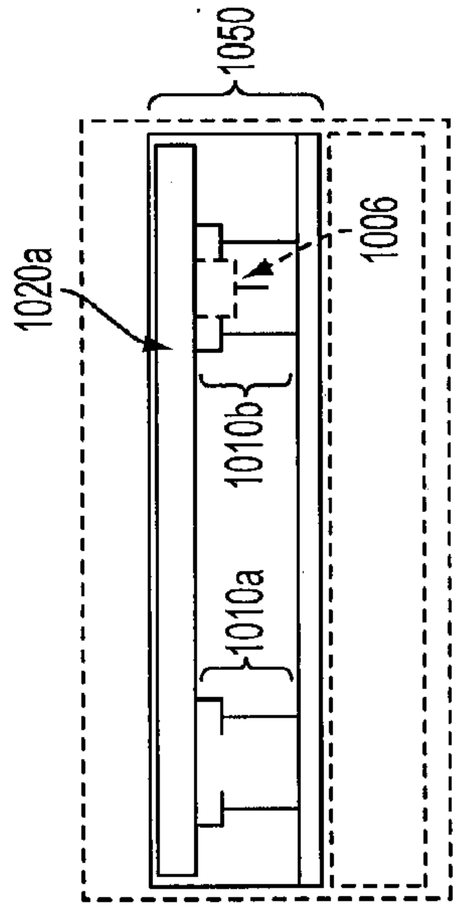


FIG. 10C

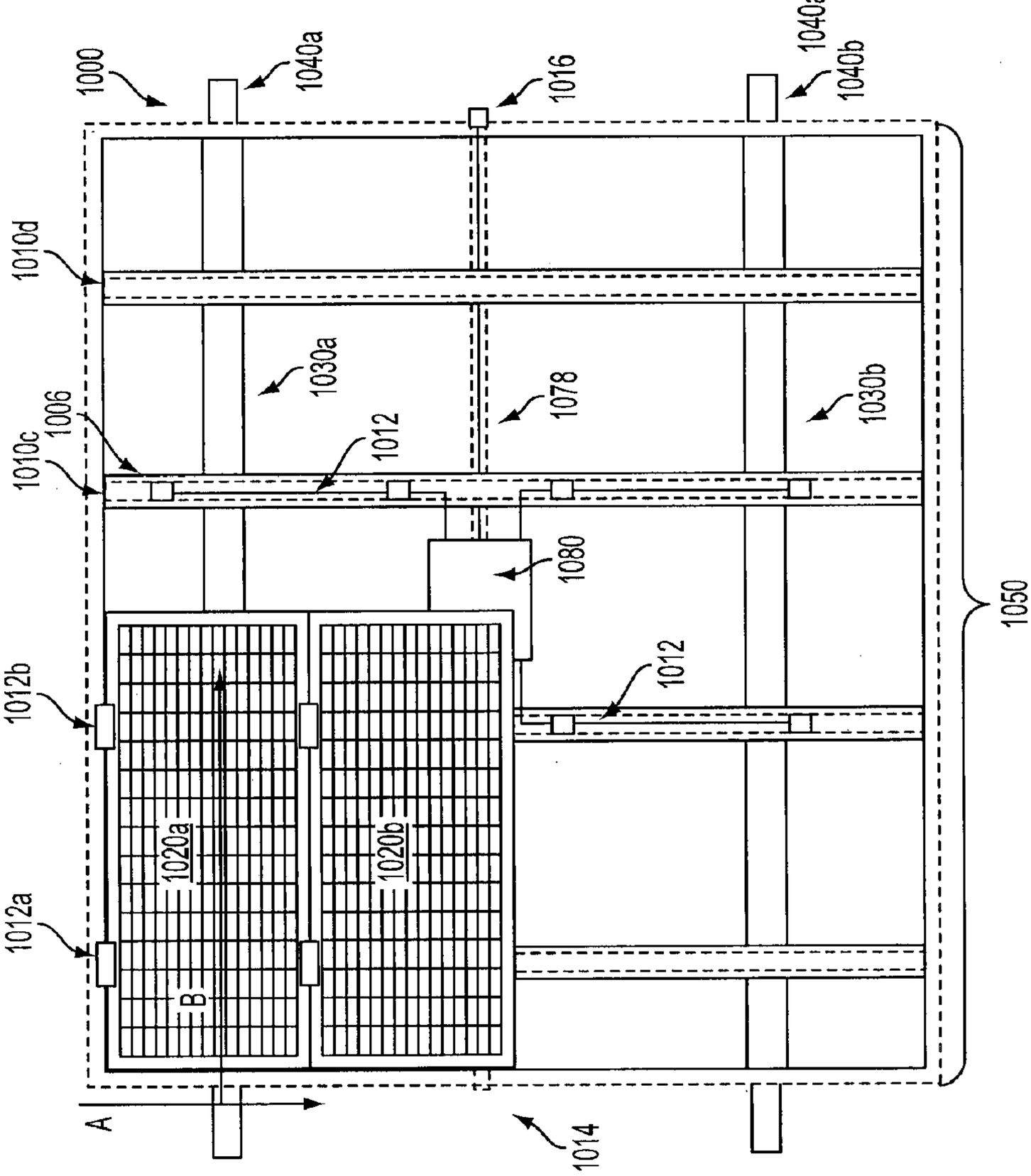


FIG. 10A

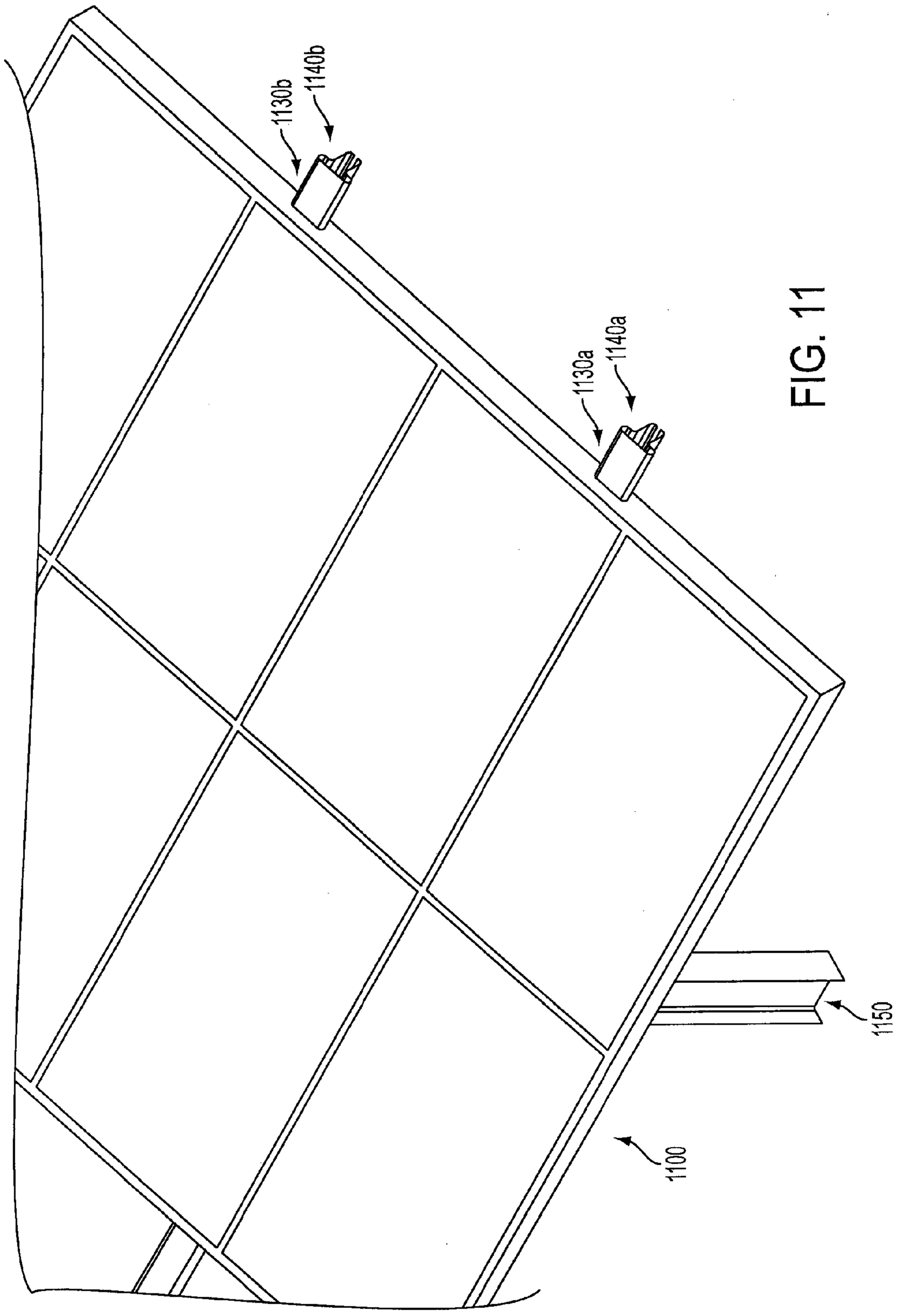


FIG. 11

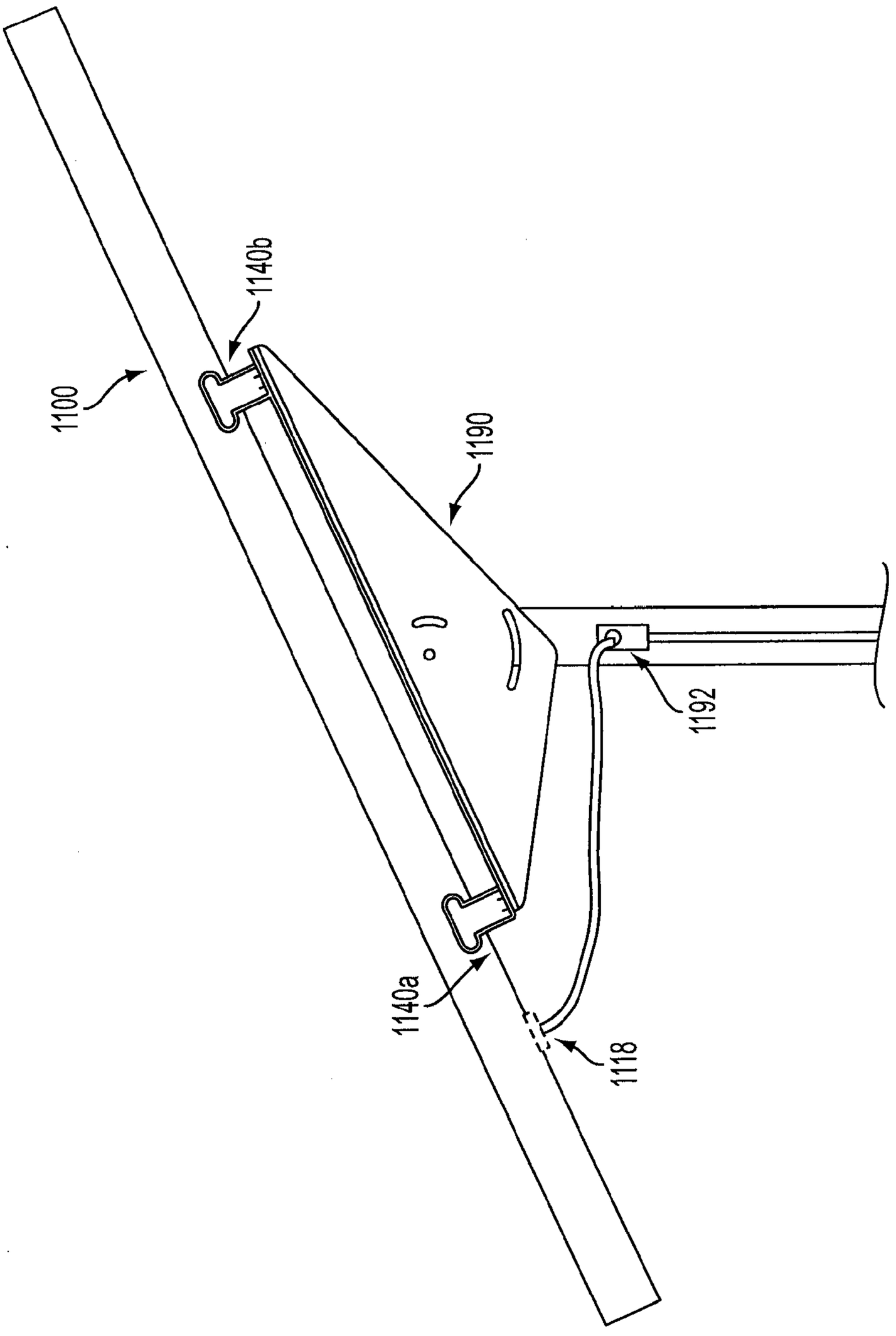


FIG. 12

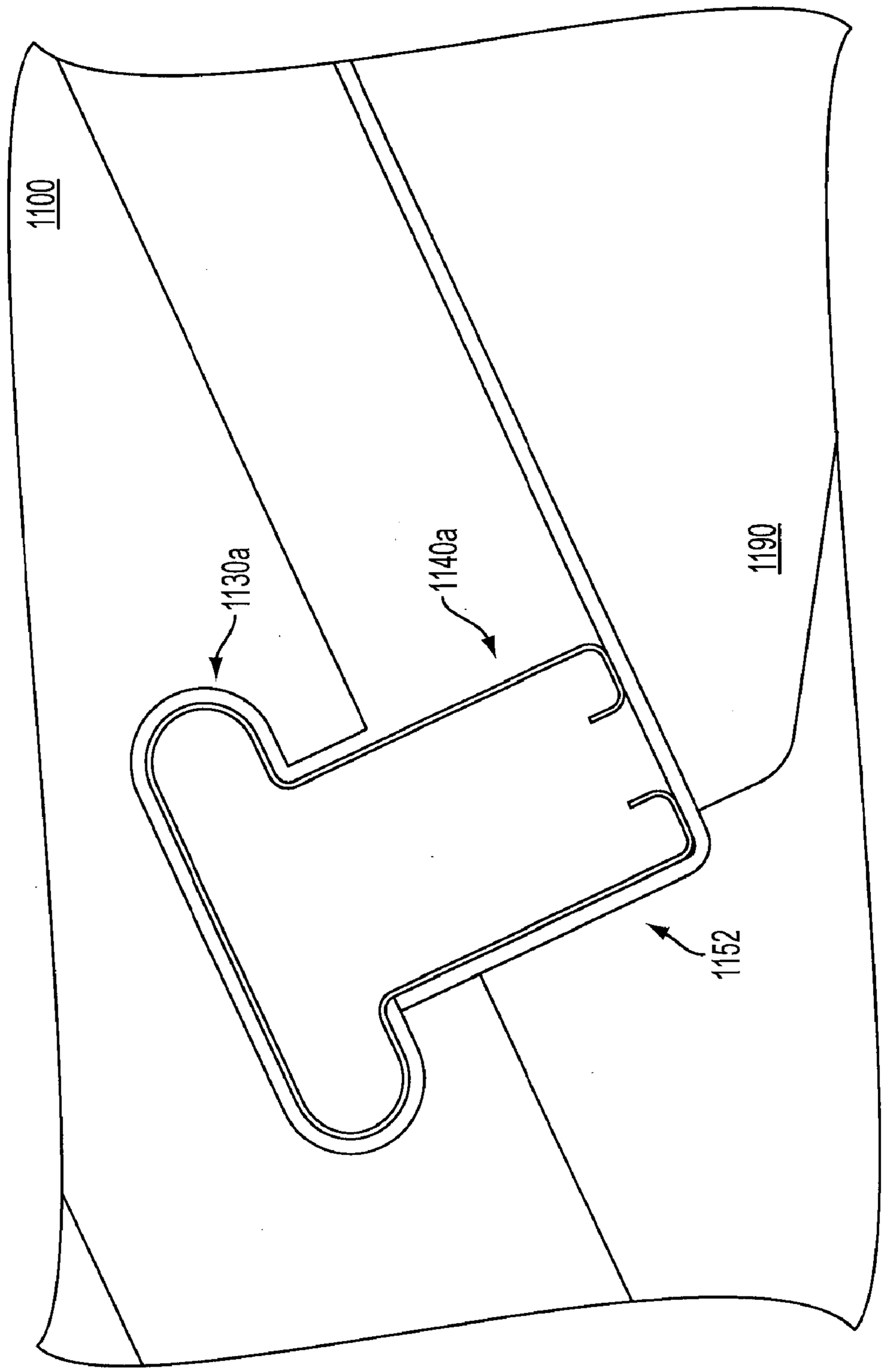


FIG. 13

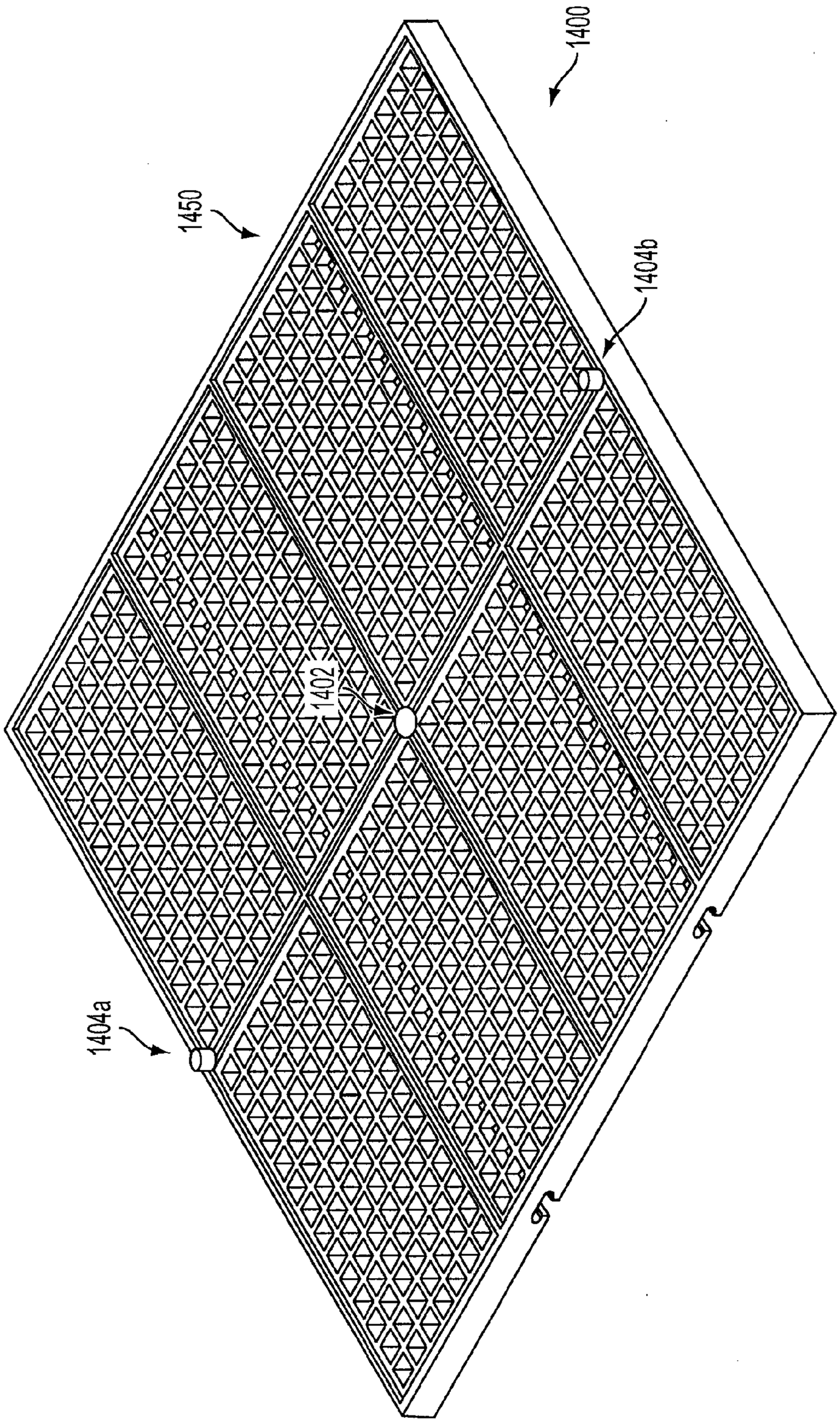
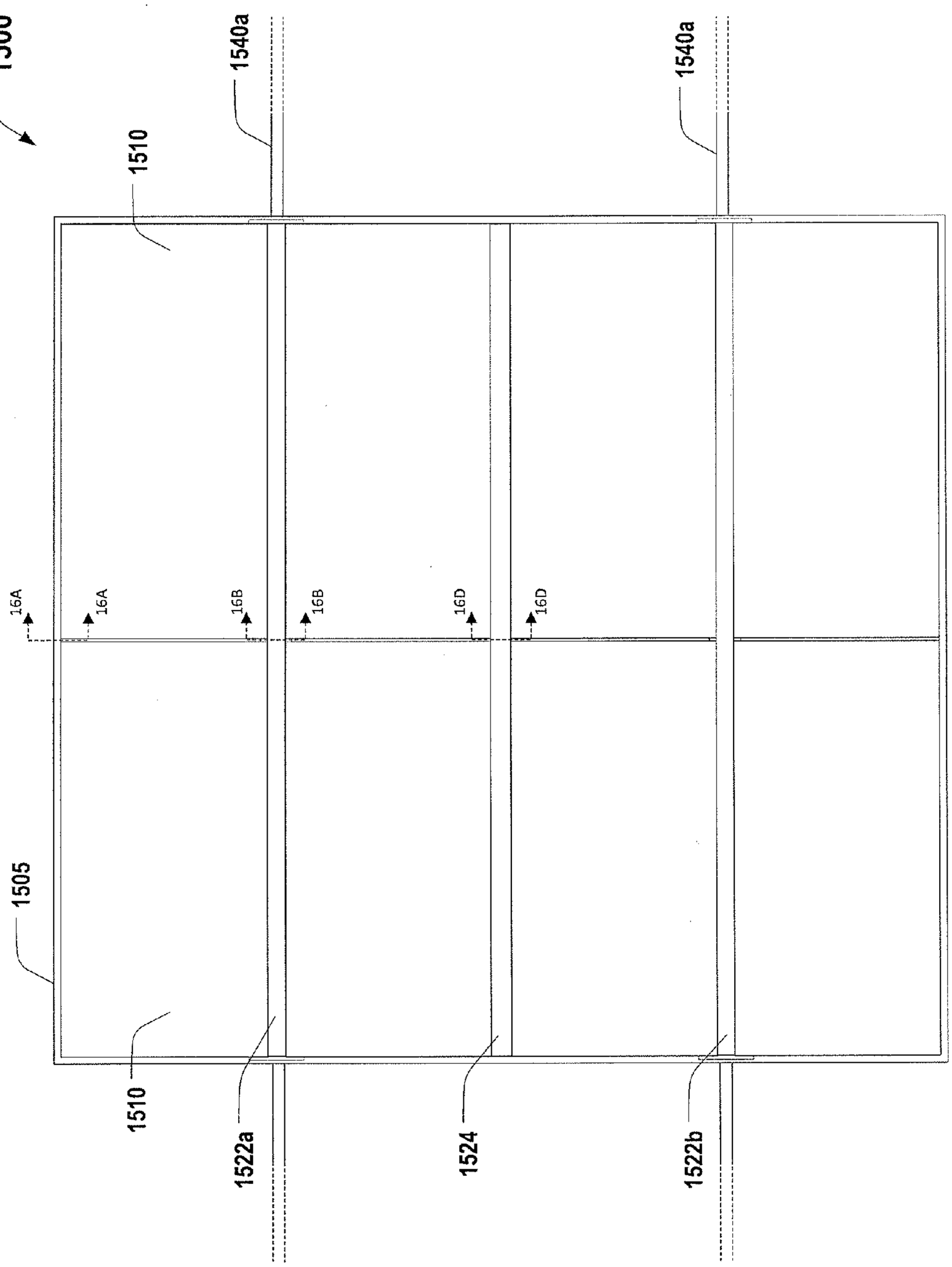


FIG. 14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16A
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FIG. 15

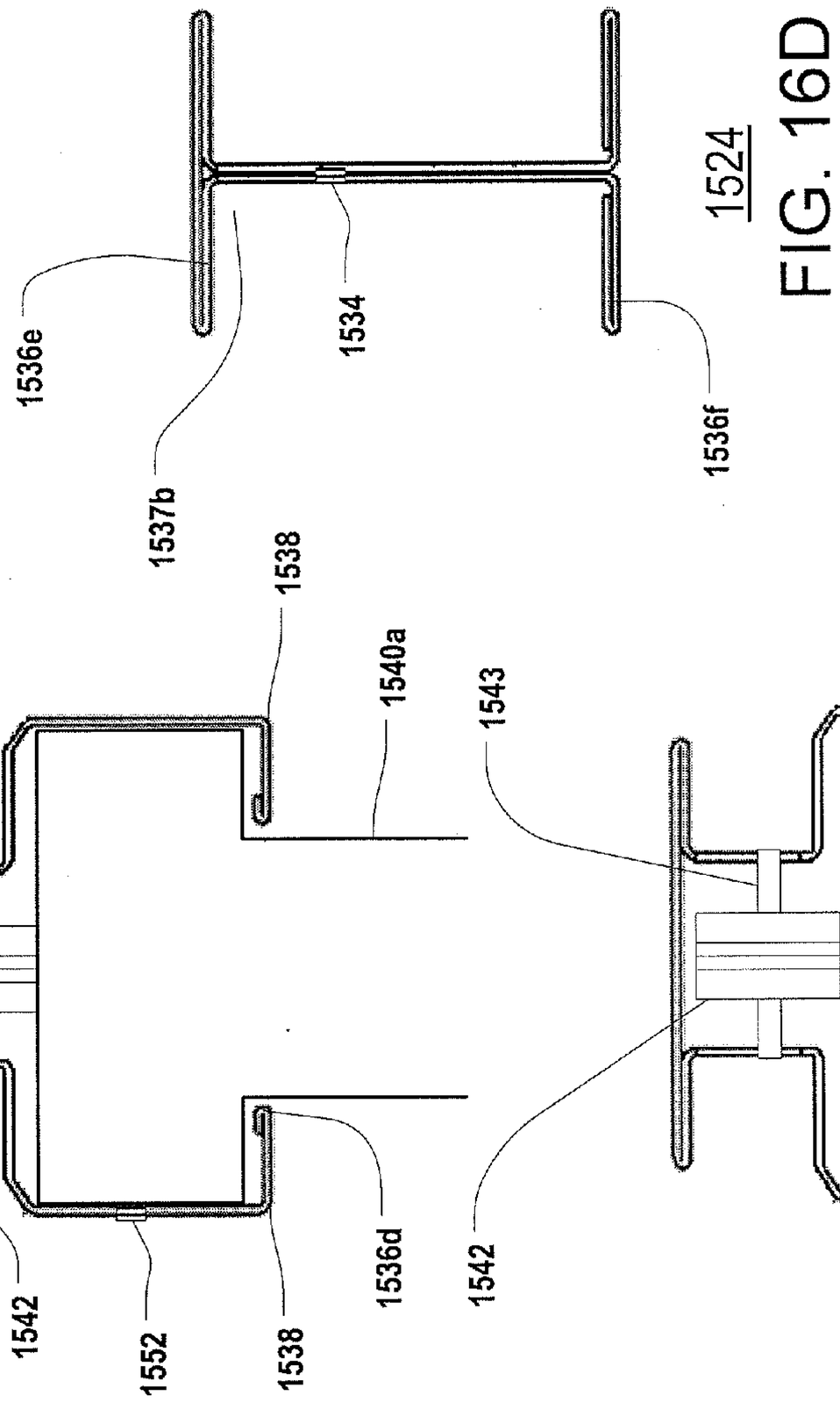

FIG. 16D

FIG. 16C

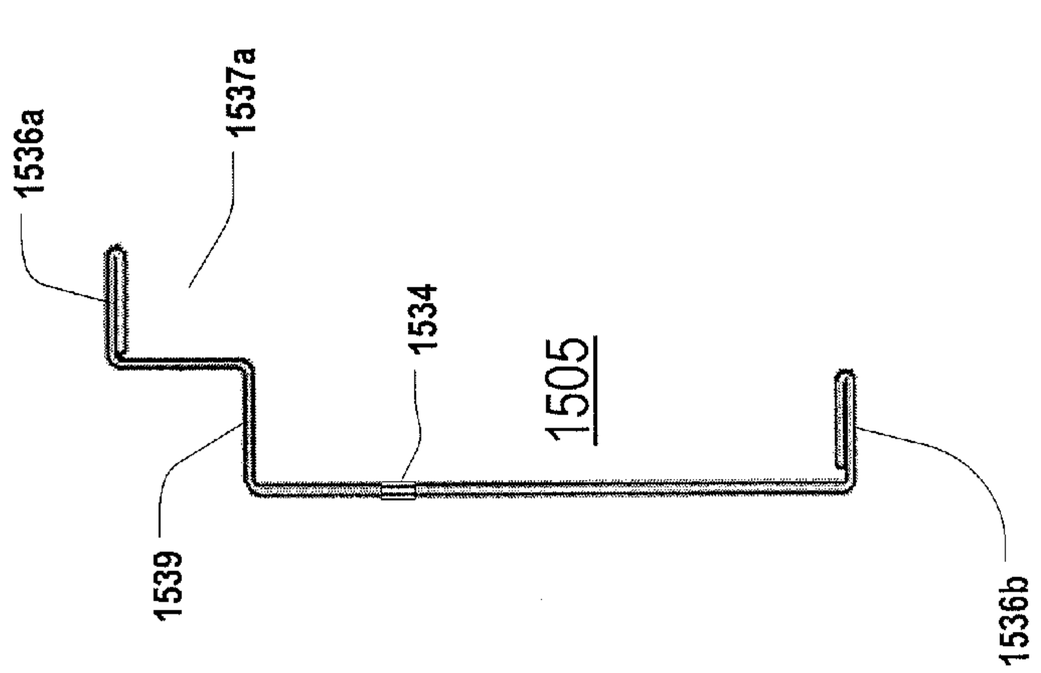

FIG. 16A

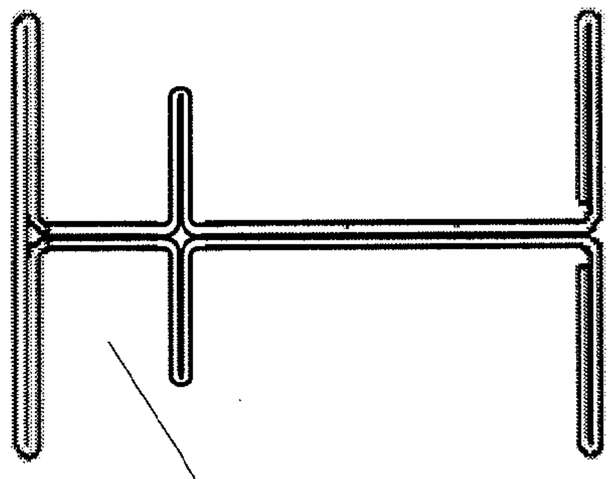

FIG. 16G

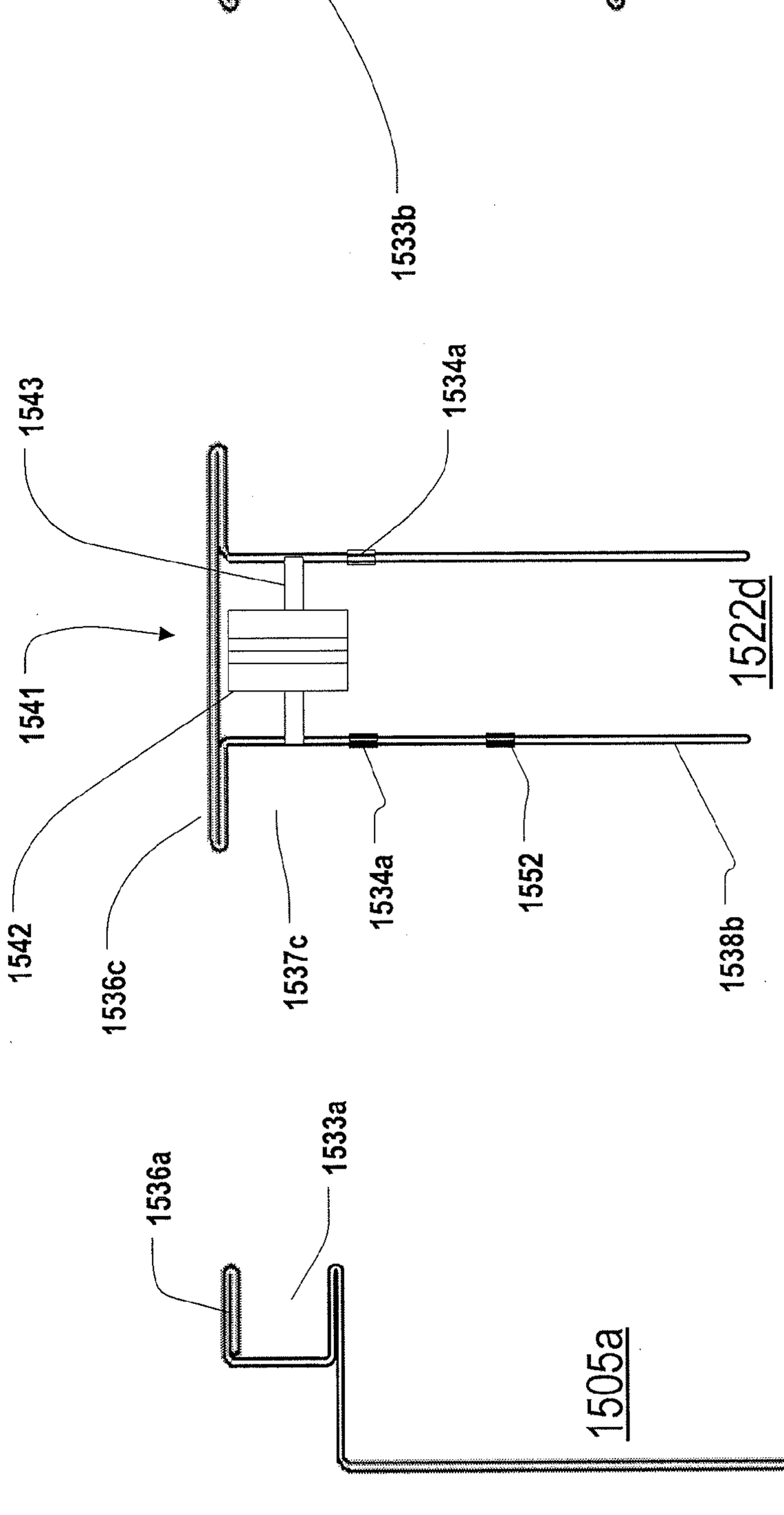

FIG. 16F

FIG. 16E

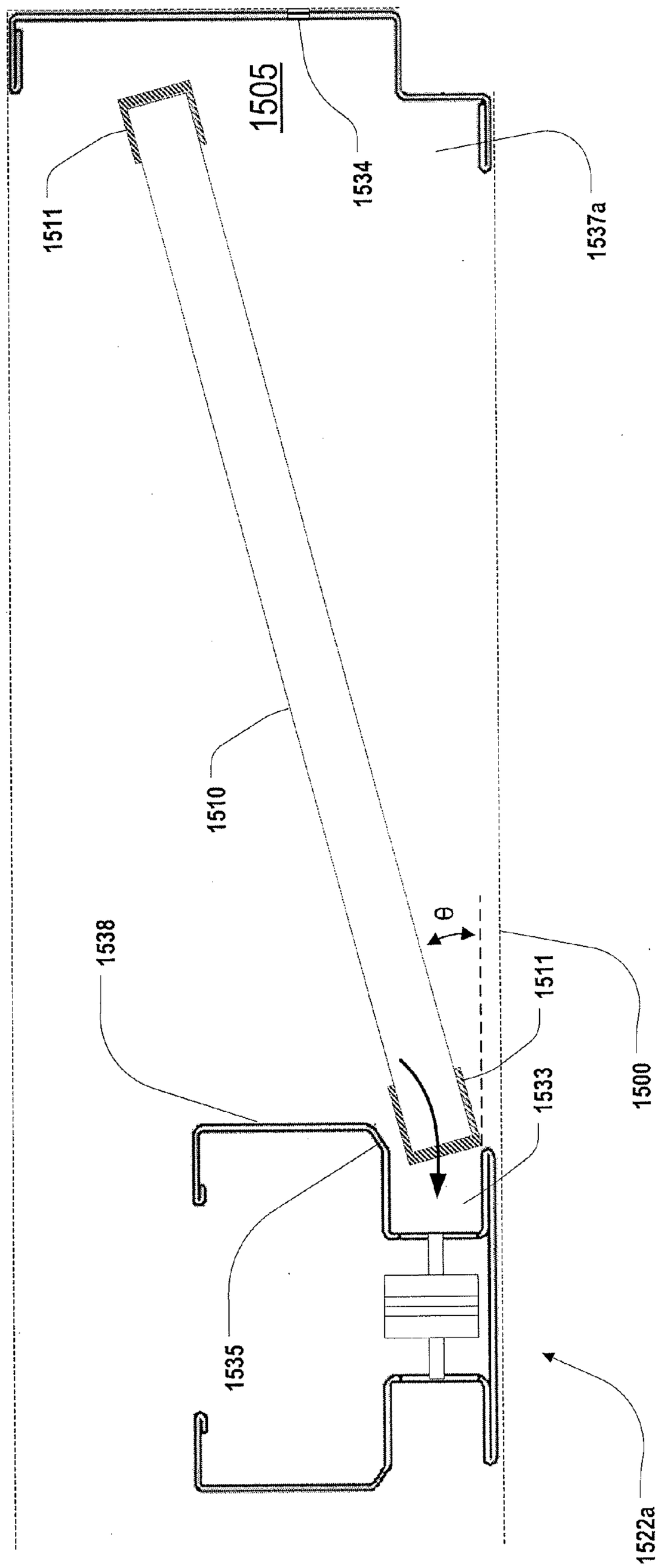

FIG. 17A

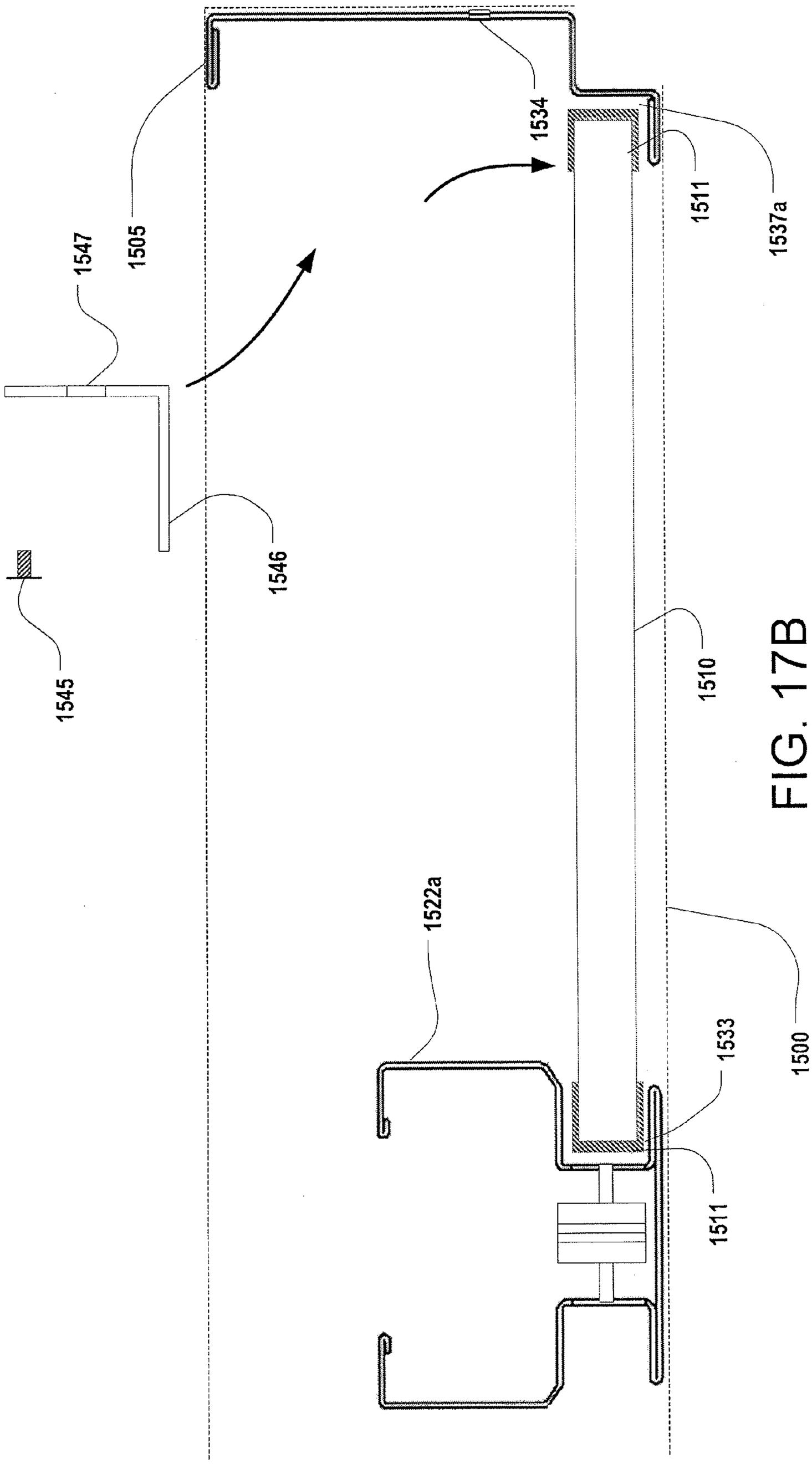
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FIG. 17B

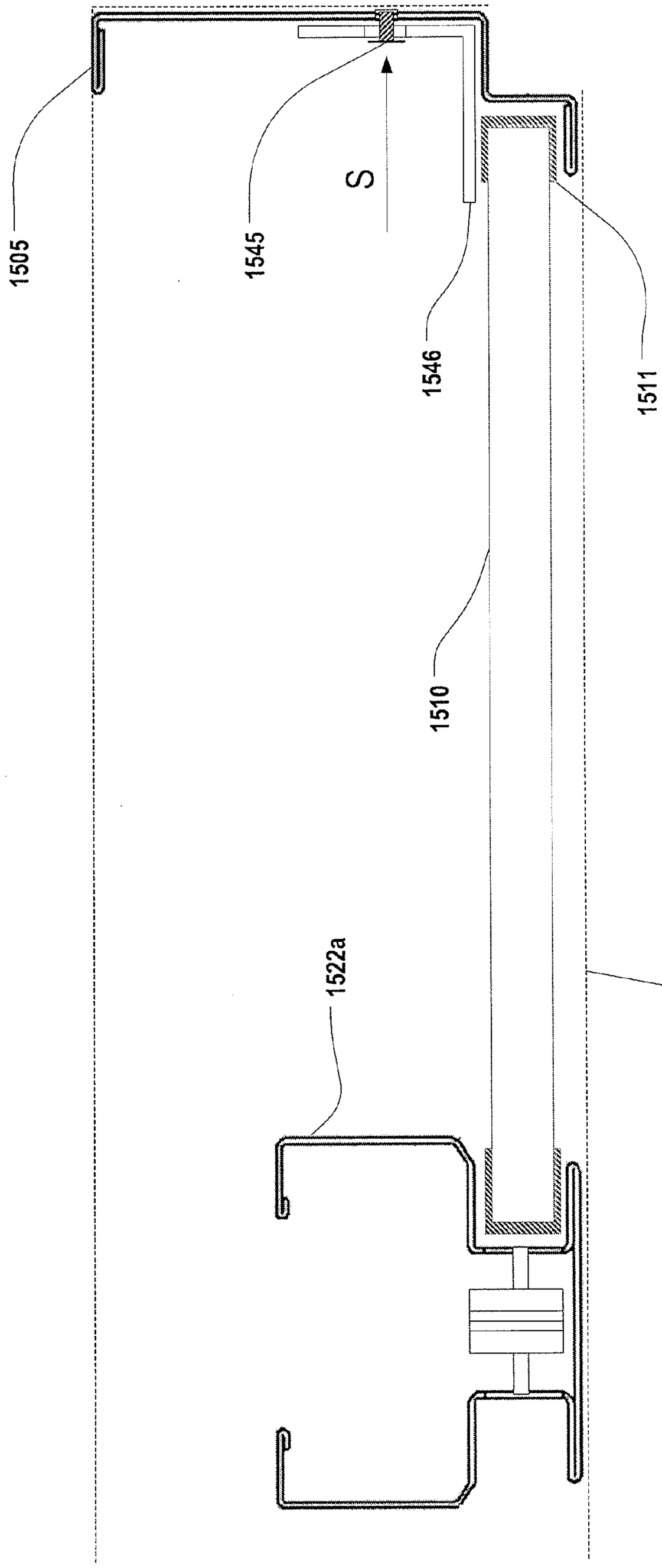

FIG. 17C

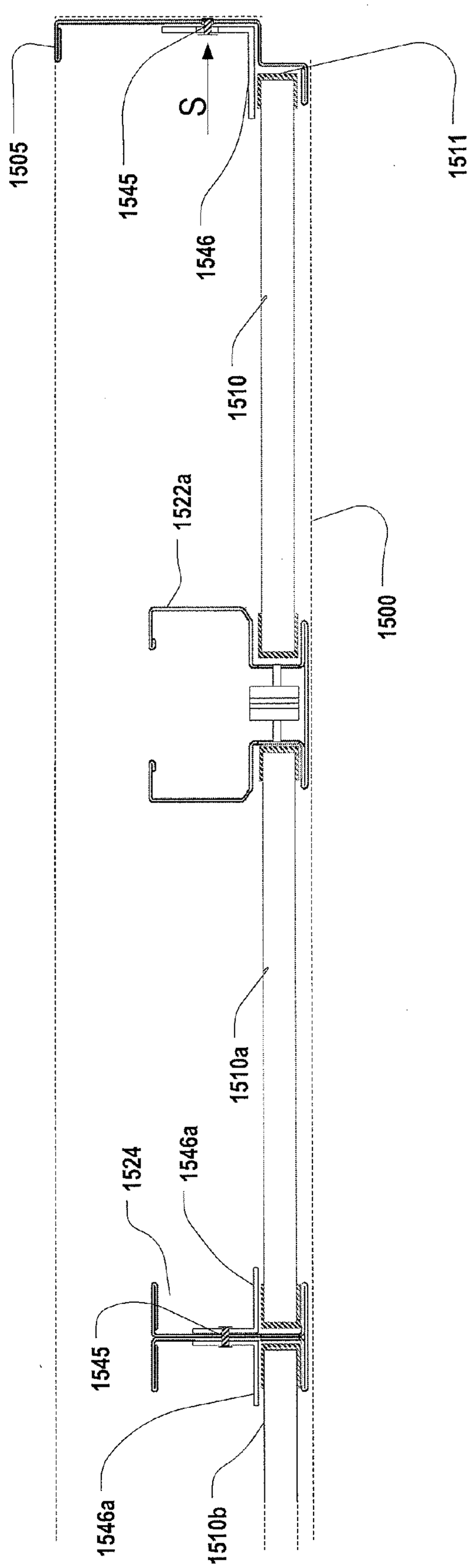
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FIG. 17D

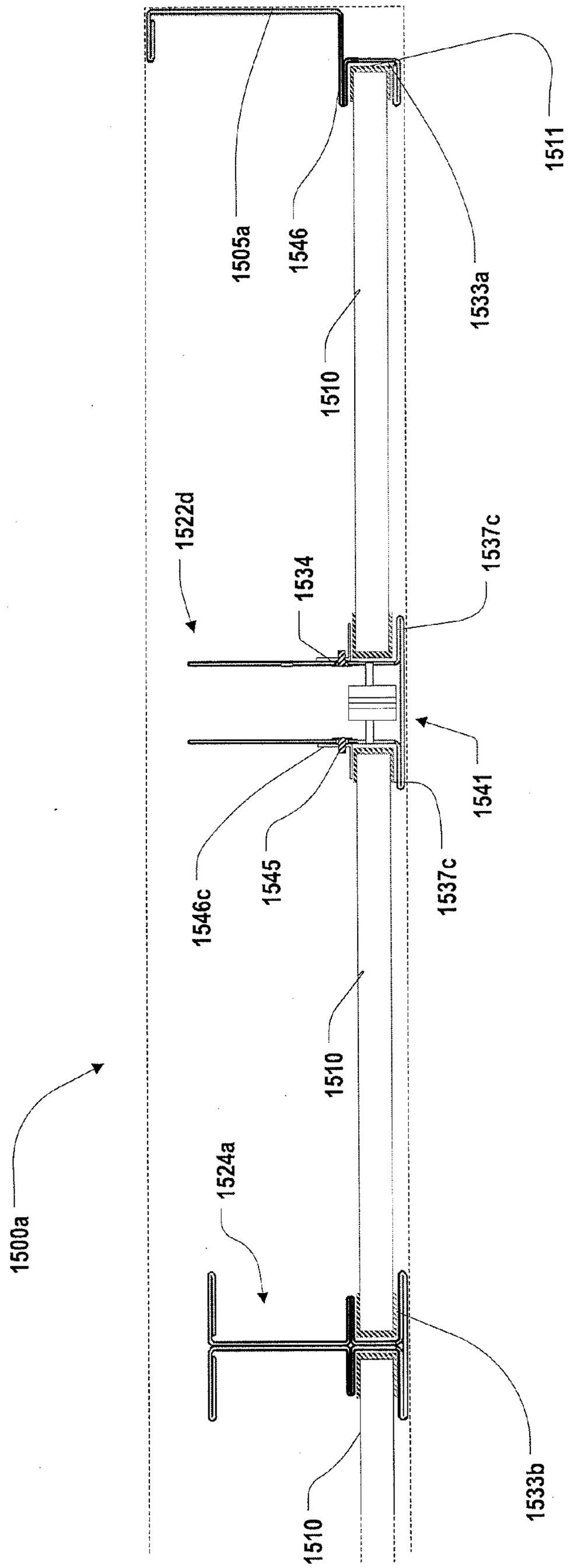
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FIG. 17E

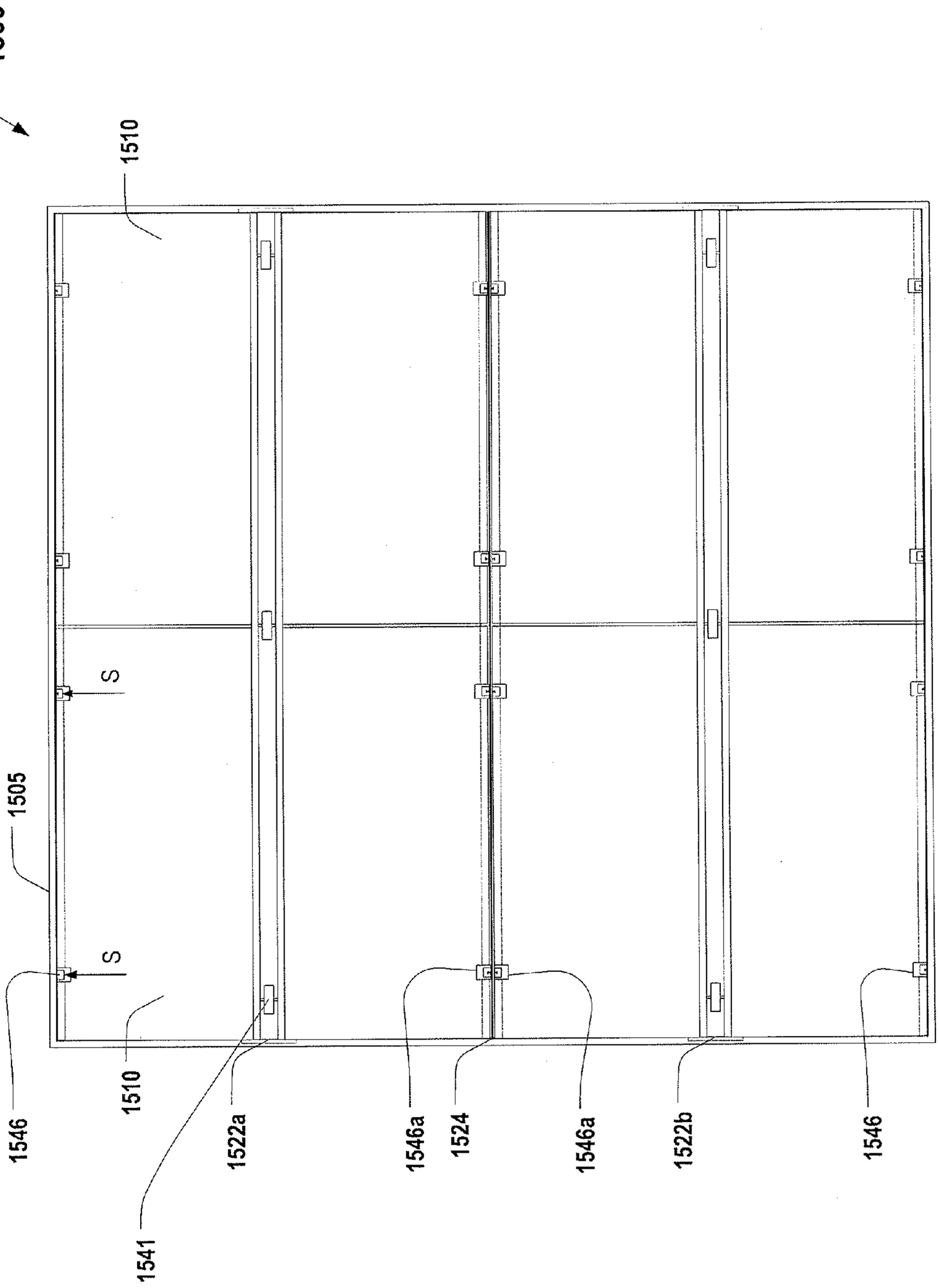
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FIG. 18

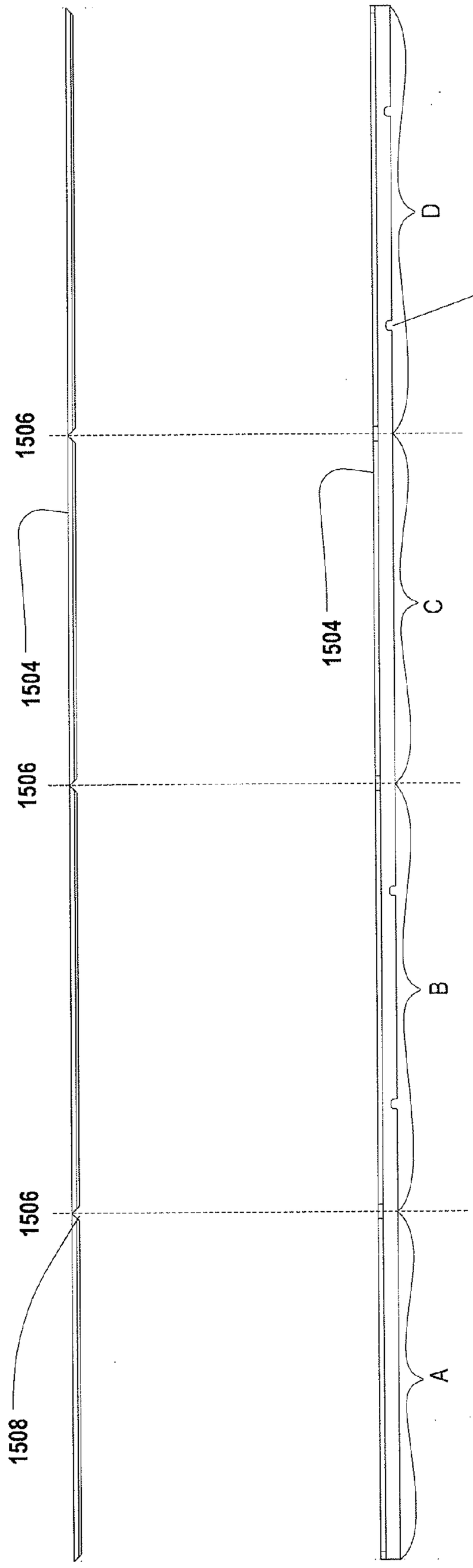

FIG. 19A

FIG. 19B

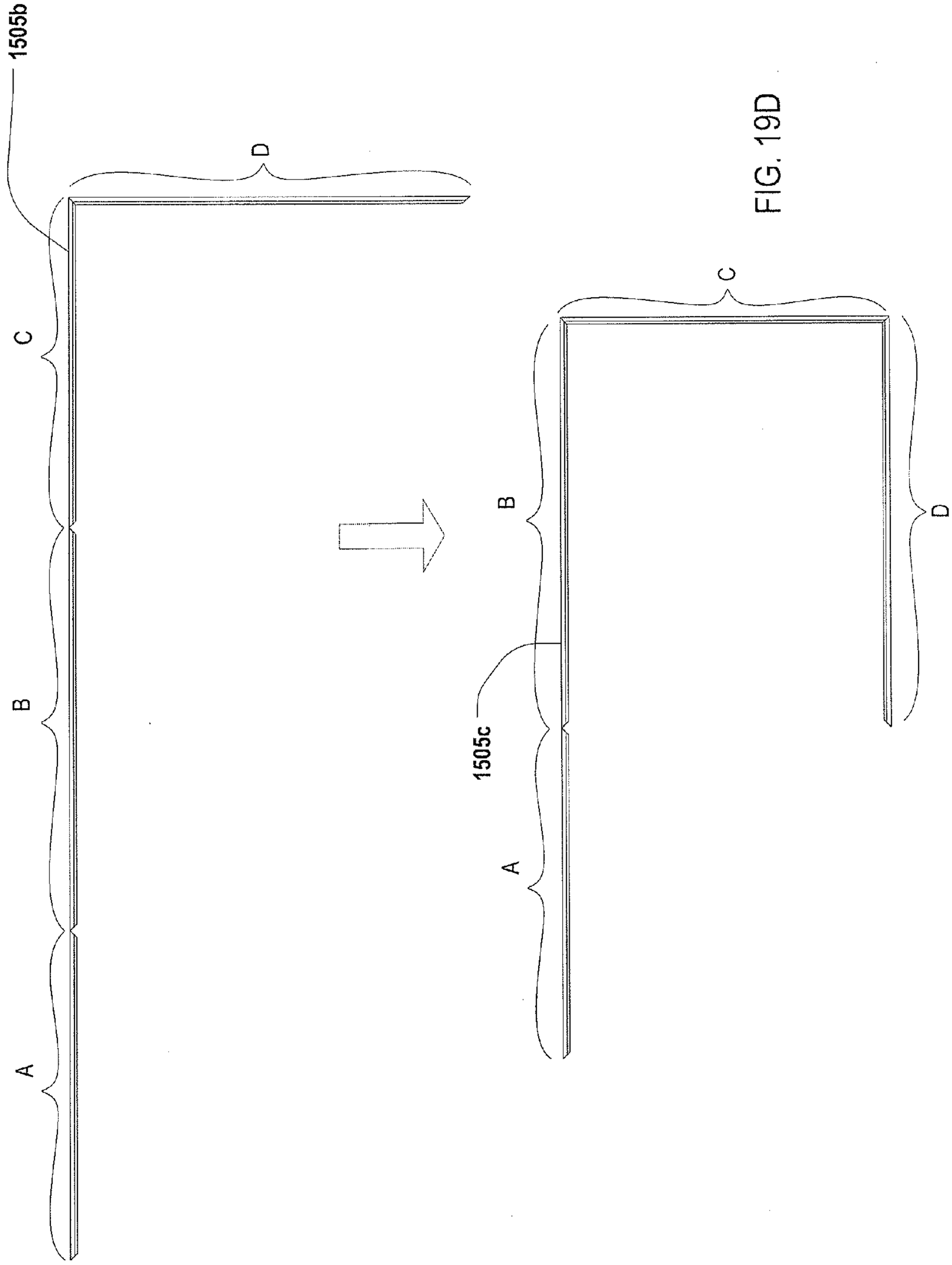

FIG. 19C

FIG. 19D

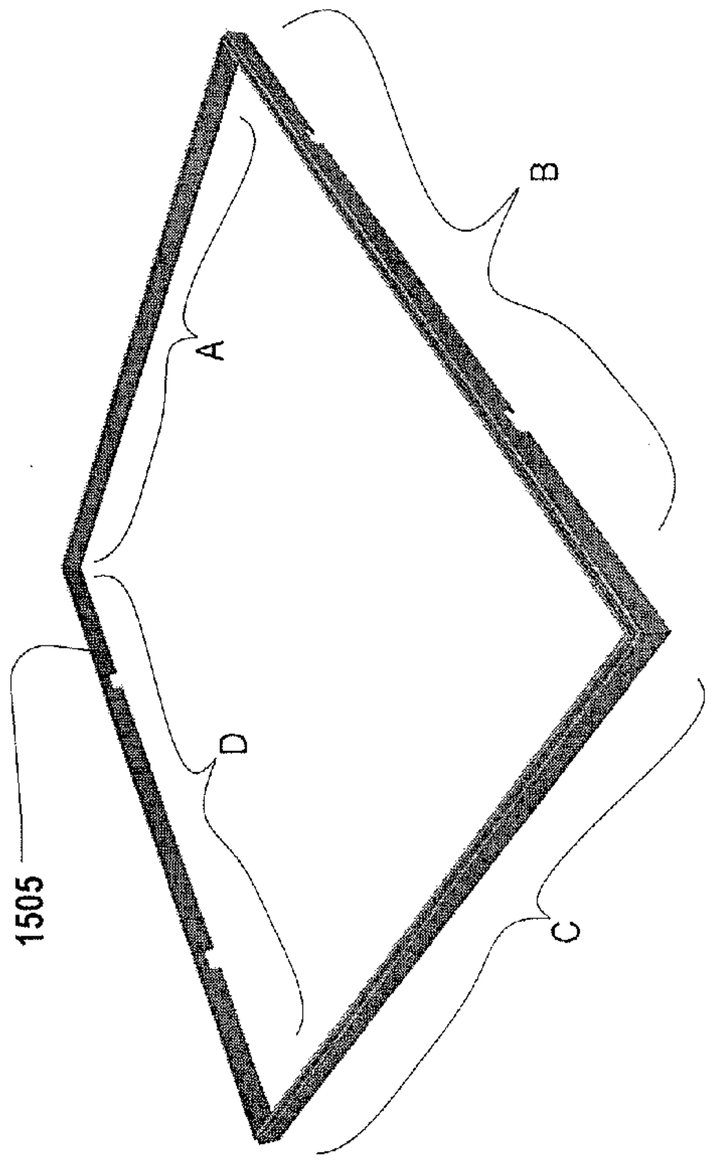

FIG. 19F

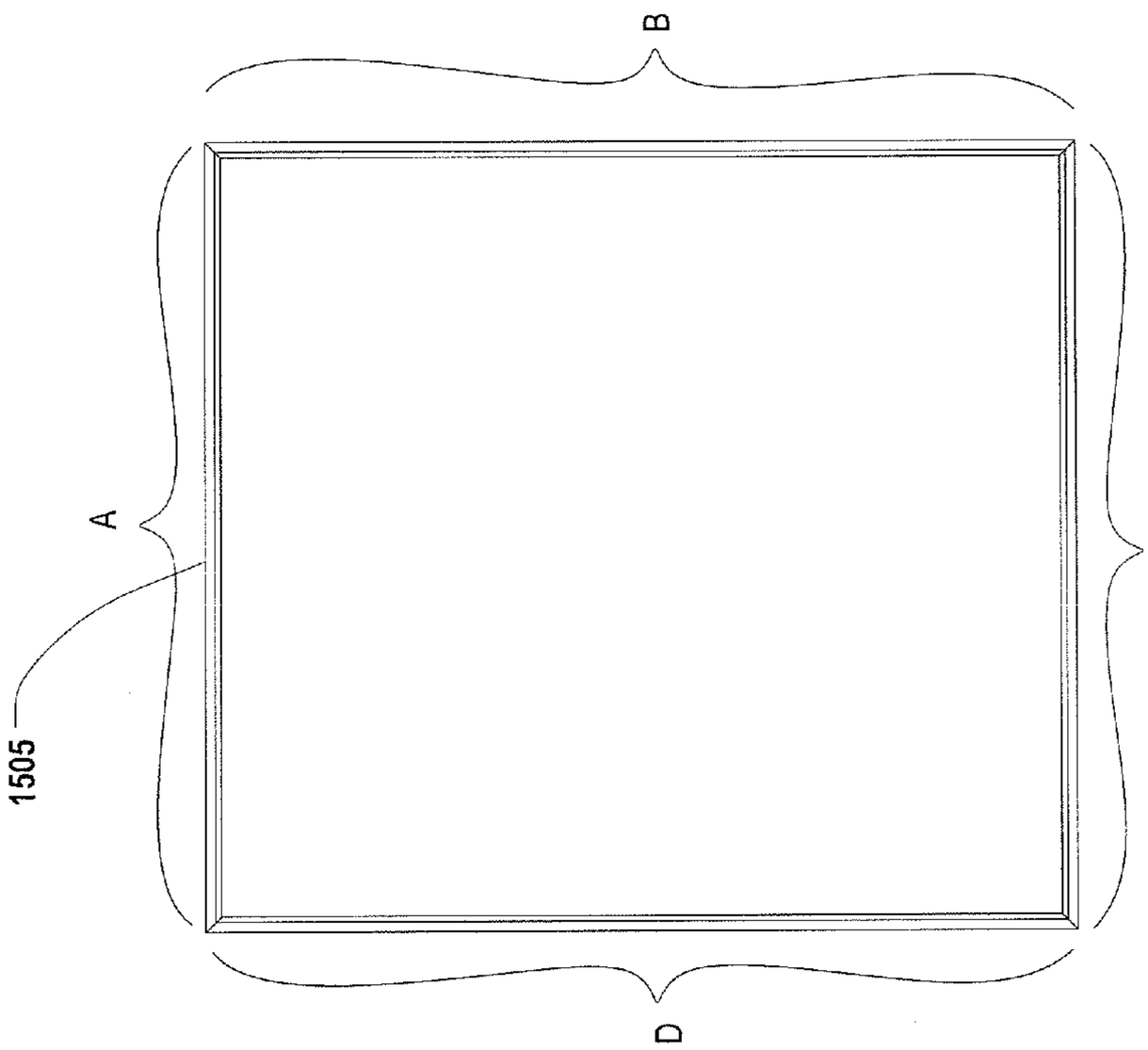

FIG. 19E

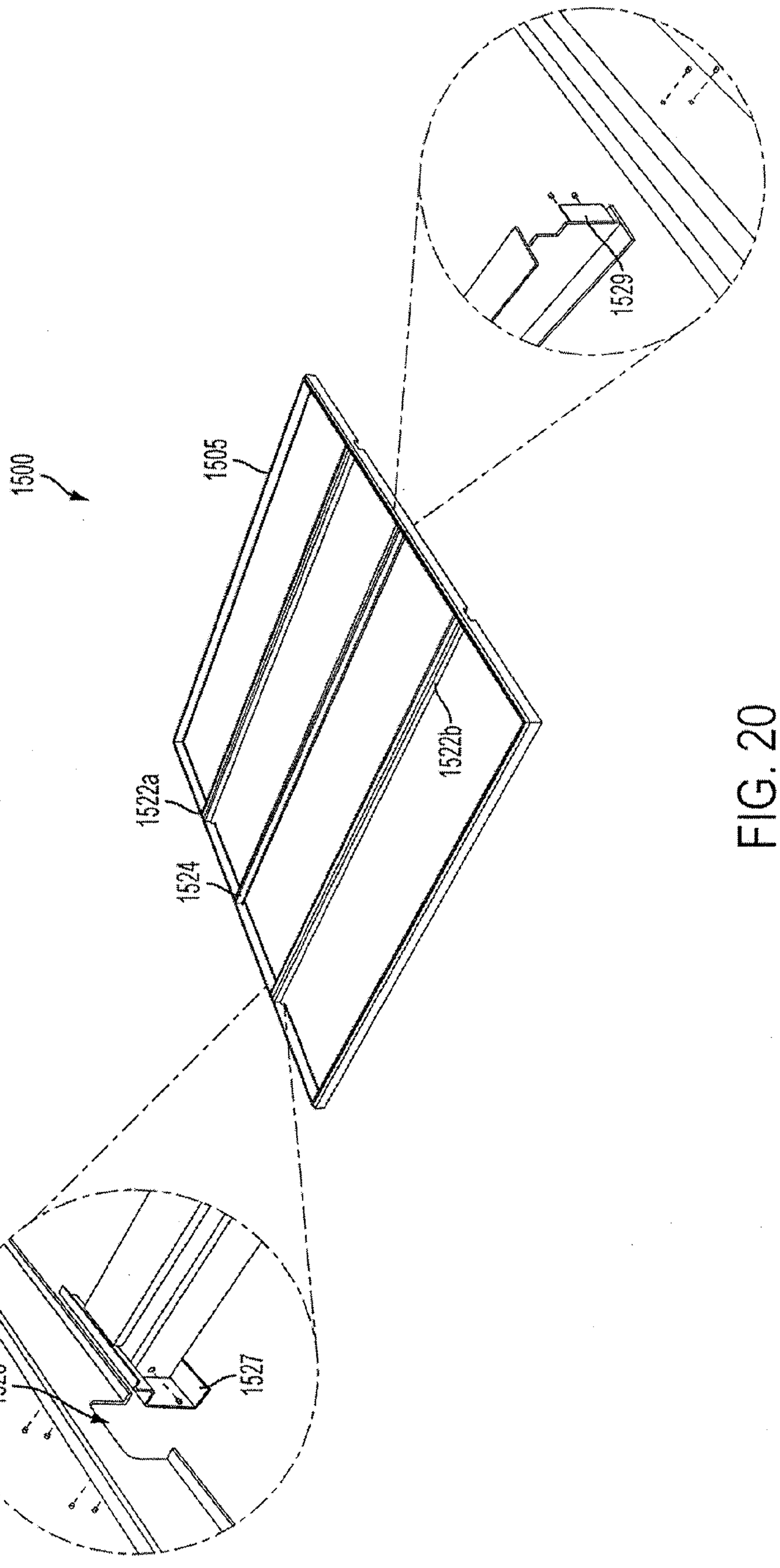

FIG. 20

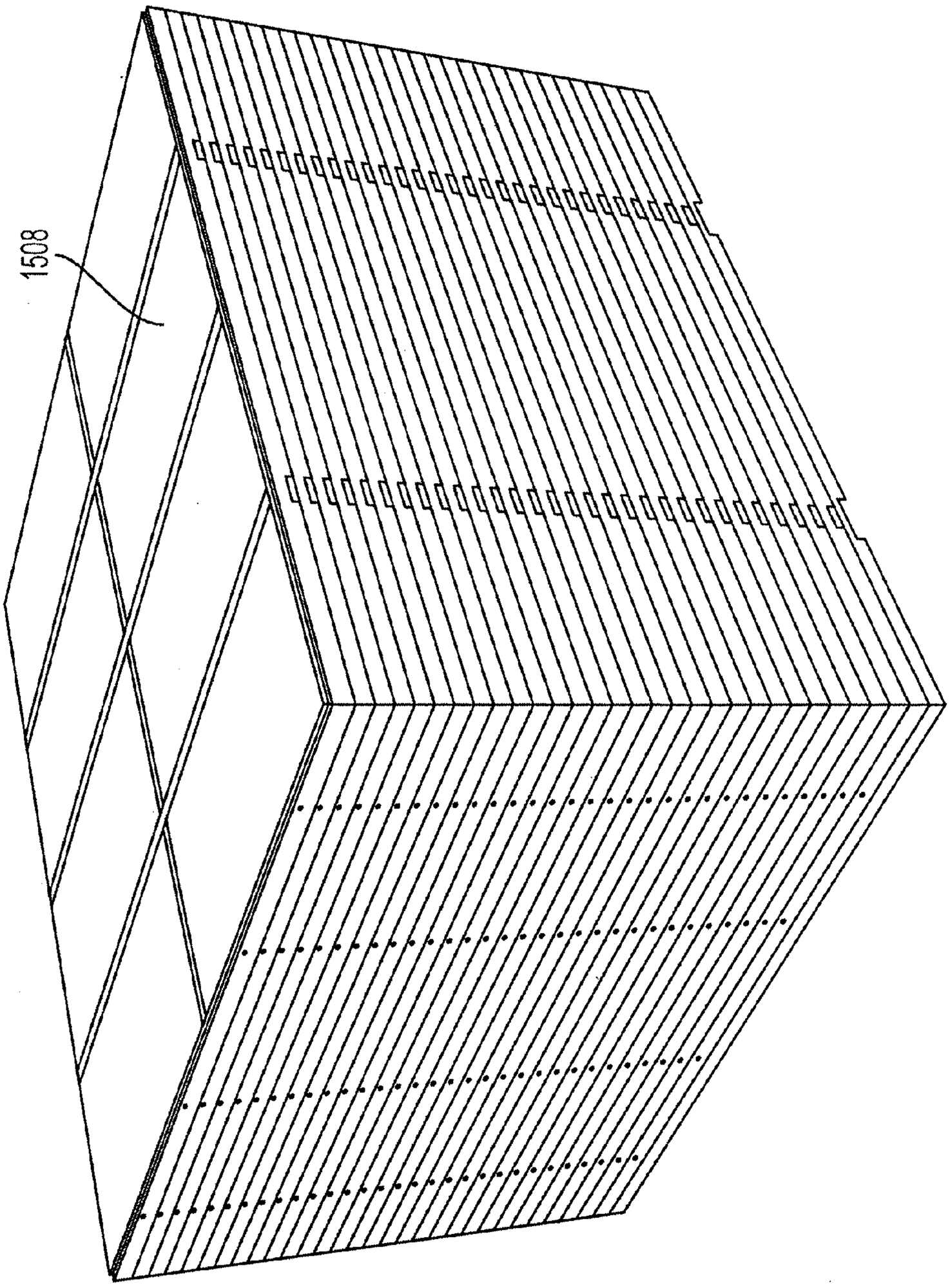

FIG. 21A

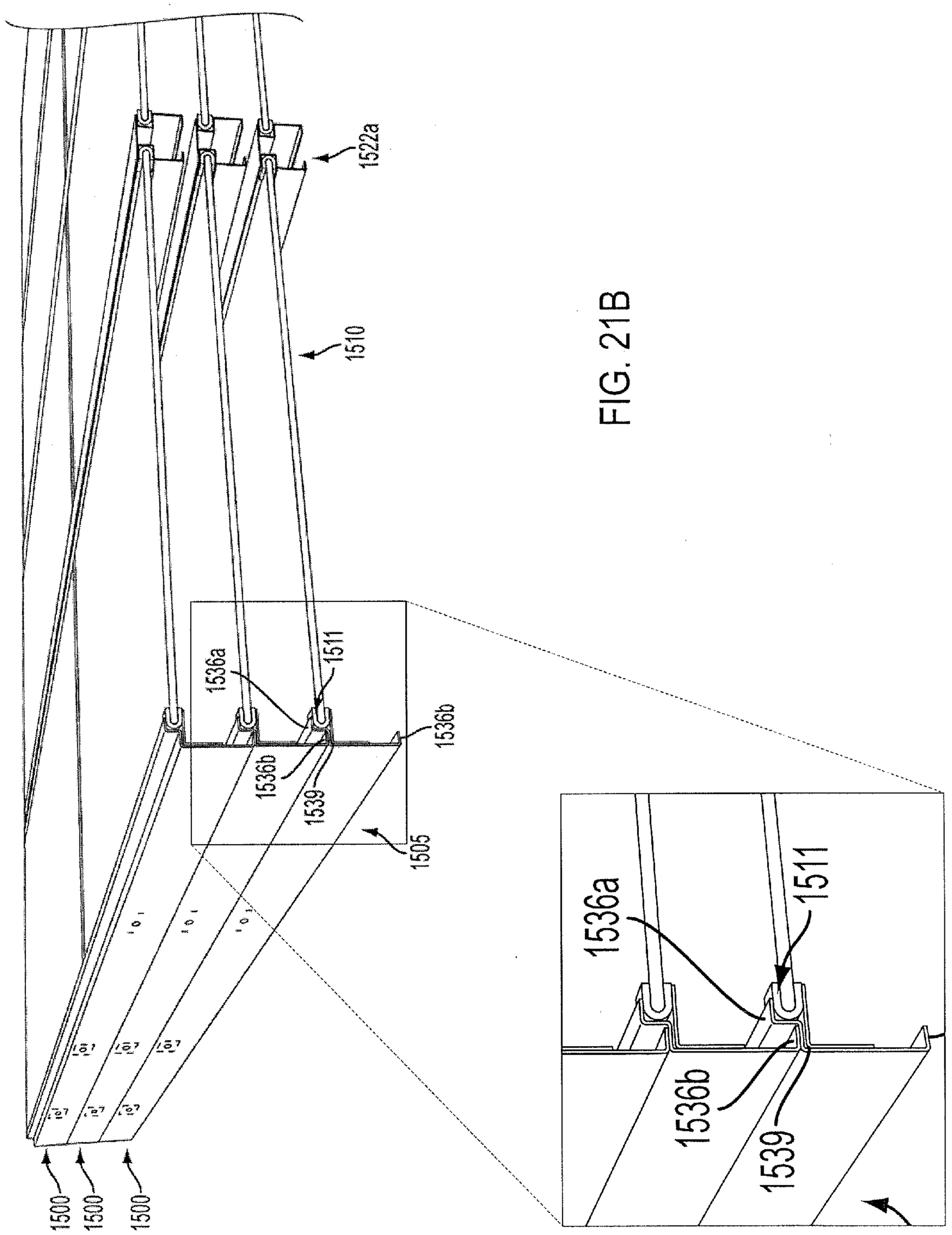
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FIG. 21B

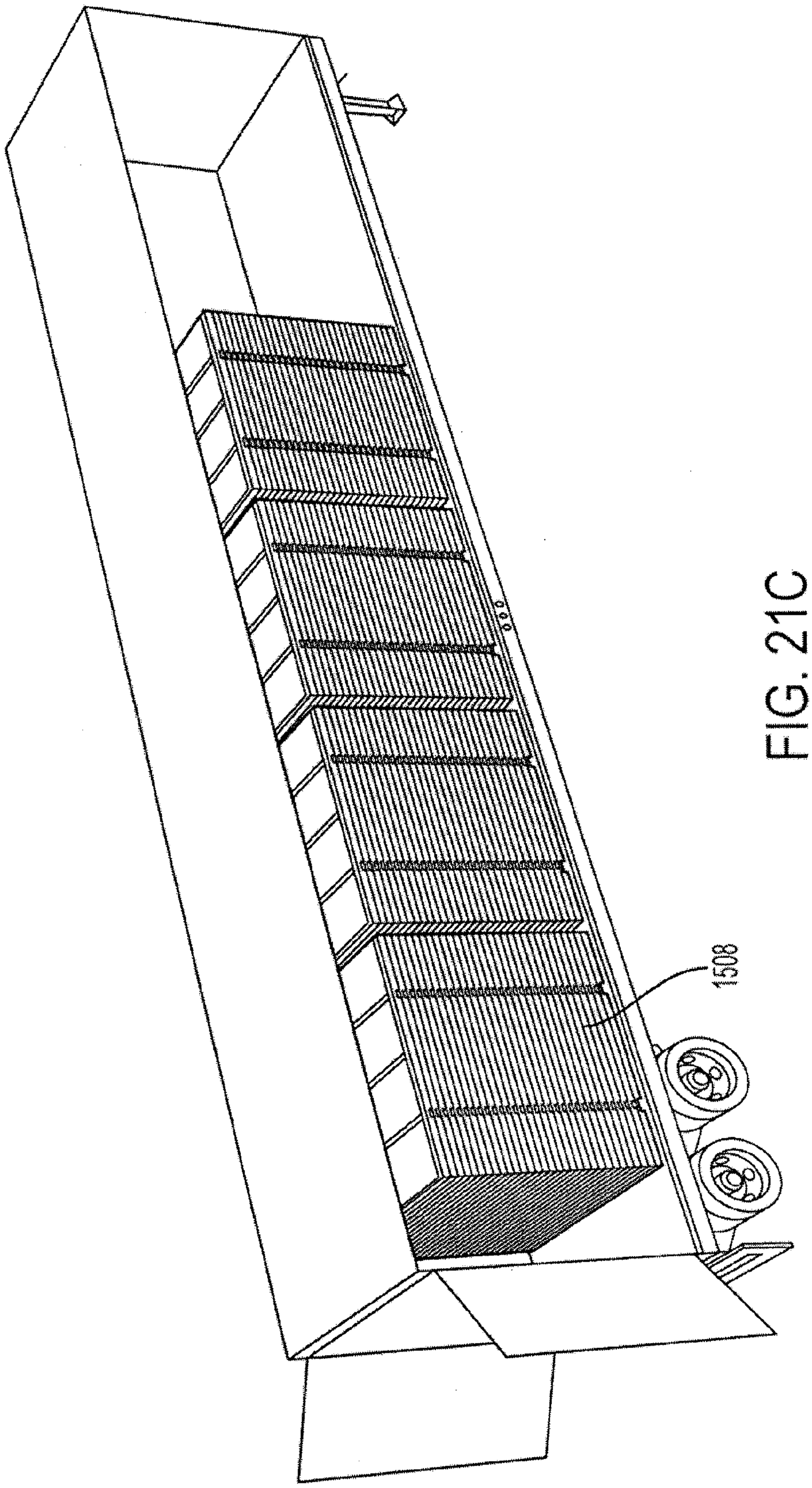


FIG. 21C

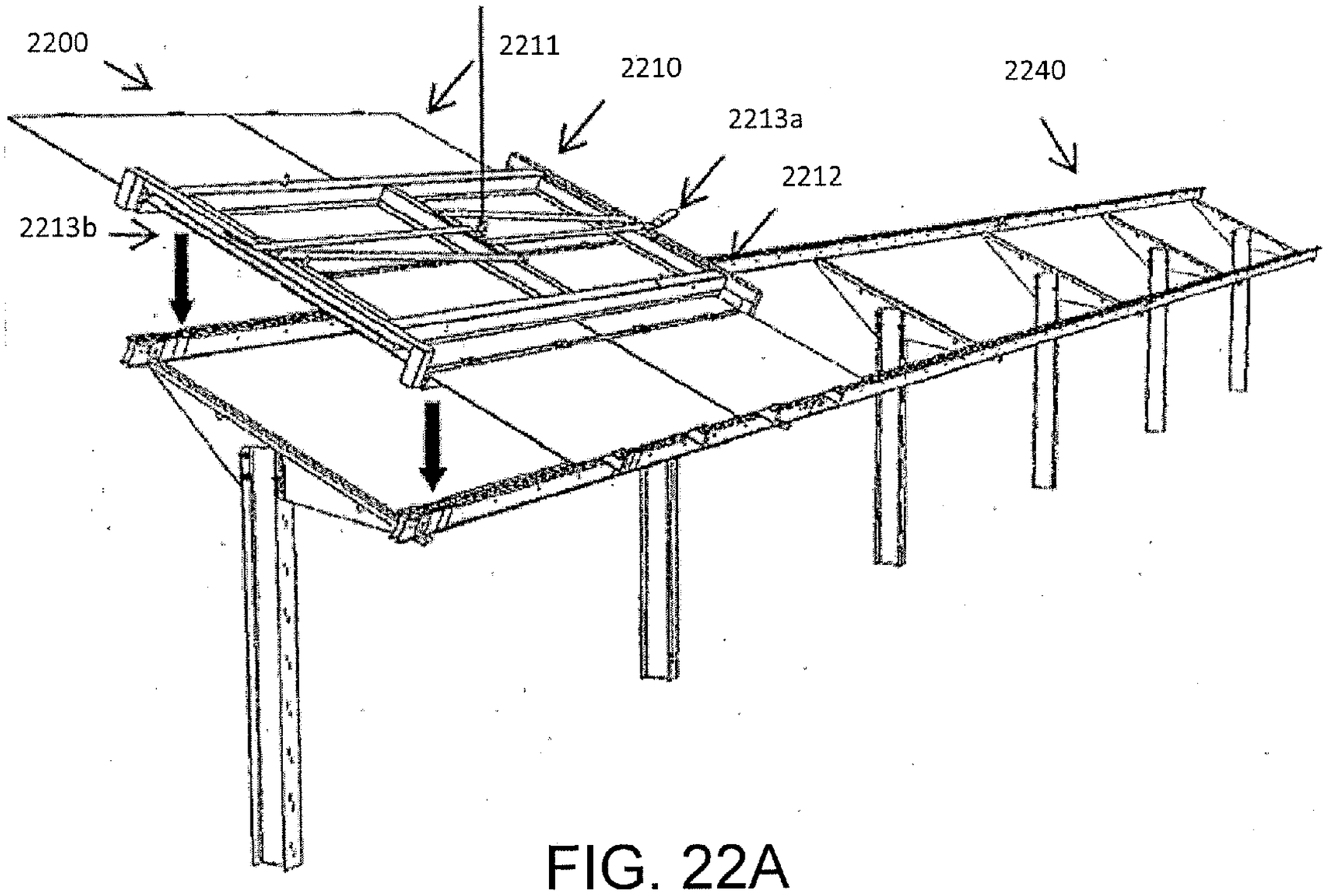


FIG. 22A

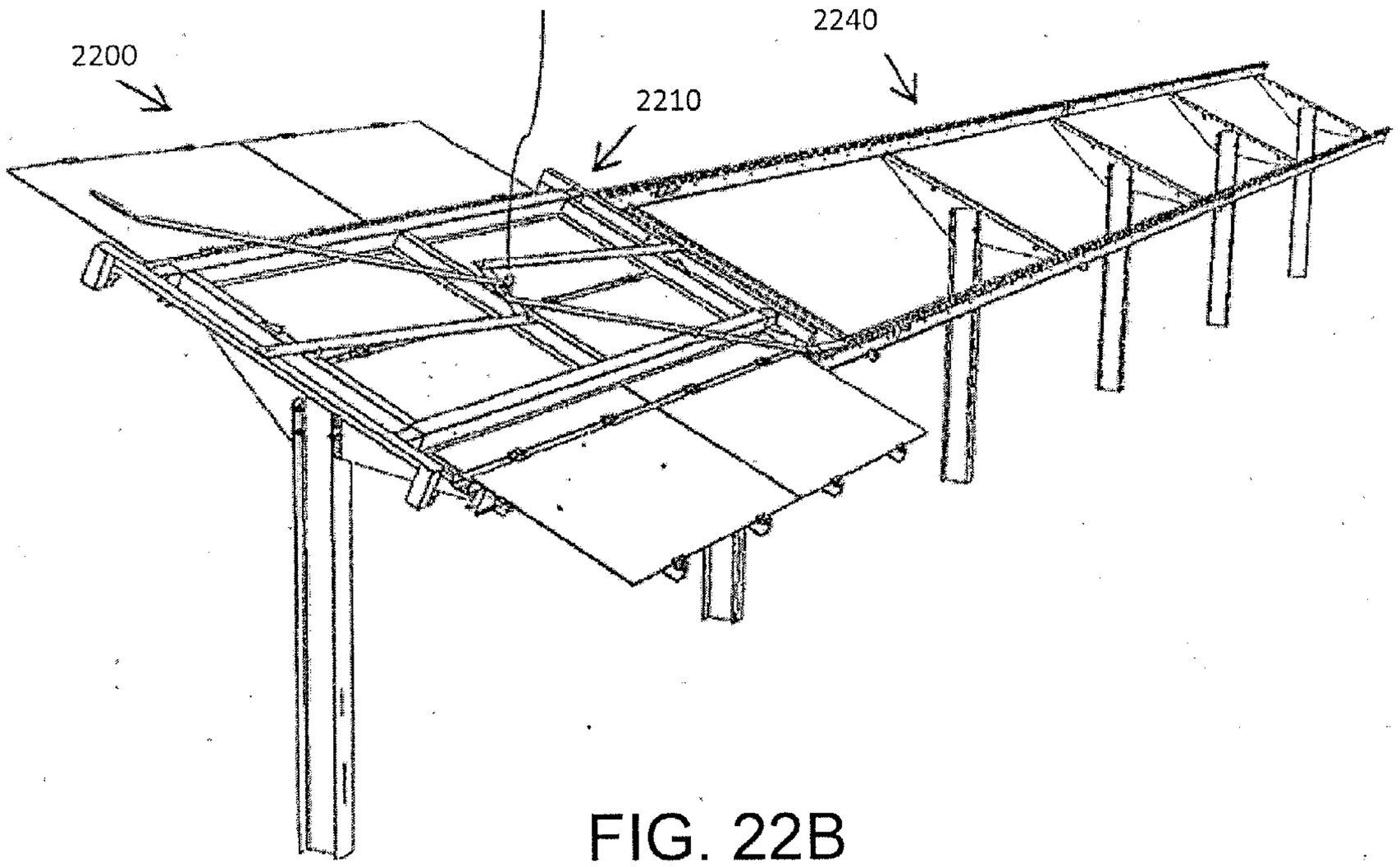
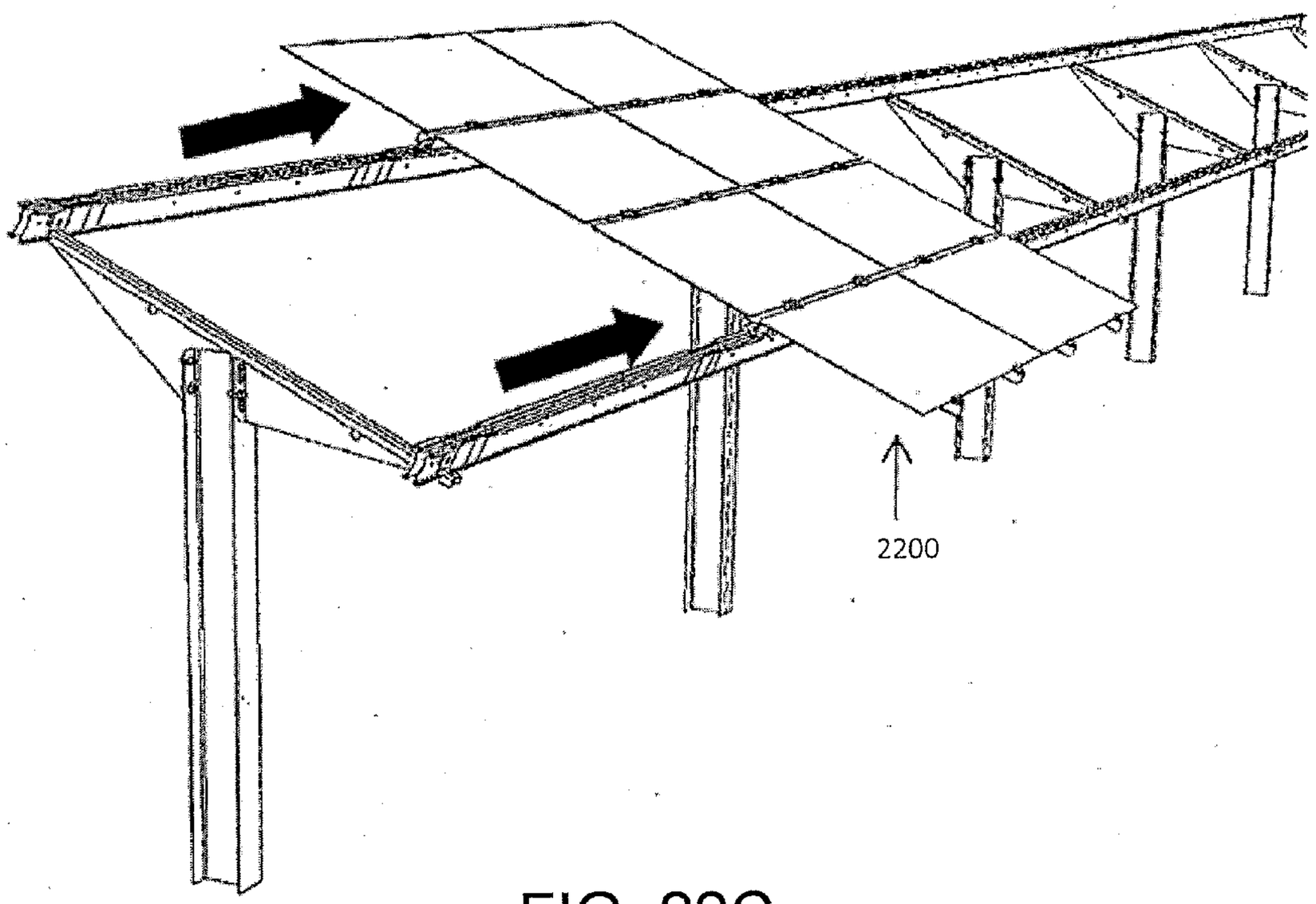


FIG. 22B



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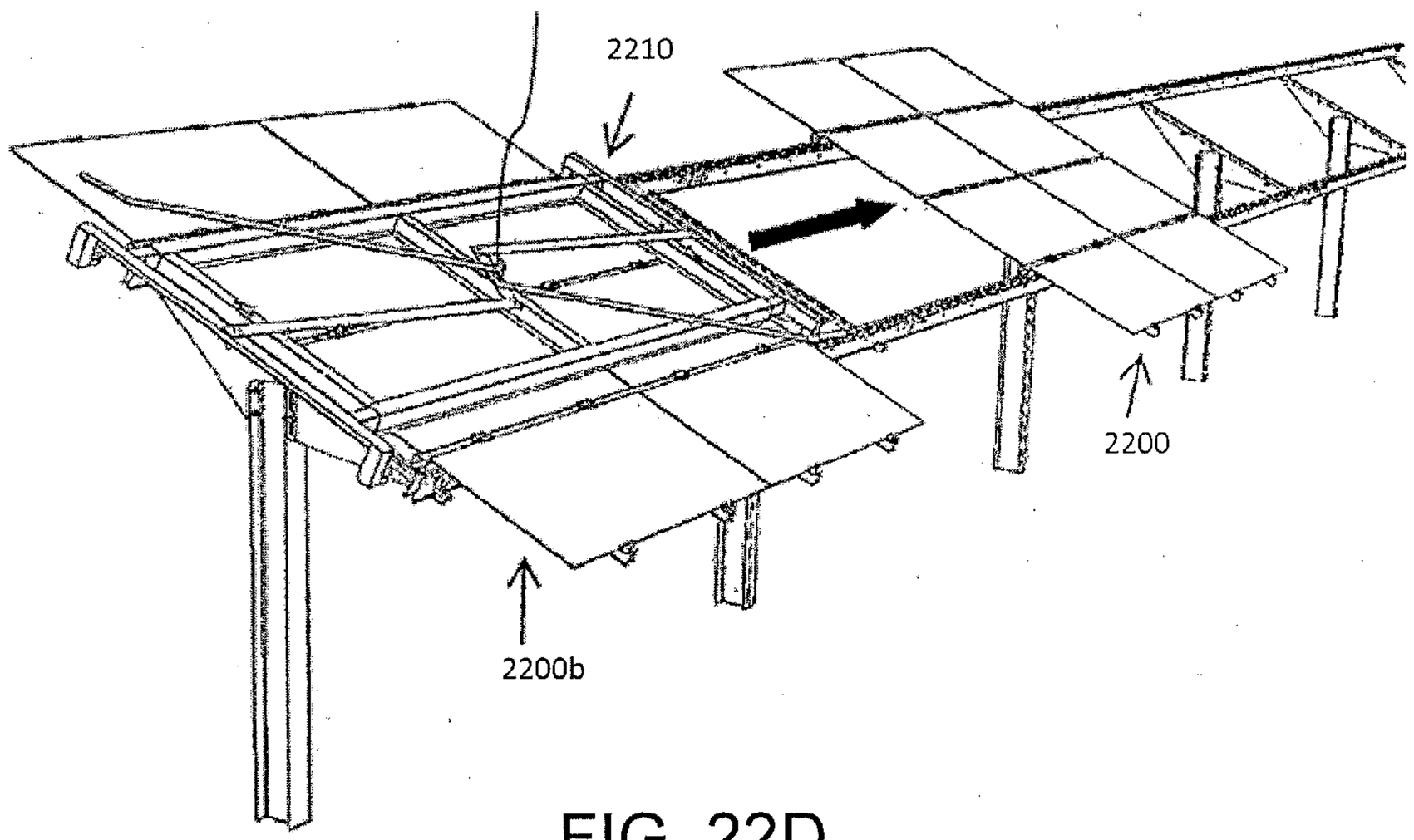

FIG. 22D

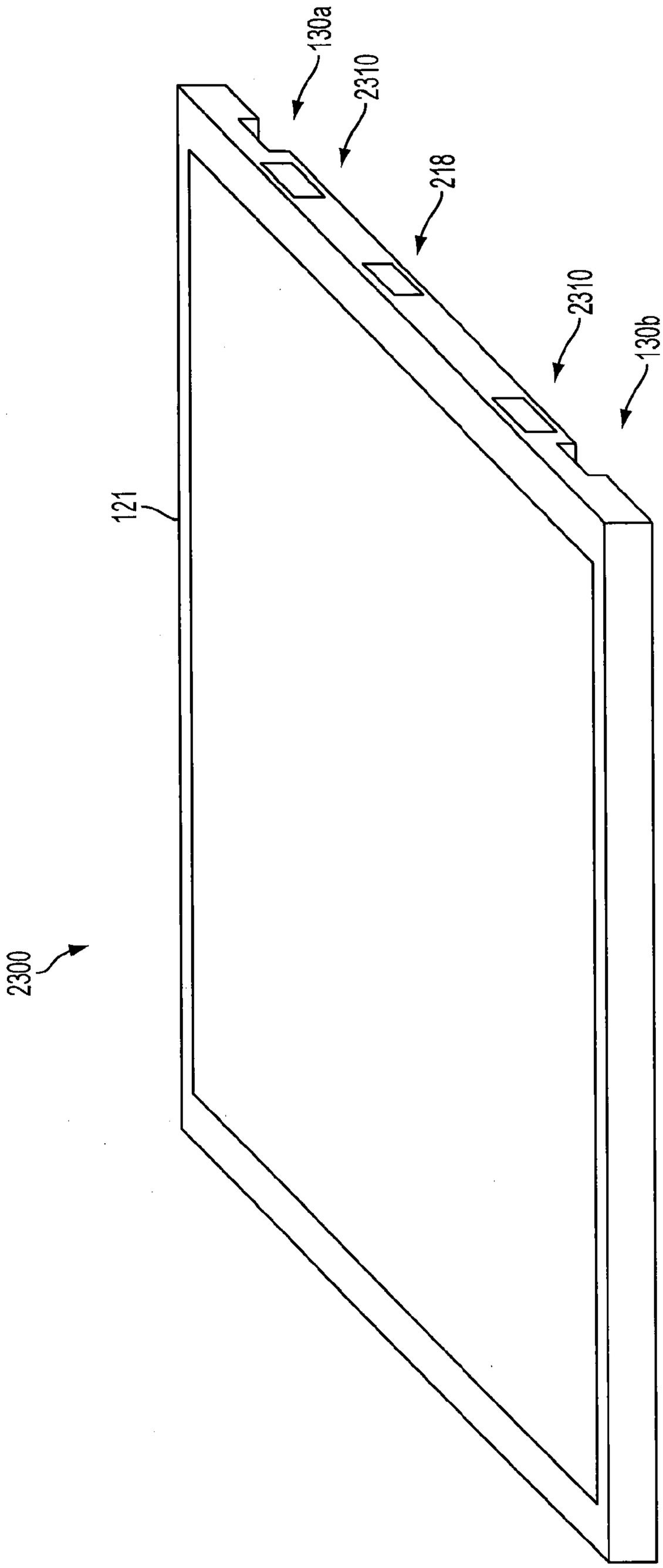

FIG. 23

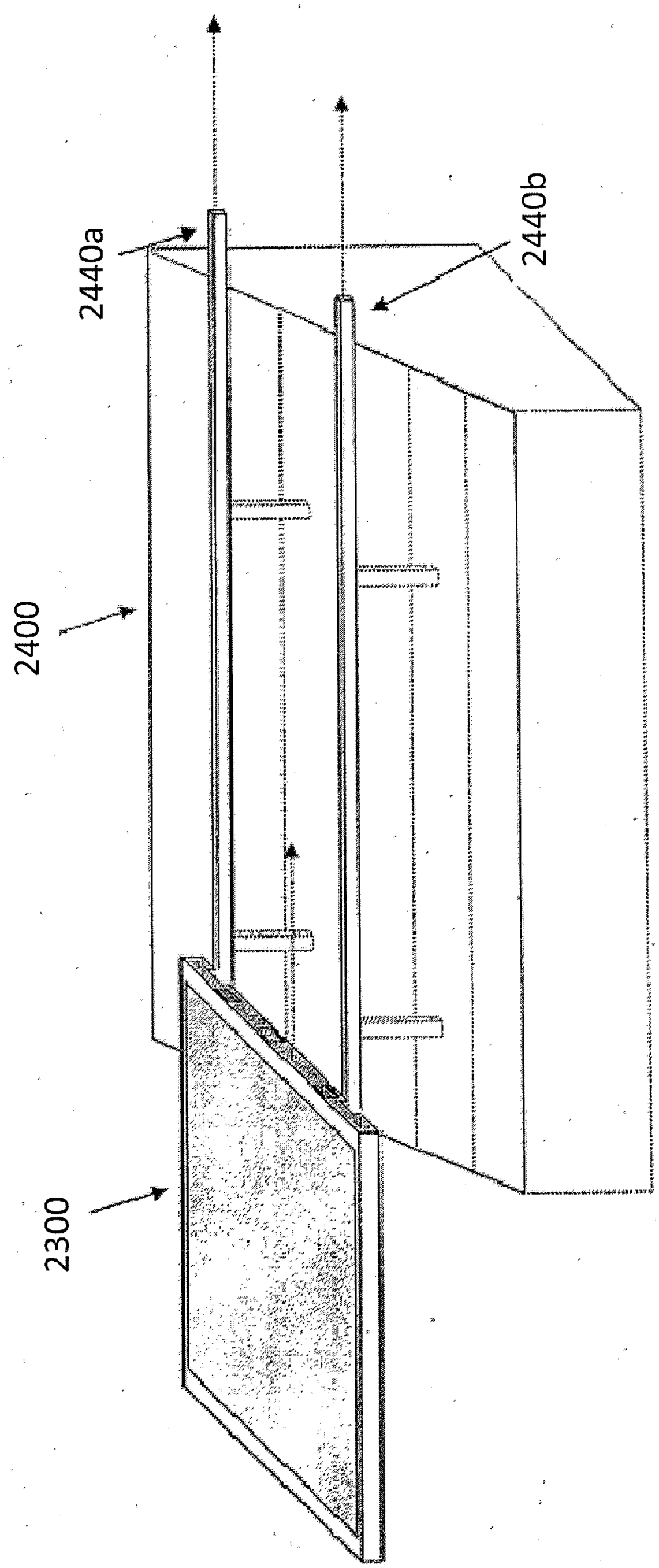

FIG. 24A

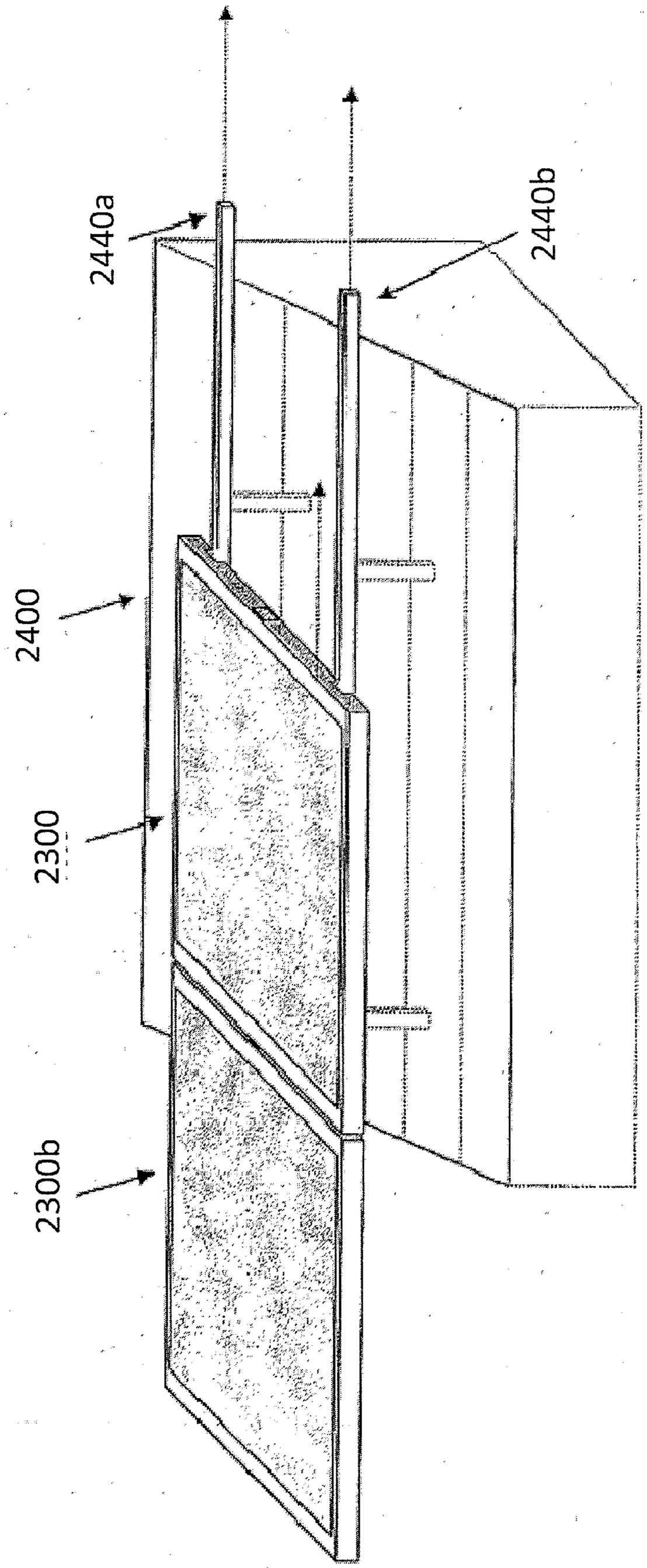

FIG. 24B

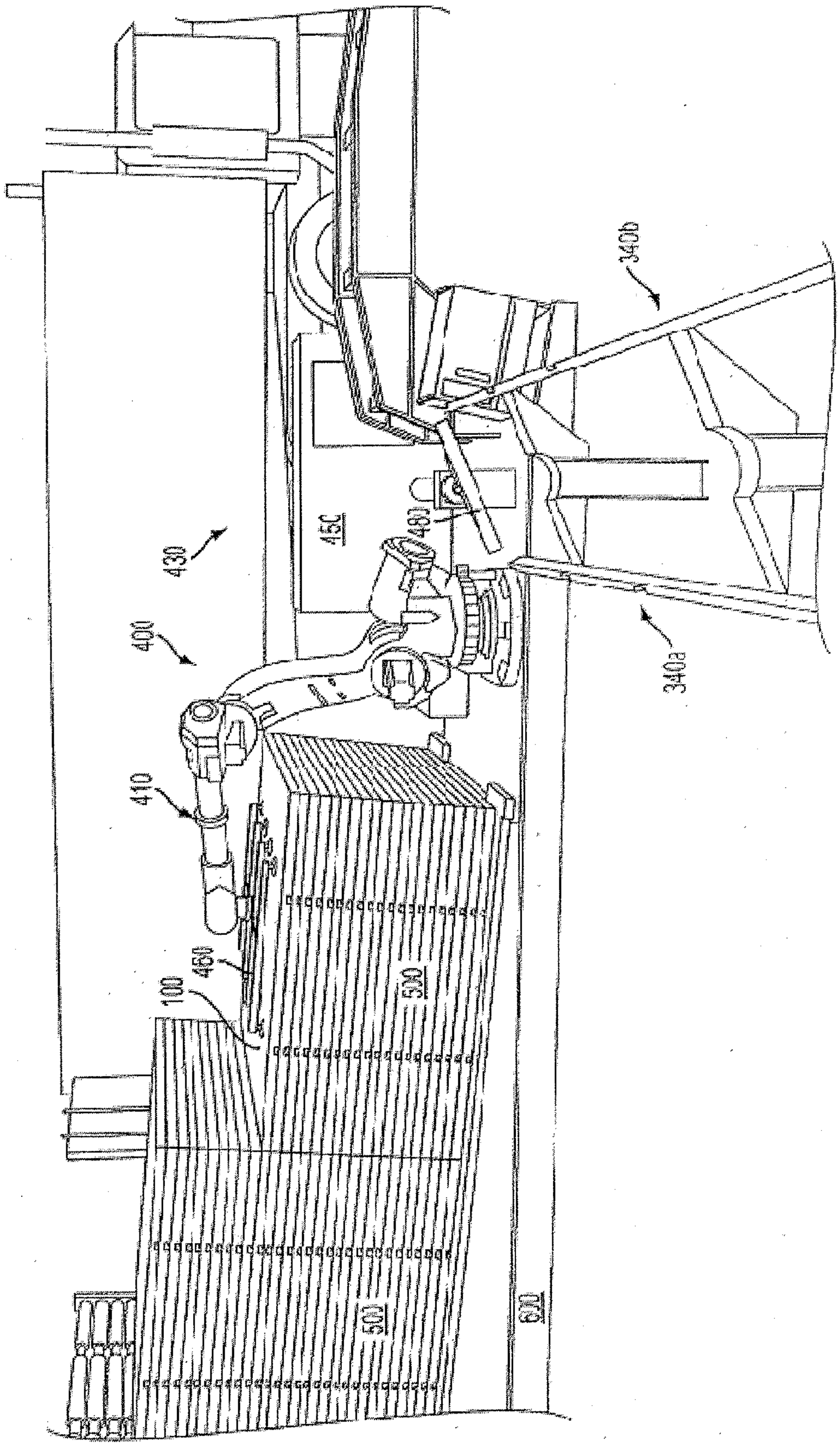

FIG. 25

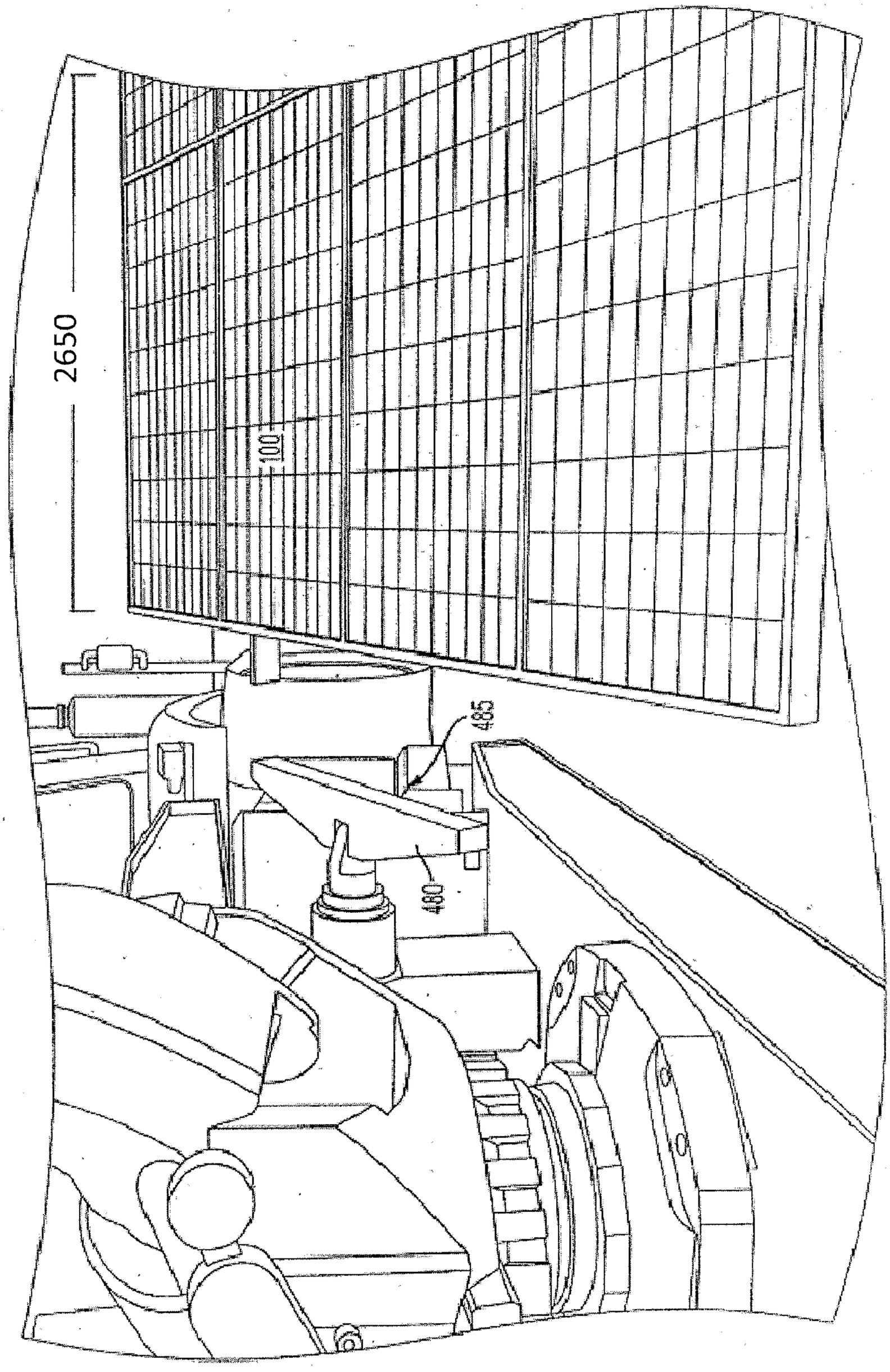

FIG. 26A

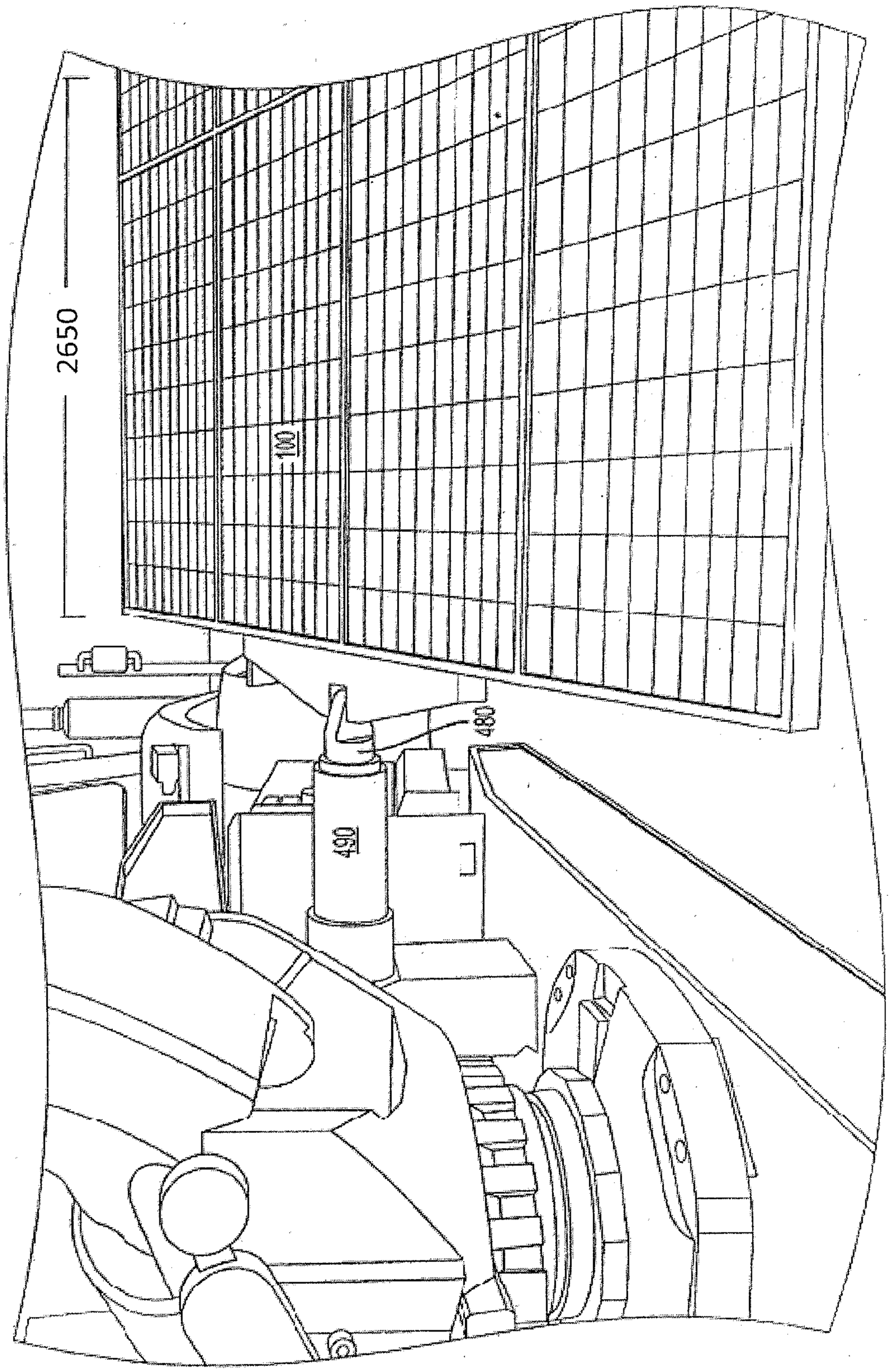

FIG. 26B

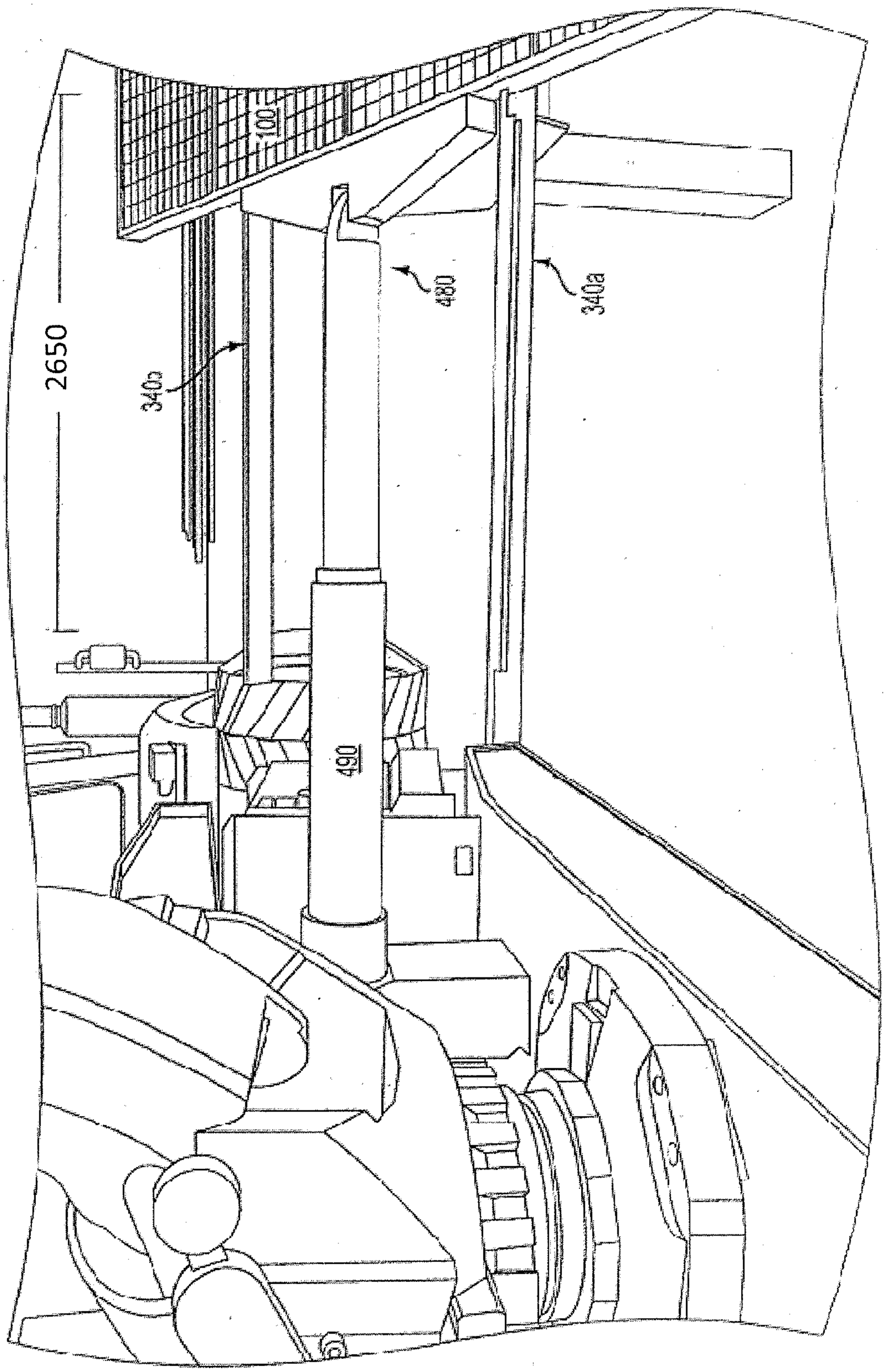

FIG. 26C

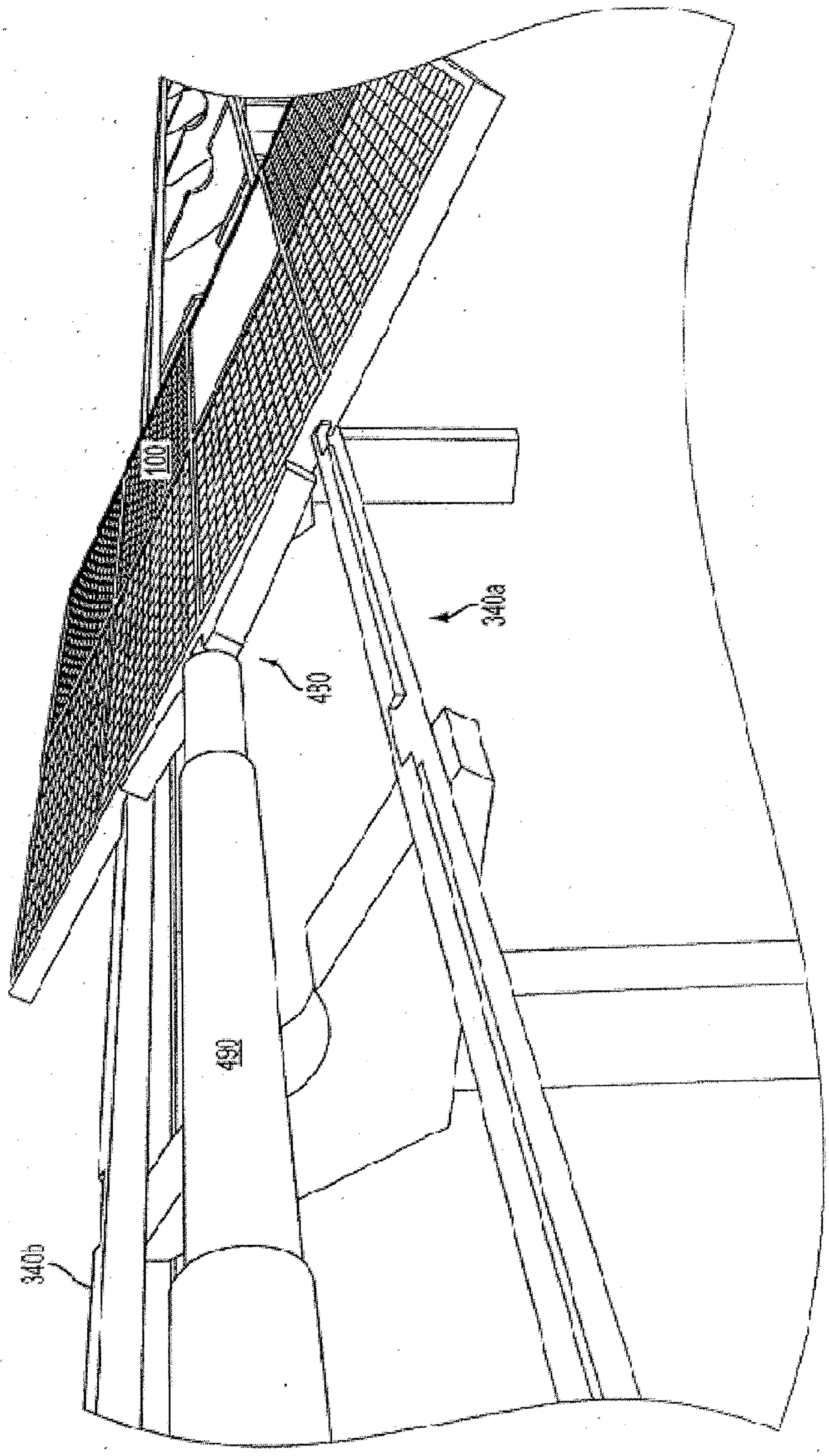

FIG. 26D

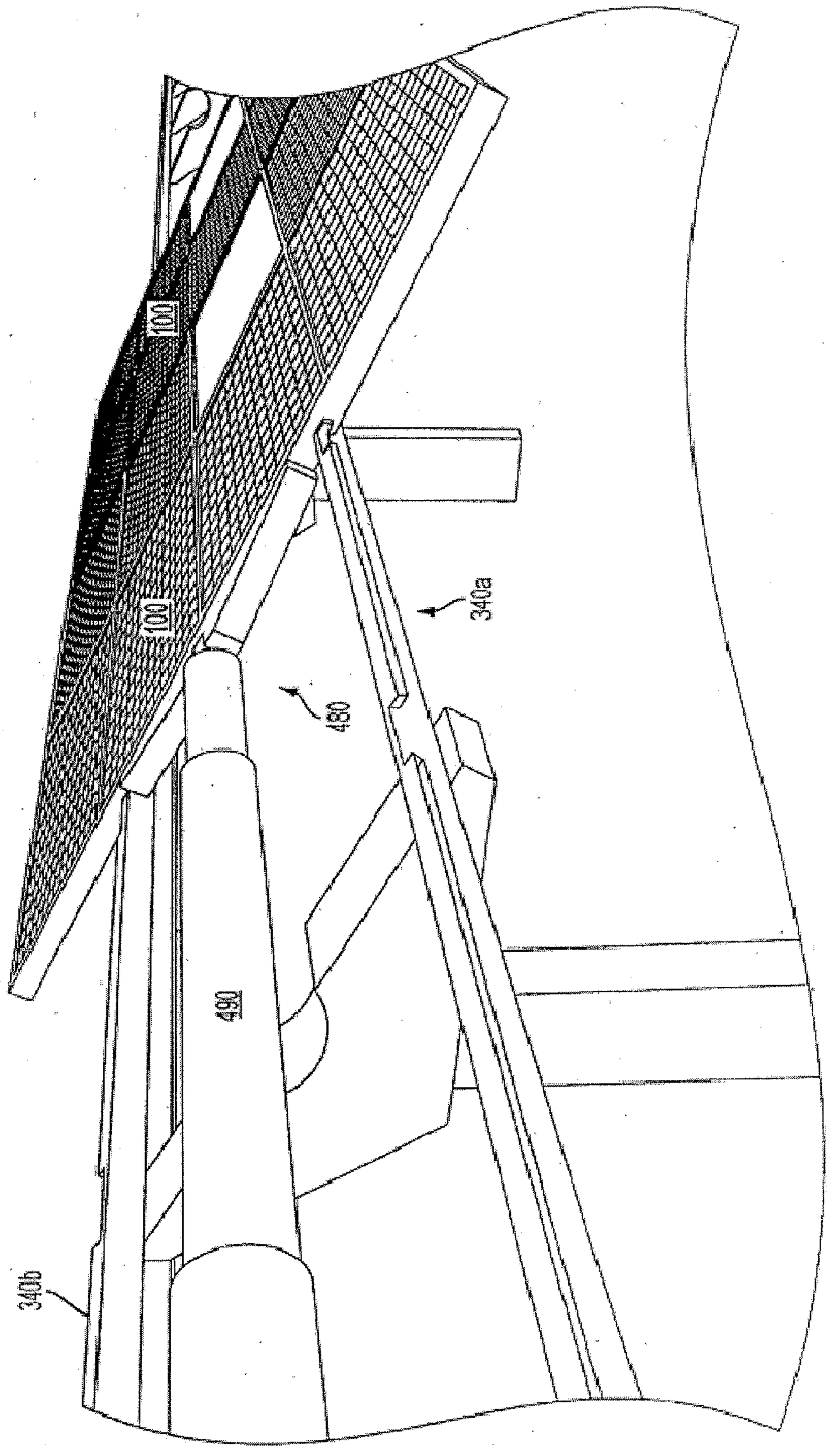

FIG. 26E

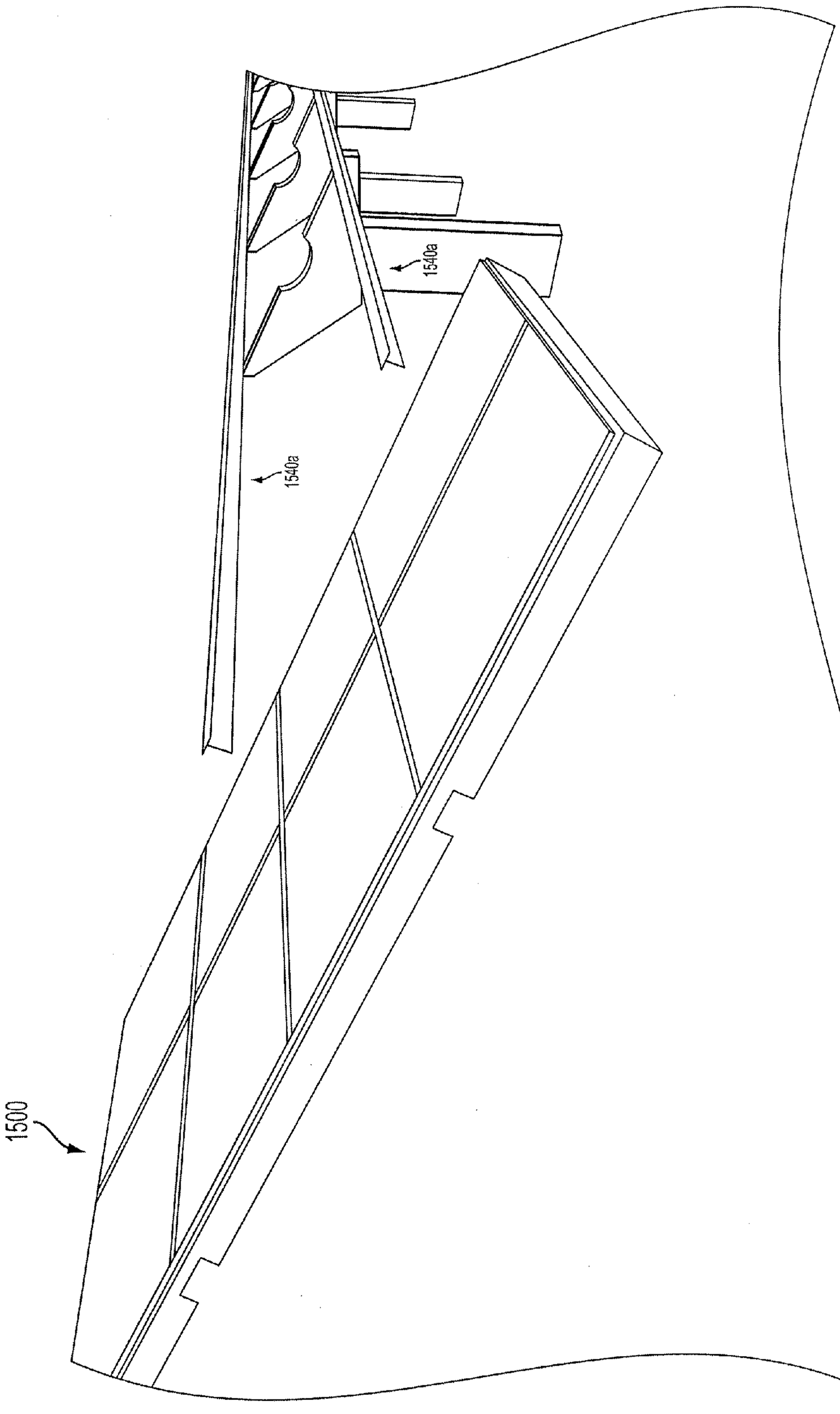

FIG. 27A

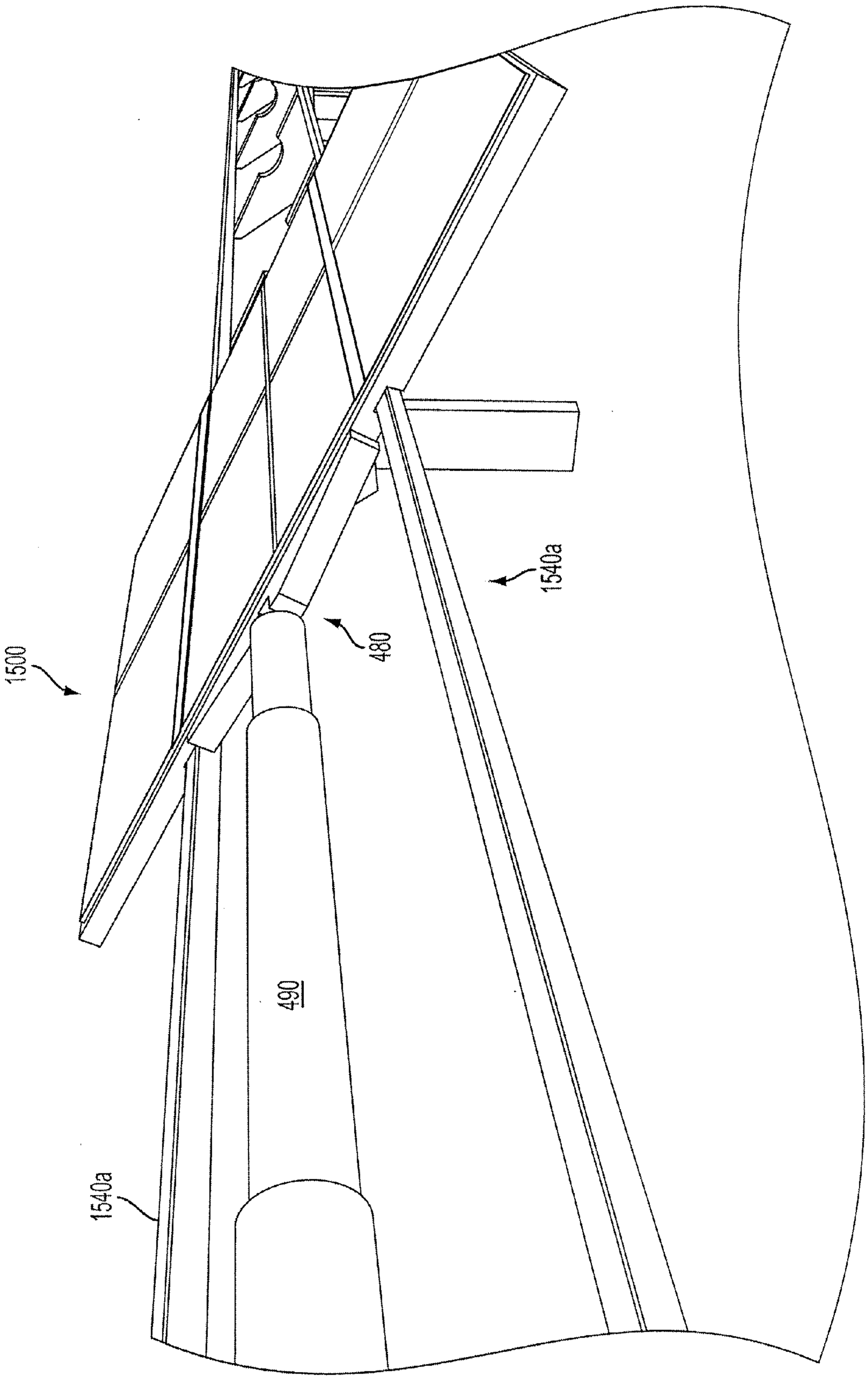

FIG. 27B

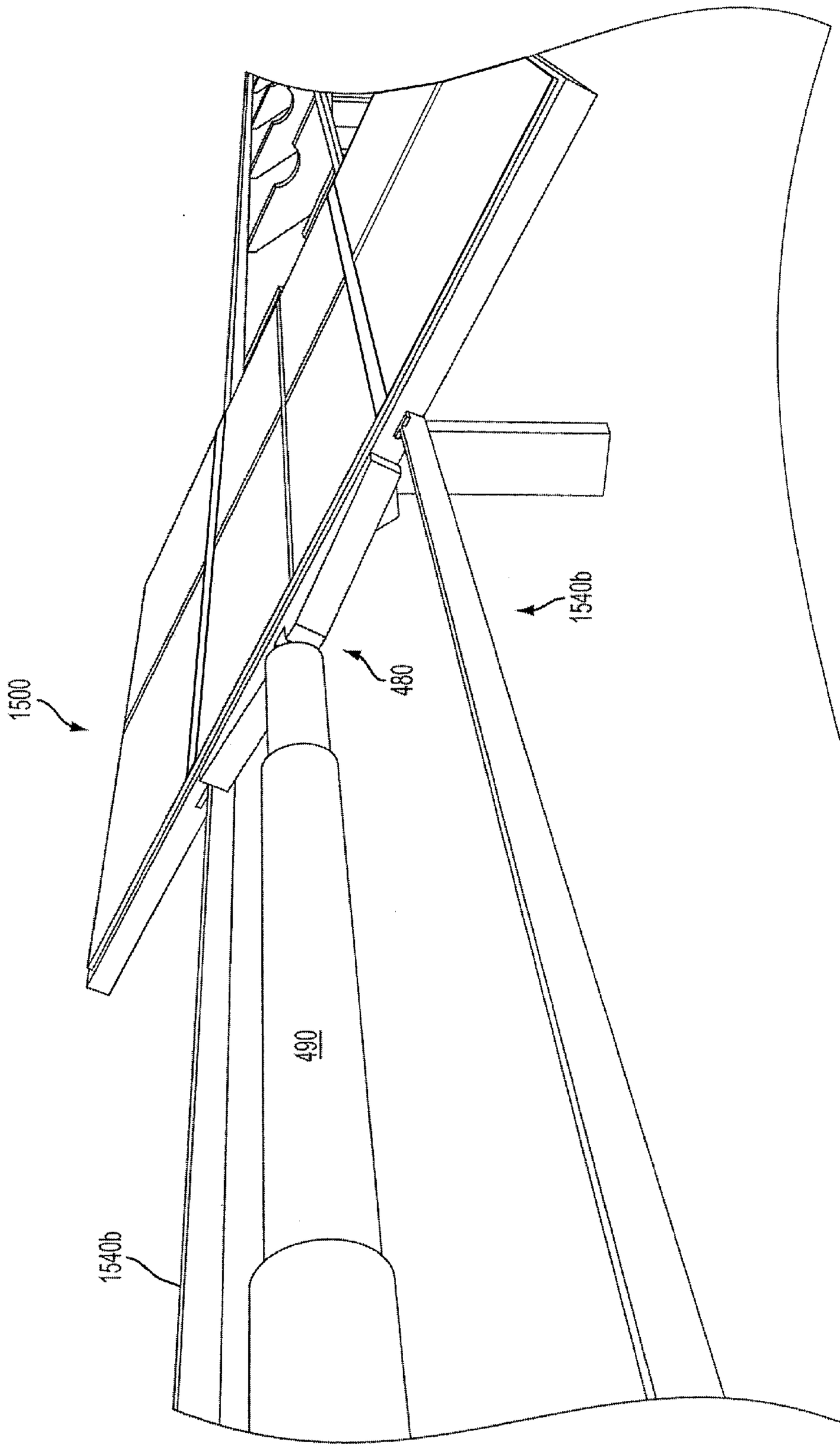

FIG. 27C

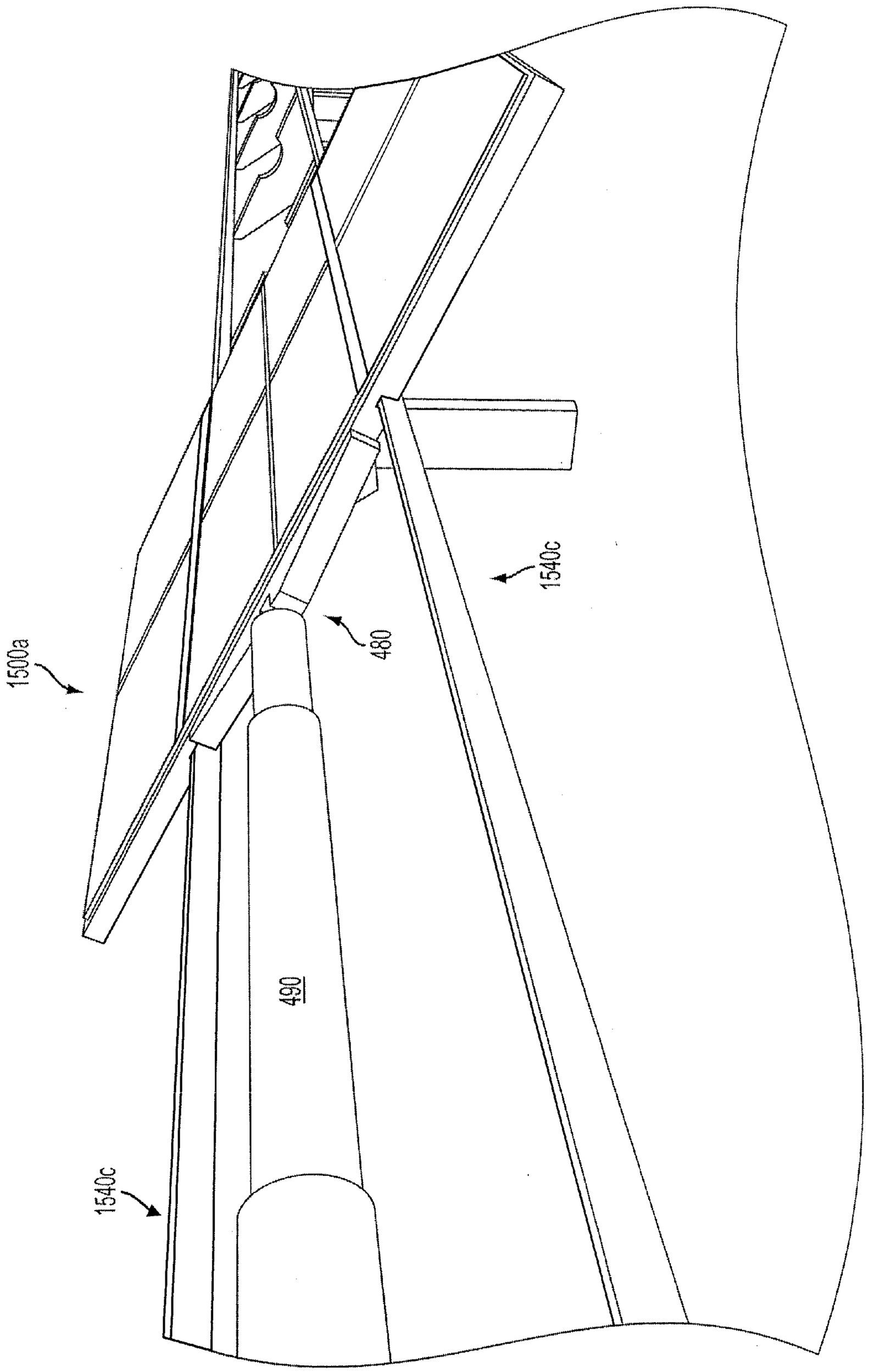

FIG. 27D

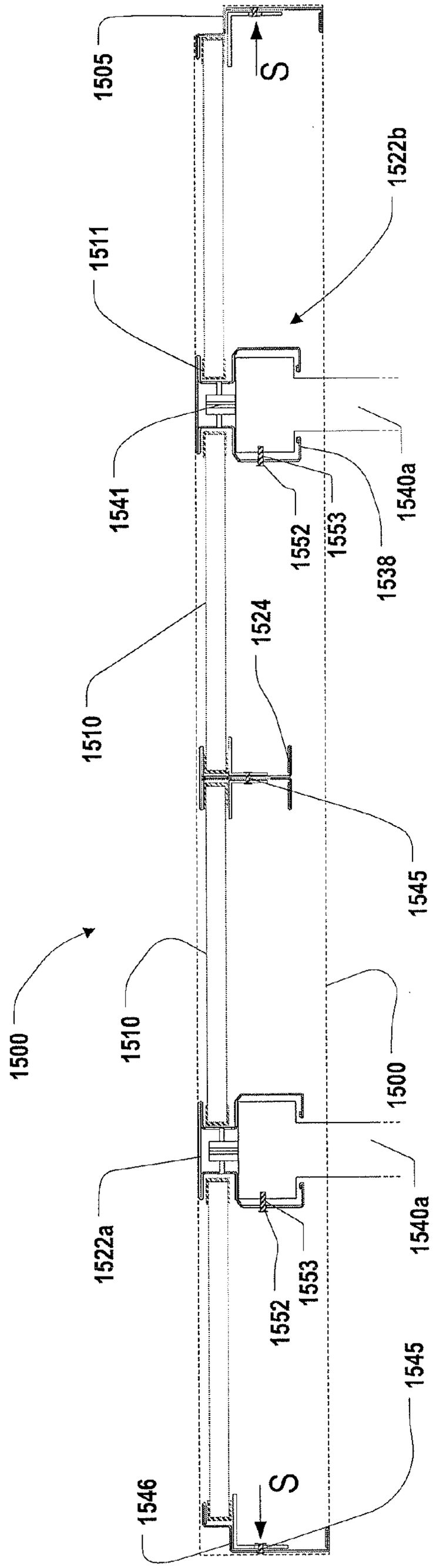
1505
S
1522b
1511
1541
1552
1553
1538
1540a
1524
1510
1545
1500
1510
1500
1522a
1540a
1553
1552
1545
1546
S

FIG. 28A

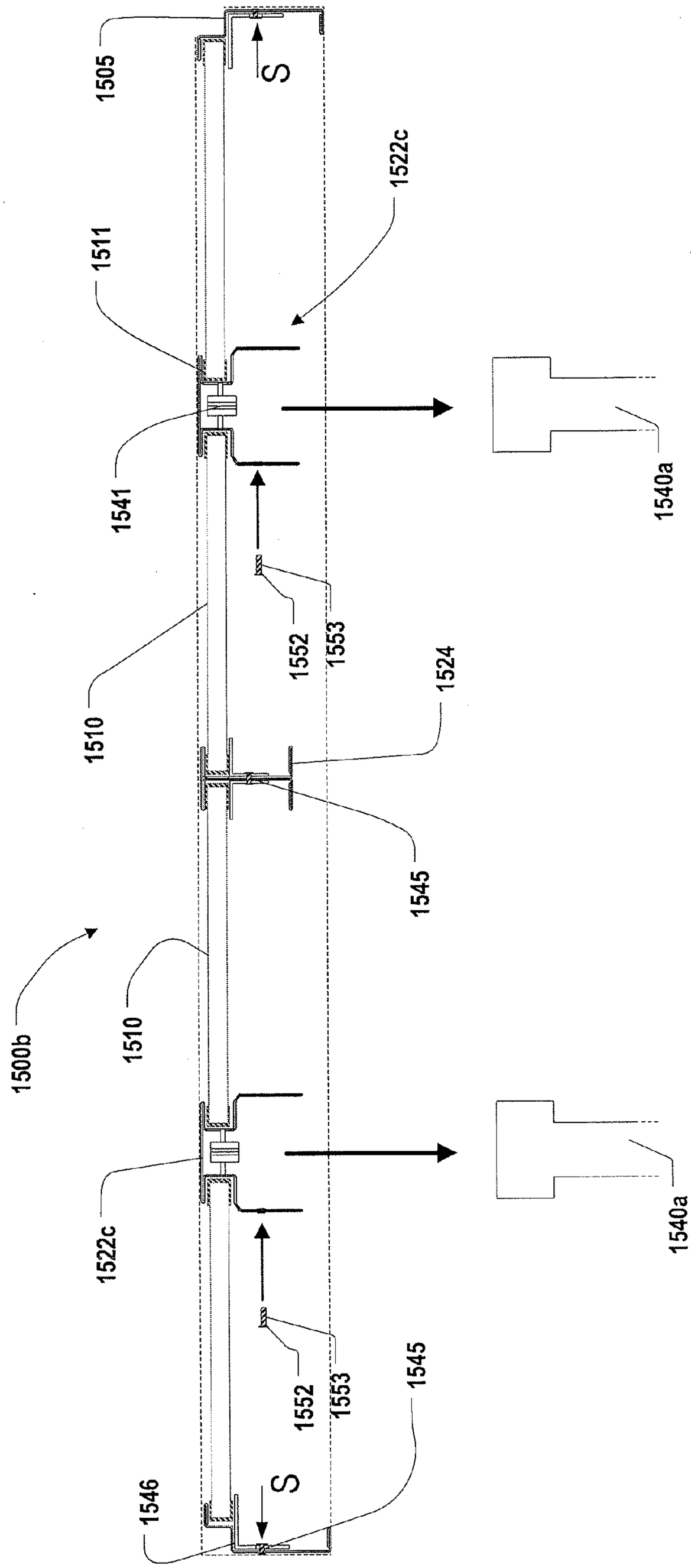
1505
S
1522c
1511
1541
1540a
1552
1553
1524
1510
1545
1500b
1510
1522c
1540a
1552
1553
1545
S
1546

FIG. 28B

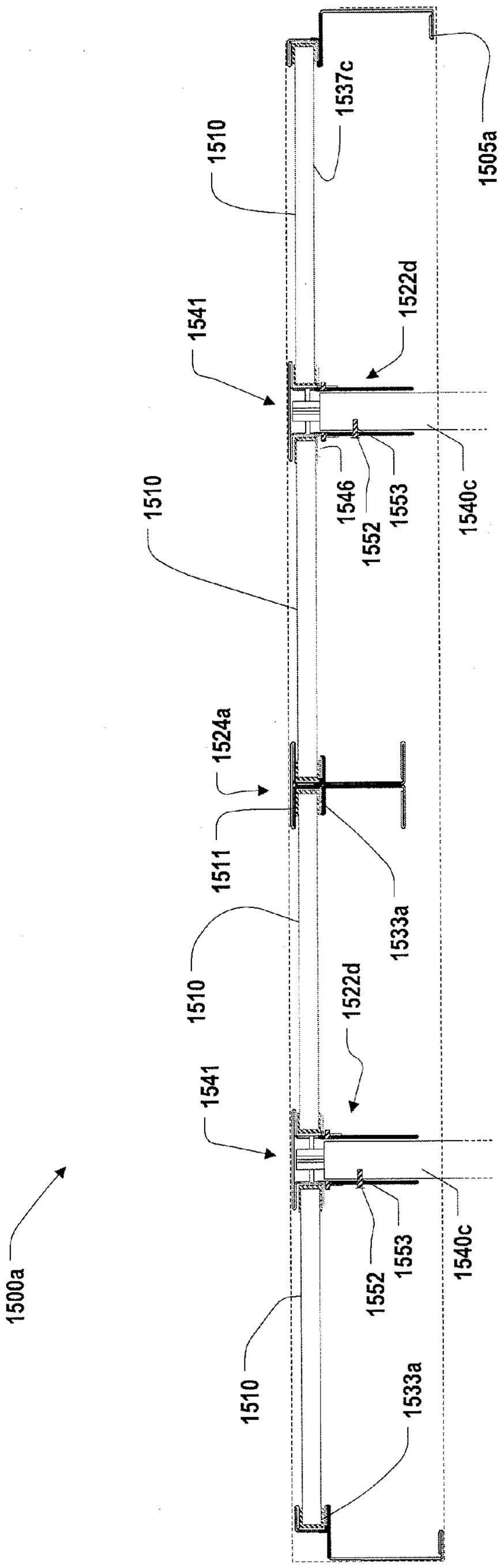
1500a
1510
1537c
1505a
1541
1522d
1546
1552
1553
1540c
1524a
1511
1533a

FIG. 28C

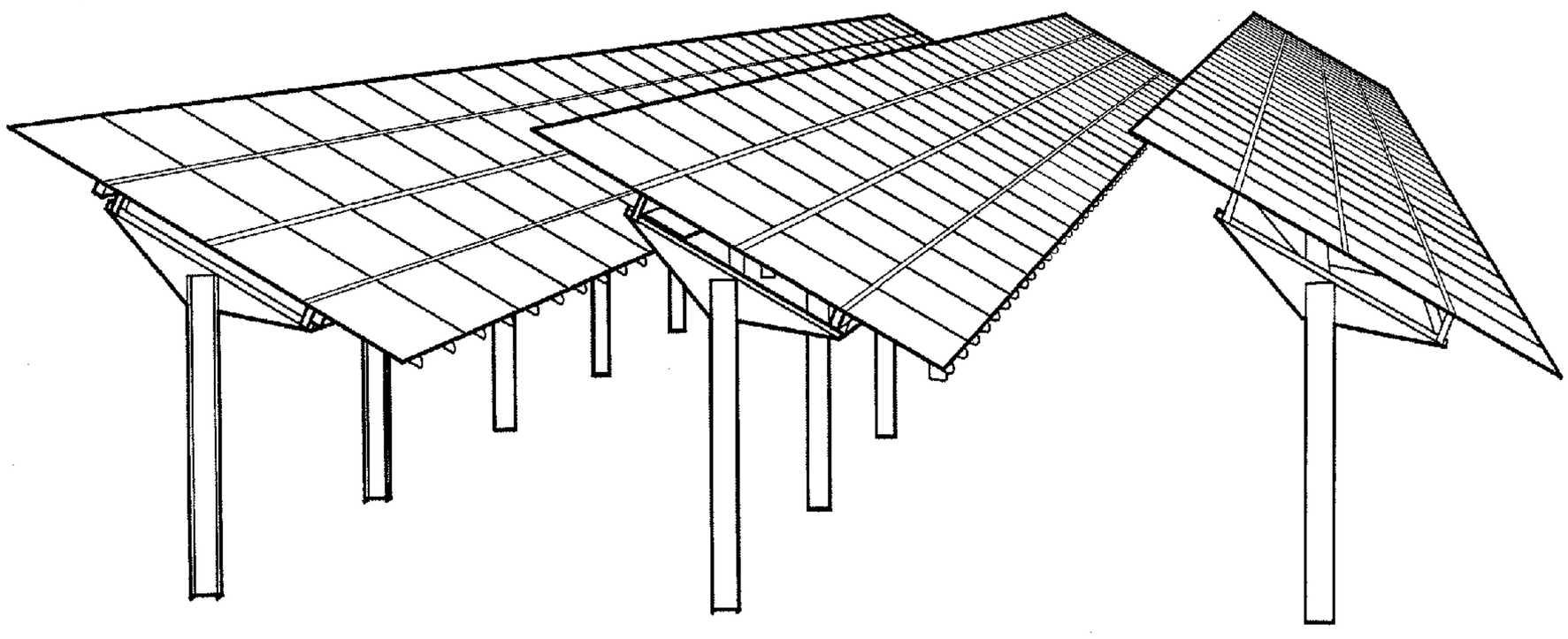

FIG. 29A

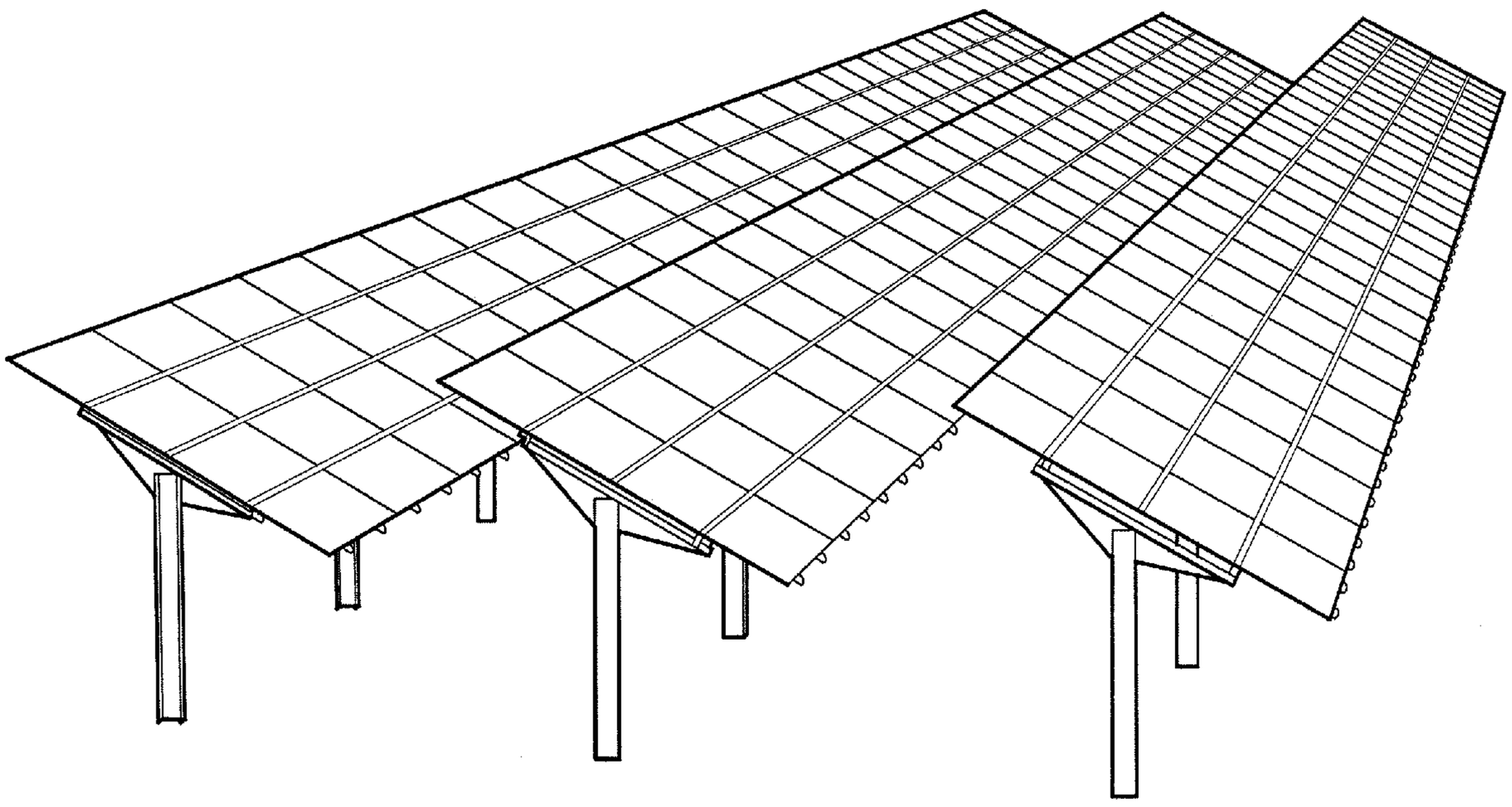

FIG. 29B

MECHANICAL PHOTOVOLTAIC MODULE CARTRIDGE AND METHOD OF CONSTRUCTION

RELATED APPLICATIONS

[0001] This application is a continuation-in-part of U.S. patent application Ser. No. 12/957,808, filed Dec. 1, 2010, which in turn is a continuation-in-part of U.S. patent application Ser. No. 12/846,621, filed Jul. 29, 2010, Ser. No. 12/846,644, filed Jul. 29, 2010, and Ser. No. 12/846,686, filed Jul. 29, 2010, the disclosures of each of which are incorporated herein by reference in their entirety.

FIELD OF THE INVENTION

[0002] Embodiments of the invention relate to the field of photovoltaic (PV) power generation systems, and more particularly to a system for simplifying installation of photovoltaic panels, also known as PV modules, in large-scale arrays.

BACKGROUND OF THE INVENTION

[0003] Photovoltaic power generation systems are currently constructed by installing a foundation system (typically a series of posts or footings), a module structural support frame (typically brackets, tables or rails, and clips), and then mounting individual photovoltaic panels to the support frame. The photovoltaic panels are then grouped electrically together into PV strings, which are fed to an electric harness. The harness conveys electric power generated by the photovoltaic panels to an aggregation point and onward to electrical inverters.

[0004] Prior art commercial scale PV systems such as this must be installed by moving equipment, materials, and labor along array rows to mount photovoltaic panels on the support frames one-at-a-time. This is a time-consuming process, which becomes increasingly inefficient with larger scale systems.

[0005] With innovations in PV cell efficiency quickly making PV-generated energy more cost-effective, demand for large-scale PV systems installations is growing. Such systems may have a row length of half a mile or more. Accordingly, a simplified system for photovoltaic panel installation is needed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. **1** is a perspective view showing a cartridge for mounting a plurality of photovoltaic panels in a first embodiment.

[0007] FIG. **2** is a close-up perspective view showing a recessed area in the cartridge.

[0008] FIGS. **3**A-**3**B are close-up perspective views showing photovoltaic panels mounted in the cartridge.

[0009] FIG. **3**C is a cross-sectional side view showing a photovoltaic panel mounted in the cartridge.

[0010] FIG. **4** is a top-down view showing a schematic of the electrical wiring in the cartridge

[0011] FIG. **5** is a perspective view showing attachment structures on the underside of the cartridge.

[0012] FIGS. **6**A-**6**B are perspective views, respectively showing different arrangements for mounting the cartridge to spaced parallel support rails.

[0013] FIG. **7** is a cross-sectional side view showing one embodiment of an attachment structure for mounting the cartridge to a support rail.

[0014] FIG. **8** is a perspective view showing another embodiment of an attachment structure for mounting the cartridge to a support rail.

[0015] FIG. **9** is a cross-sectional side view showing another embodiment of an attachment structure for mounting the cartridge to a support rail.

[0016] FIG. **10**A is a top-down view showing another embodiment of the cartridge.

[0017] FIGS. **10**B-C are a side view and cross-sectional side view of the cartridge along axes A and B, as shown in FIG. **10**A.

[0018] FIG. **11** is a perspective view showing another embodiment of an attachment structure for mounting a cartridge to parallel support rails.

[0019] FIG. **12** is a side view showing the attachment structure of FIG. **11** for mounting a cartridge to parallel support rails provided on a folding table.

[0020] FIG. **13** is a close-up cross-sectional side view of the attachment structure of FIG. **11**.

[0021] FIG. **14** is a perspective view of another embodiment of a cartridge.

[0022] FIG. **15** is a top view of a cartridge according to another embodiment of a cartridge.

[0023] FIG. **16**A is a cross sectional view of a cartridge frame employed in the FIG. **15** embodiment.

[0024] FIG. **16**B is a cross sectional view of a strut employed in the FIG. **15** embodiment.

[0025] FIG. **16**C is a cross sectional view of a strut according to a second embodiment.

[0026] FIG. **16**D is a cross sectional view of a central beam employed in the FIG. **15** embodiment.

[0027] FIG. **16**E is a cross sectional view of a cartridge frame according to another embodiment.

[0028] FIG. **16**F is a cross sectional view of a strut according to a third embodiment.

[0029] FIG. **16**G is a cross sectional view of a central beam according to another embodiment.

[0030] FIGS. **17**A-D illustrate the process of installation of photovoltaic panels into a cartridge depicted in FIG. **15**.

[0031] FIG. **17**E illustrates the process of installation of photovoltaic panels into a cartridge using the frame, struts, and central beam depicted in FIGS. **16**E-G.

[0032] FIG. **18** is a bottom view of the FIG. **15** embodiment.

[0033] FIGS. **19**A-F illustrate the process of formation of a cartridge frame.

[0034] FIG. **20** is a top perspective view of a partially completed cartridge.

[0035] FIG. **21**A is a top perspective view of a stack of completed cartridges.

[0036] FIG. **21**B is a cut-away top perspective view of stacked cartridges.

[0037] FIG. **21**C is a top perspective view of a partially loaded shipping container containing stacks of completed cartridges.

[0038] FIGS. **22**A-D are perspective views of cartridges being mounted to support rails one after another.

[0039] FIG. **23** is a perspective view showing a cartridge for mounting a single photovoltaic panel.

[0040] FIGS. **24**A-B show perspective views of FIG. **23** cartridges being mounted to support rails on a roof structure one after another.

[0041] FIG. **25** is a view showing operation of a robotic installation system for installing FIG. **1** cartridges.

[0042] FIGS. **26**A-E are views showing operation of a push actuator of the FIG. **25** robotic installation system.

[0043] FIG. **27**A is a perspective showing the installation of a cartridge of FIG. **15** to cartridge mounting rails.

[0044] FIG. **27**B is a perspective view showing a cartridge of FIG. **15** being slid along cartridge mounting rails.

[0045] FIG. **27**C is a perspective view showing a cartridge of FIG. **15** being slid along cartridge mounting rails according to a second embodiment.

[0046] FIG. **27**D is a perspective view showing a cartridge of FIG. **17**E being slid along cartridge mounting rails.

[0047] FIG. **28**A is a side view of the FIG. **15** embodiment mounted to cartridge mounting rails.

[0048] FIG. **28**B is a side view of the FIG. **17**E embodiment mounted to cartridge mounting rails.

[0049] FIGS. **29**A-B are perspective views showing a field array installation using cartridges and support structures detailed herein.

DETAILED DESCRIPTION OF THE INVENTION

[0050] In the following detailed description, reference is made to the accompanying drawings which form a part hereof, and which illustrate specific embodiments of the invention. These embodiments are described in sufficient detail to enable those of ordinary skill in the art to make and use them. It is also understood that structural, logical, or procedural changes may be made to the specific embodiments disclosed herein.

[0051] Described herein is a method for mounting and sliding a multiplicity of mountable photovoltaic panels along a rail system using a photovoltaic panel cartridge. For utility scale ground mounted photovoltaic systems or commercial or residential rooftop systems, the use of a rail system to slide cartridges each containing one or more photovoltaic panels into place provides several benefits. By moving all work to one or more locations along each row, e.g., at the head, the system maximizes the use of preassembled components, minimizes material movement logistics, and reduces both on-site field labor and equipment movement over the site. One embodiment of the system is constructed by installing a support structure comprising a plurality of spaced parallel rails, which may be ground or structure supported, designed to receive and allow sliding movement of a pre-assembled cartridge that supports either a single photovoltaic panel or a plurality of photovoltaic panels as a unit. The support structure could also comprise a photovoltaic tracking system which would allow the rails to be rotated.

[0052] A first embodiment of a cartridge **100** is depicted in FIGS. **1**, **2**, **3**, **4** and **5**. Cartridge **100** is a lightweight, cartridge-like structure that provides structural support and contains and supports a plurality of photovoltaic panels **120***a-h* in a 4×2 array and facilitates their electrical interconnection. The cartridge **100** is made of either synthetic or natural structural material, including, but not limited to, aluminum, rolled steel, or other metals and plastics. As an alternative, and as shown by element **1400** in FIG. **14**, the cartridge **1400** can be constructed in a honeycombed or gridded structure. This saves weight while maintaining structural strength.

[0053] As shown in more detail in FIGS. **1**, **2** and **3**A-**3**B, a plurality of photovoltaic panels **120***a-h* are mounted in respective recessed areas **110***a-h* of cartridge **100**, with one such recessed area **110***f* being shown without an installed photovoltaic panel in FIG. **2**. Photovoltaic panels **120***a-h* are held in place by being snapped, clipped, or otherwise securely seated in each of the recessed areas **110***a-h*. The photovoltaic panels **120***a-h* are preferably mounted in the recesses **110***a-h* before conveyance of a cartridge to an installation site, so all that needs to be done at the installation site is to mount the cartridge **100** containing a plurality of photovoltaic panels to a support structure. Although an array of eight photovoltaic panels **120***a-h* in a 4×2 array is shown in the figures as being supported by cartridge **100**, it is understood that any number or arrangement of photovoltaic panels could be mounted on and supported by a cartridge **100**. For instance, FIG. **24** shows a 4×1 array of photovoltaic panels on a cartridge **2200**, while FIG. **25** shows a single photovoltaic panel on a cartridge **2300**.

[0054] FIGS. **2** and **3**A show one embodiment of an arrangement for mounting photovoltaic panels in the recessed areas **110***a-h* of cartridge **100**. One edge of a photovoltaic panel, e.g., **210***f* (not shown) is slid under a lip groove **204** within recessed area **110***f* and lowered into position. To secure a photovoltaic panel in place, clips **302***a-b* which engage with an opposite edge of a photovoltaic panel are themselves engaged by screws or other fasteners with openings **202***a-b* provided on a side of the recess **110***f* opposite the side containing lip groove **204**. Together with lip groove **204**, clips **302***a* and **302***b* hold a photovoltaic panel in place within a recess. An alternate embodiment for securing the photovoltaic panels in the recesses is shown in FIG. **3**B, which uses spring-back clips **312***a-b* that overhang an edge of the recess. As one edge of a photovoltaic panel is slid under a lip groove **204** in a recess, it is then lowered into position, causing the opposite edge to press against the spring-back clips **312***a-b*, which push back and bend until the photovoltaic panel clears the bottom of the clips. Once clear, the clips **312***a-b* will slide back over top of the photovoltaic panel, securing it in place.

[0055] Clips and grooves are not the only way photovoltaic panels can be mounted in recesses of the cartridge **100**; glue, Velcro™, or other known engagement means can be used. In another embodiment for securing the photovoltaic panels to the recesses, resilient engagement members can be used to hold the panels in place. FIG. **3**C, for instance, shows a pair of rubber stoppers **322***a-b* at opposite ends of a recessed area **110***f* which allow panel **210***f* to be slid under one of the stoppers **322***a* and then pressed down past the other stopper **322***b* to be held in place. The cartridge **100** is preferably configured so that whichever structure are used to hold a photovoltaic panel within a recess is used, photovoltaic panels **120***a-h* are either flush with or below a top surface **210** of the cartridge **100**. This allows the cartridge **100** to be stacked with like cartridges for shipping and also protects the photovoltaic panels **120***a-h* while in storage or transit to an installation site.

[0056] In general, solar-generated electricity is harvested and transmitted through a pre-wired common bus or cable system integral to the cartridge **100**. Some examples of a common bus system that may be employed are described in more detail in co-pending application Ser. No. 12/846,671, the disclosure of which is incorporated by reference herein. One embodiment of pre-wiring a cartridge **100** for connection to a common bus system **280** is schematically shown in FIGS. **2** and **4**. As shown in FIG. **2**, an electrical connector **206** can be provided in the lower surface of the recessed area **110***f* so that when a photovoltaic panel is placed in a recessed area **110***f*, a plug on the bottom of a photovoltaic panel engages electrical connector **206** to connect it to the common bus system **280**. FIG. **2** also shows an electrical connector **208**

provided in a sidewall of the recess **110***f* that could be used in lieu of connector **206** to connect wiring **212** to side electrical connectors on a photovoltaic panel. An exemplary electrical connection schematic for a cartridge **100** is shown in FIG. **4**.

[0057] As shown in FIG. **4**, the wiring **212** for a cartridge **100** runs from the electrical connectors **206** in each recessed area **110***a-h* into channels **232***a-b* provided in cartridge **100** which run above each attachment area **130***a-b* (a similar channel **732***a* is also shown in FIG. **7**). Each of the channels **232***a-b* is connected to a transverse central channel **278** which runs through cartridge **100**, which houses the common bus system **280**. The wiring **212** connects electrical connectors **206**, and thus the photovoltaic panel engaged in each recess **110***a-h* to the common bus system **280**. Although the common bus system **280** in each cartridge **100** can be terminated at an electric harvester on a cartridge **100** support structure, such as is shown in FIG. **12**, FIG. **4** shows an embodiment where each cartridge **100** can be equipped with a male electrical connector **216** and female electrical connector **218** for interconnecting the common bus systems **280** of multiple cartridges **100**, together. In this manner, as the cartridges **100** are slid into position on a support structure in the manner discussed in more detail below and pressed against each other, corresponding male **216** and female **218** connectors engage to electrically connect the photovoltaic panels of adjacent cartridges **100**. Interconnected cartridges **100** can then transfer electric power to a common point and onward to an electrical inverter before connecting to an electrical grid.

[0058] As shown in FIGS. **1** and **5**, each cartridge **100** has attachment structures **130***a-b* in the form of grooves on the cartridge underside to seat the cartridges **100** on support structures. FIG. **6**A shows an exemplary cartridge **100** with its attachment structures **130***a-b* being slidably mounted on a support structure **600** comprising a set of spaced parallel rails **640***a-b*. FIGS. **1**, **5** and **6**A show that for cartridge **100**, the attachment structures **130***a-b* are on the under side of the cartridge **100**. FIG. **6**B shows an alternate embodiment of a cartridge **600** where the attachment structures are provided in the form of slots **630***a-b* on side edges of the cartridge **600**, which are mounted on and engage with a support structure **601** that also comprises a set of spaced parallel rails **641***a-b*.

[0059] As can be seen in FIGS. **6**A, **6**B, a cartridge **100**, **600** can be slid onto the rails **640***a*, **640***b* or **641***a*, **641***b* (FIG. **6**B) for mounting in the field. Successive cartridges **100**, **600**, each containing a plurality of photovoltaic panels (in this embodiment), can be advanced (by sliding) onto the rails one after another, resulting in considerably reduced field installation time. In addition, adjacent cartridges **100**, **600** can be electrically connected to one another by mating male and female electrically connectors **216**, **218**.

[0060] As mentioned above, row length in large-scale PV systems can be half a mile or more. In order to easily slide cartridges along such a long path, as shown in FIG. **7**, cartridge **700** may use a roller truck **760** mounted within the attachment structure **730***a*, which facilitates easier sliding movement across long stretches of rail **740**. FIG. **7** also shows a channel **732***a* above attachment structure **730***a*, for routing wiring **712** to an electrical connector **708** in a corresponding recessed area **710***a*.

[0061] The truck **760** comprises a plurality of paired spaced rollers **764***a-b* mounted on a corresponding axle **762**. The truck **760** only takes up a small portion of space inside the attachment structure **760***a*, so that a rail **740**, which may have a T or other cross-sectional shape, can extend far enough in the attachment structures **730***a-b* to stabilize the cartridge **700**. Once a cartridge **700** is slid into position on the rails **740**, it can be secured to the rails **740** by extending a set screw **752** (in channel **750**) or other fastener to engage a groove **742** in the rail **740**. Advantageously, the set screw **752** also functions as an electrical ground, if made of conductive material, grounding a conductive cartridge **700**, to a conductive rail **740**.

[0062] Although, as shown in FIG. **7**, truck **760** may use multiple equally spaced rollers **764***a-b*, a truck could also use any sliding movement assisting structure, including a single roller on an axle (such as the rollers **864***a-b* in FIG. **8**) or ball bearings (such as bearings **766***a-b* in FIG. **9**). Generally, the trucks **760** are manufactured separately from the cartridges **700** and are mounted in the attachment structures **730***a-b* by screw, bolt, glue, or other fastener. However, the trucks **760** could also be integral to the attachment structures, and, as shown in the alternate embodiment of FIG. **8**, rollers **864***a-b* could be installed directly inside attachment structure **830***a*. Referring back to FIGS. **1**, **5** and **6**A, the attachment structures **130***a-b* or **630***a-b* can take the form of simple grooves, and a non-stick, or low friction slidable surface such as a Teflon®-coated surface can be applied within the grooves instead of using a truck **760** to facilitate sliding movement of a cartridge.

[0063] FIG. **9** shows an alternate embodiment of a cartridge **900** having a truck **960** which comprises a plurality of paired spaced ball bearings **966***a-b*, which are mounted in upper and lower housings **964***a-b* and **968***a-b* respectively. Truck **960** also has a pair of arms **962***a-b* that extends to engage corresponding grooves **942***a-b* in a support rail **940**. Though only shown in this embodiment, it should be understood that any truck **760**, **960** could use such arms **962***a-b* which engage the corresponding grooves **942***a-b* in the support rail. The FIG. **9** truck **960** is secured to attachment structure **930***a* by means of screw **970** or other fastener, which is driven through a top surface of the attachment structure **930***a* into the body of cartridge **900**. Other trucks that may be employed are described in more detail in co-pending application Ser. No. 12/846,686, the entire disclosure of which is incorporated herein by reference. The trucks **760**, **960** described herein and in application Ser. No. 12/846,686 can be used on any of the cartridges **100**, **600**, **700**, **800**, **900**, **1000**, **1100**, **1400**, **1500**, **2200**, and **2300** described herein.

[0064] FIGS. **10**A-**10**C show an embodiment in which cartridge **1000** is constructed of a frame structure of spaced elongated members **1010***a-d*. The spaced elongated members **1010***a-d* are preferably formed in a U-shape with outwardly extending flanges on either top side. This shape is also known as a hat channel. Attachment structures **1030***a-b* are fastened transversely across and beneath the spaced elongated members **1010***a-d* for, as shown in FIG. **10**A, slidably connecting the cartridge **1000** to support rails **1040***a-b*. Photovoltaic panels, e.g., **1020***a-b*, are mounted on top of the spaced elongated members **1010***a-d* and secured by clips **1012***a-b* or other fastener to the elongated members **1010***a-d*. As with the FIG. **1-5** embodiment, glue, Velcro™, or other known engagement means can be used to secure the photovoltaic panels **1020***a-d* to the spaced elongated members **1010***a-d*. An optional exterior rim **1050**, shown in dotted lines in FIG. **10**A, is fit around the outside of the cartridge and fastened to the ends of both the spaced elongated members **1010***a-d* and attachment structures **1030***a-b*. The optional exterior rim **1050** provides added structural support and also enables the cartridge **1000** to be

stacked with other cartridges. Preferably, the spaced elongated members **1010***a-d,* photovoltaic panels **1020***a-d,* and attachment structures **1030***a-b* are all arranged within the dimension of the thickness of exterior rim **1050** so they do not project beyond a top or bottom surface of the rim **1050** of the cartridge **1000**, enabling stacking of cartridges **1000**.

[0065] Cartridge **1000** is also equipped with a common bus system **1080**. Wiring **1012** for the common bus system **1080** is run through the spaced elongated members **1010***a-d.* FIG. **10**A shows a series of plugs **1006**, for connecting the photovoltaic panels **1020***a-d* to the common bus system **280**. The common bus system **1080**, through a channel **1078** transversely mounted to the bottom of spaced elongated members **1010***a-d,* also has a plug **1014** and plug **1016** on opposite sides of the exterior rim **1050** of the cartridge **1000** for electrically interconnecting adjacent cartridges **1000**.

[0066] FIG. **10**B shows a side view of cartridge **1000** along axis A of FIG. **10**A, showing a photovoltaic panel **1020***a* mounted on spaced elongated member **1010***a,* along with attachment structure **1030***a* and rail **1040***a.* It should be understood that trucks, e.g., **760**, **960** can be mounted in attachment structure **1030***a* as well, and that attachment structure **1030***a* may be fitted with holes or screw threads (not shown) that can be used with fasteners, e.g., screw **970** on truck **960** or fit with portions of the truck, e.g., **760**, **960** to secure and stabilize the truck within the attachment structure **1030***a*D. FIG. **10**C shows a cross-section of cartridge **1000** along axis B of FIG. **10**B, showing photovoltaic panel **1020***a* mounted on spaced elongated members **1010***a-b* along with exterior rim **1050**.

[0067] FIGS. **11-13** show another embodiment of a cartridge **1100** that does not employ a truck. The cross sectional profile of the attachment structures **1130***a-b,* which are formed as grooves in the underside of cartridge **1100**, matches that of the rails **1140***a-b,* which are generally T-shaped in cross-section. FIGS. **12** and **13** show this embodiment in more detail. Rails **840***a-b* are mounted on a support table **1190** or other supporting structures, such that cartridge **1100** is suspended above the table by the rails **840***a-b.* As can be seen in FIG. **11**, the rails **1140***a-b* are transversely mounted to flange **1152** on the table **1050**. The rails **1140***a-b* themselves are hollow and can be compressed, which allows sliding of the cartridges **1100** along the rails, and after the cartridges **1100** are slid into place, provide resistance which holds the cartridges **1100** to the rails **1140***a-b.* FIG. **12** also shows that cartridge **1100** is connected to an electrical harness **1192** on a support table post support structure **1150** via plug **1118**, so that collected photovoltaic-generated electricity can be gathered and sent to a power grid.

[0068] Although the rails depicted in FIGS. **6**A-**9** and **11-13** have a generally T-shaped profile, it should be understood that another cross-sectional rail profile, e.g., circular or I-shaped, could be used. Further, it should be understood that although the mounting system described herein (e.g., **601** shown in FIG. **6**B) is generally used for ground mounted installations (as in FIG. **12**).

[0069] A plurality of cartridges may be stacked together and shipped to an installation site. For this reason, the cartridges, e.g., **100**, **600**, **700**, **800**, **900**, **1000**, **1100**, **1400**, **1500**, **2200**, and **2300** are generally designed to lie flat or fit together vertically and are configured to protect the photovoltaic panels in transit, and the trucks, e.g., **760**, **960** are designed to be completely contained flush or preferably entirely within the attachment structures. In addition, as noted above, the photovoltaic panels are preferably recessed in the cartridges **100**, **600**, **700**, **800**, **900**, **1000**, **1100**, **1400**, **1500**, and **2300**. Optionally, as is shown in FIG. **14**, a cartridge **1400** can have one or more openings **1402** so that when cartridges are stacked, a threaded securing member (not shown) can be inserted in opening **1402** and topped with bolts to ensure the cartridges remain secure in place during transit. Cartridge **1400** may also have a plurality of protrusions **1404***a,* **1404***b* to engage corresponding recesses (not shown) in the backside of cartridge **1400** to help hold a stack of cartridges together as an integrated unit. Alternately, or in addition to the protrusions **1404***a,* **1404***b,* and associated recesses, the cartridge **1400** can be formed with a self-aligning lip **1450** that engages a corresponding recess (not shown) on the backside of cartridge **1400** for the same purpose.

[0070] FIG. **15** shows a cartridge **1500** according to another embodiment from a top view. In this embodiment, the cartridge **1500** may be manufactured from a frame **1505**, central beam **1524**, and a pair of struts **1522***a,b.* The cartridge **1500** is then loaded with an array of eight photovoltaic panels **1510** in a two column-four row array as shown. The cartridge **1500** is mounted and installed on parallel cartridge mounting rails **1540***a.* The cartridge mounting rails **1540***a* may be provided on a ground or roof support structure as is shown and described below.

[0071] FIGS. **16**A, B, and D show the frame **1505**, central beam **1524**, and struts **1522***a,b* (only **1522***a* is shown in FIG. **16**B) in more detail. FIG. **16**A shows a cross-section of the frame **1505** along line **16**A-**16**A of FIG. **15**. FIG. **16**B shows a cross-section of the strut **1522***a* along line **16**B-**16**B of FIG. **15**. FIG. **16**D shows a cross section of the central beam **1524** along line **16**D-**16**D of FIG. **15**. Each of the frame **1505**, central beam **1524**, and strut **1522***a* are formed from a rolled metal, such as galvanized steel. As is shown in FIGS. **16**A, B, and D, a reinforced area **1536***a-f* of folded over metal is provided along the entire length of the frame **1505**, central beam **1524**, and strut **1522***a* at the top and bottom parts to provide increased stability and torsion resistance. The frame **1505** and central beam **1524** are provided mounting regions **1537***a,b* to facilitate installation of photovoltaic panels as described below. Similarly, the strut **1522***a* is provided a mounting channel **1533**. The frame **1505** and central beam **1524** also have fixation holes **1534** to permit installation of a bracket (shown in FIG. **20**A-C) to secure the photovoltaic panels within the mounting regions **1537***a,b* as described below. In one embodiment, shown in FIG. **16**A, the frame **1505** is formed to create a nesting channel **1539** to allow one cartridge **1500** to be stacked upon another cartridge, as shown below in FIG. **21**A-C. As is shown in FIGS. **16**A, B, and D, the frame **1505** is taller than the central beam **1524** and struts **1522***a,b* to allow one cartridge to stack upon another cartridge but prevent the central beam **1524** and struts **1522***a,b* from contacting with and damaging the photovoltaic panels **1510** of the next lowest cartridge when cartridges are stacked.

[0072] As is shown in FIG. **16**B, the strut **1522***a* is formed with opposed arms **1538**, to allow the strut to wrap around a T-shaped cartridge mounting rail **1540***a* to prevent the cartridge **1500** from lifting off of the cartridge mounting rails **1540***a,* while also permitting the cartridge **1500** to slide along the rails **1540***a.* In another embodiment, shown in FIG. **16**C, the strut **1522***c* and opposed arms **1538***a* are formed with a generally U-shaped cross section, which permits the strut **1522***c* to be attached to a T-shaped or other shaped cartridge mounting rail in either a downward direction from above the

rail or slid onto the rail from the rail end. Once attached to the mounting rail the cartridge utilizing the strut **1522***c* could be slid to a mounting location along the rails

[0073] A wheel assembly **1541** formed of a wheel **1542** and axle **1543** can be provided which allows the cartridge **1500** to slide easily along the cartridge mounting rails **1540***a* of FIG. **15**. It can be appreciated that other means may be used to facilitate the sliding of the cartridge **1500** to slide along the cartridge mounting rails **1540***a,* such as ball bearings or low friction surfaces, as described in U.S. patent application Ser. No. 12/846,686, and described above and shown in FIGS. **8** and **9**. The strut **1522***a* also has a fastener hole **1552** to allow a fastener to be inserted through the strut **1522***a* and engage the strut **1522***a* with the cartridge mounting rail (shown in FIG. **15**) to allow the cartridge **1500** to be fixed in place once the cartridge **1500** has reached a desired mounting location.

[0074] In another embodiment, shown in FIGS. **16**E-G, the mounting channels **1533***a,b* are provided on the central beam **1524***a* and frame **1505***a*. The mounting regions **1537***c* are provided on the strut **1522***d*. Similar to FIG. **16**C, the strut **1522***d* has a generally U-shaped cross-section, allowing it to be attached to a cartridge mounting rail from above the rail or to be attached by sliding the cartridge onto the rail from the rail end.

[0075] FIGS. **17**A-D show the installation of a photovoltaic panel **1510** into a cartridge strut **1522***a* and frame element **1505** from the side perspective. In the embodiment shown, the photovoltaic panel **1510** is installed with the top surface of the cartridge **1500** facing down. In another embodiment, the photovoltaic panel may be installed from below with the cartridge **1500** facing up. The mounting regions **1537***a* of frame **1505** and mounting channel **1533** of strut **1522***a* are configured to hold a photovoltaic panel **1510**. The photovoltaic panel **1510** may be provided with molded cushion pads **1511** to protect the photovoltaic panel **1510** edges from being damaged when installed into the cartridge **1500**. The photovoltaic panel **1510** is inserted into the C-shaped mounting channel **1533** at an angle θ, which may be in a range of 30° to 60°. In order to facilitate the installation of the photovoltaic panel **1510** into the mounting channel **1533** and allow the panel **1510** to tilt to the proper angle, the arms **1538** of the strut **1522***a* may be provided an angled portion **1535** at the mounting channel **1533**.

[0076] Next, as shown in FIG. **17**B, once one edge of the photovoltaic panel **1510** is inserted into the C-shaped mounting channel **1533** and the photovoltaic panel is lowered into position so that the opposite edge is seated into a corresponding mounting region **1537***a* on the frame **1505**, a bracket **1546** is provided to fasten the photovoltaic panel in place as is shown in FIGS. **17**B-C. A fastener **1545** is provided to be inserted through a fastener hole **1547** in the bracket **1546**, and into the fixation hole **1534** of the frame **1505**. In one embodiment, the fixation hole **1534** and/or the fastener hole **1547** are threaded to engage a threaded fastener. In another embodiment, the fixation hole **1534** and/or the fastener hole **1547** are smooth and the fastener is a bolt and nut. FIG. **17**C shows the bracket **1546** being fastened to the frame element **1505** to secure the photovoltaic panel **1510** in place. The bracket **1546** may be fastened to the frame element by use of rivets, welds, or other similar fastener means or attachment structures. A second and third photovoltaic panel **1510** may also be similarly installed between the central beam **1524** and the struts **1522***a,b* and shown in FIGS. **15** and **17**D. Brackets **1546***a,b* fasten the photovoltaic panels **1510** to the central beam **1524**. A fastener **1545** is passed through the two brackets **1546***a,b* and the central beam **1524** to secure the photovoltaic panels **1510** in place.

[0077] As shown in FIG. **17**E in another embodiment, the frame **1505***a,* central beam **1524***a,* and strut **1522***c* of FIGS. **16**D-F may be used in place of the frame **1505**, central beam **1524**, and strut **1522***a,* shown in FIGS. **17**A-D, to create a cartridge **1500***a* having a U-shaped channel on the struts **1522***d*. In this embodiment, the installation of the photovoltaic panels would proceed similarly to that shown in FIGS. **17**A-C. One side of the photovoltaic panels **1510** is inserted at an angle into a mounting channel **1533***a,b* of either the central beam **1524***a* or frame **1505***a*. The opposing side of the photovoltaic panel **1510** is then lowered onto the mounting regions **1537***c* of the strut **1522***d*. Finally, brackets **1534** are affixed to the strut **1522***d* to secure the photovoltaic panels **1510** in place.

[0078] FIG. **18** shows a fully-loaded cartridge **1500** from below. The cartridge **1500** has eight mounted photovoltaic panels **1510**, installed as described above. Six wheels assemblies **1541** are provided and spaced at locations along struts **1522***a,b,* however, more or fewer wheel assemblies **1541** may be utilized as desired and required to support the cartridge **1500**.

[0079] In one embodiment, shown in FIGS. **19**A-F, the frame **1505** may be formed from one continuous piece. As is shown from the top in FIG. **19**A and side in FIG. **19**B, a frame blank **1504** is provided and pre-notched at the locations **1507** where the cartridge **1500** will be mounted on the cartridge mounting rails **1540***a*. The frame blank **1504** has four sections A, B, C, and D, each correspond to one side of the completed frame **1505**. In one embodiment, the four sections (A, B, C, and D) are of equal length. In another embodiment, a given section (e.g. A) is equal in length with its opposing sections (i.e. C), but is of a different length from adjacent sections (i.e. B and D). The frame blank **1504** is then bent as shown in FIG. **19**C-E at locations **1506** between the sections A, B, C, and D to form the completed frame **1505**. The frame blank **1504** is notched at locations **1508** in the reinforced areas **1536***a,b* at the locations **1506** to allow the frame blank **1504** to be bent into the configuration shown in FIGS. **19**E and **19**F. Once the bends have been made, the notched reinforced areas **1536***a,b* may be welded together or otherwise fastened together to increase the strength of the frame **1505**. The ends of the completed frame **1505** are joined together by fasteners, welding, or other fastening techniques.

[0080] Once the frame **1505** is assembled, as shown in FIGS. **19**E and **19**F, the central beam **1524** and the struts **1522***a,b* are fastened in place as shown in FIG. **20**. The struts **1522***a,b* are attached to align with the notches in the frame **1505**, with the central beam **1524** centered between the struts **1522***a,b*. The struts **1522***a,b* and central beam **1524** are provided with flanges **1527**, **1529** by which the struts **1522***a,b* and central beam **1524** are fastened to the frame **1505**. The struts **1522***a,b* and central beam **1524** may be fastened to frame **1505** using flanges **1527**, **1529** with bolts, screws, rivets, welds, or other similar attachment techniques.

[0081] FIG. **21**A shows a stack **1508** of completed cartridges **1500**, which FIG. **21**B shows in more detail. As is shown in FIG. **21**B, a cross-section of **21**A with one side of the frame **1505** removed, the frames **1505** are configured to nest with one another. As was discussed above with respect to FIG. **16**A, the lower reinforced area **1536***b* of a cartridge **1500** rests upon the nesting channel **1539** of the cartridge **1500**

below it. Because this reinforced area **1536***b* and nesting channel **1539** follow the perimeter of the cartridge **1500**, the cartridges **1500** nest into one another to prevent the cartridges **1500** from sliding and becoming damaged. This allows multiple cartridges **1500** to be transported together more easily and compactly as shown in FIG. **21**C, while protecting the edges of the photovoltaic panels **1510** and eliminating the necessity of using dunnage and pallets in transporting the cartridge stacks **1508**.

[0082] Once the cartridges of the various embodiments discussed above (e.g. **100**, **600**, **700**, **800**, **900**, **1000**, **1100**, **1400**, **1500**, **2200**, and **2300**) have been transported to the installation site and are prepared for installation on the corresponding support structure, the cartridges **100**, **600**, **700**, **800**, **900**, **1000**, **1100**, **1400**, **1500**, **2200**, and **2300** may be installed in one of several manners. These installation methods, described below, may be used with cartridges **100**, **600**, **700**, **800**, **900**, **1000**, **1100**, **1400**, **1500**, **2200**, and **2300** of any of the embodiments discussed above but are described in detail in the following exemplary embodiments.

[0083] As discussed above, the cartridges **100**, **600**, **700**, **800**, **900**, **1000**, **1100**, **1400**, **1500**, **2200**, and **2300** may be installed by manually placing the cartridges **100**, **600**, **700**, **800**, **900**, **1000**, **1100**, **1400**, **1500**, **2200**, and **2300** one after another onto the rails (e.g. **640***a,b*), (for example, by lowering the cartridge **100** onto the rails **640***a,b* or aligning attachment structures (e.g. **130***a,b,* **1130***a,b,* **1522***a,b,c,d*) on the cartridges to the rails) and advancing them by having an operator slide them on the rails **640***a,b* into a desired position. This placing and sliding can be done at the head end of a row or at spaced positions along a row. Head-end installation reduces equipment and labor movement. Both the rails **640***a,b* and the cartridges **100**, **600**, **700**, **800**, **900**, **1000**, **1100**, **1400**, **1500**, **2200**, and **2300** are designed so that cartridges can quickly be placed onto rails and slid into a final position.

[0084] The cartridges (e.g. **2200**, **2200***b*) may be deployed manually as shown in FIGS. **22**A-D. FIG. **22**A shows a first cartridge **2200** being lowered onto support structure **2240** via a lifting device **2210**. Lifting device **2210**, which is attached to an overhead cable **2211**, can comprise (as shown) an adjustable frame **2212** that holds a cartridge (e.g., **2200**) by its edges. Each side of the frame **2212** can be opened or closed by engaging a corresponding latch **2213***a,* **2213***b.* FIG. **22**B shows cartridge **2200** securely placed on the support structure **2240**, after which it can be slid down the structure, as shown in FIG. **24**C. FIG. **22**D shows the placement and subsequent positioning of a second cartridge **2200***b* after the first cartridge **2200**.

[0085] FIG. **23** shows another embodiment of a cartridge **2300** for holding a single photovoltaic panel **121** and having a pair of attachment structures **130***a-b.* Similar to the cartridge of FIG. **1** which holds multiple panels, cartridge **2300** can be optionally connected to other cartridges **2300** using a male electrical connector **216** (not shown) and female electrical connector **218** on an outer part of a frame of the cartridge **2300**. It should be understood that the various methods and structures described herein for mounting photovoltaic panels on a multi-panel cartridge, e.g., **100**, are applicable to single panel cartridges, e.g., **2300**, as well. For instance, similar to cartridge **100**, cartridge **2300** can have a recessed area (**110** in FIG. **1**) and an engagement mechanism for holding photovoltaic panel **121** within the recessed area, and an electrical connector (**206** in FIG. **2**) located within the recessed area for electrically connecting the photovoltaic panel **121** to connectors **216**, **218**.

[0086] Similar to FIG. **6**A, as shown in FIG. **24**A, a first single-panel cartridge **2300** can be placed on the parallel spaced rails **2440***a-b* of support structure **2400** and slid down the rails far enough to place another cartridge on the rails **2440***a-b* in place behind it, so it too can be slid down the rails **2440***a-b.* It should be understood that cartridge **2300** could be placed on the rails **2440***a-b* by simple lifting, or a winch could be used. Alternatively, cartridge **2300** could be lined up over the rails **2440***a-b* and lowered on top of them. It should also be appreciated that the same methods of mounting the cartridges described in other embodiments, e.g., for cartridge **100**, can be used. Further, since it may be difficult to manually push successive cartridges, e.g., **100**, **2300** over long distances, cartridges could be lowered onto a rail e.g., **640***a-b,* **2440***a-b* at set locations spaced along the rail and then slid into position. Alternatively, a robotic system as described in application Ser. No. 12/846,644 can be used to place the cartridge **2300** on rails **2440** *a-b* and slide them down the rails.

[0087] FIG. **24**B shows a second cartridge **2300***b* being placed on parallel spaced rails **2440***a-b* of the support structure **2400** behind the first cartridge **2300**. The cartridges **2300**, **2300***b* are pressed together, so as to facilitate movement in tandem along the support structure. As mentioned above, this connection may also facilitate electrically interconnecting the photovoltaic panels on the cartridges **2300**, **2300***b* via connectors **216**, **218**. Cartridges **2300**, **2300***b* can also be held together by any suitable fastening means **2310** (shown in FIG. **23**), such as complementary locking or latching structures, or Velcro™, or any other fastening mechanism, mounted on the outside of the cartridges **2300**, **2300***b.* Once contacted, cartridges **2300**, **2300***b* can be slid in tandem along the support structure. As subsequent cartridges **2300** are placed on the rails, the installer can advance the already mounted cartridges **2300** incrementally further down an array row. The installation process continues until a desired number of cartridges have been placed on the rail and slid into position.

[0088] It should be noted that the support structure **2300** is shown as being designed to run along a horizontal surface of a roof, as opposed to perpendicular to it (i.e. in a vertical direction). Although the support structures (e.g., **2400**) described herein could be adapted to vertical mounting, horizontal mounting is preferred because it permits cartridges to be slid into a desired position without requiring a locking mechanism to prevent the cartridges from falling back down the structure. It should also be understood that various combinations of trucks or no trucks, and different types of rails can be used with any of the cartridges (e.g., **100**, **600**, **700**, **800**, **900**, **1000**, **1100**, **1400**, **1500**, **2200**, and **2300**) described herein.

[0089] Since, as noted above, manual installation of cartridges can become difficult as the row length increases, a more automated cartridge mounting and delivery system may be used. One such delivery system is described in more detail in co-pending application Ser. No. 12/846,644, which is incorporated by reference herein.

[0090] FIG. **25** shows such a robotic installation system **400** for deployment of cartridges. For simplification, only cartridges **100** are shown in FIG. **25**, but it should be understood that the illustrated installation system **400** may be used with any of cartridges **600**, **700**, **800**, **900**, **1000**, **1100**, **1400**, **1500**, **2200** and **2300**. During operation, the robot arm **410**, to

which the frame **460** of a vacuum system **430** is attached, moves to align the frame **460** over a first exemplary FIG. **1** cartridge **100**, situated as the top cartridge **100** in a magazine **500** comprising a plurality of cartridges **100** stacked together. Once aligned, the vacuum is activated and suction cups **470** are engaged with the photovoltaic panels **120***a-h* of the cartridge **100**. The robot arm **410** the lifts the cartridge **100** off the magazine **500** and moves the cartridge **100** over to the rail system **340***a-b*.

[0091] As seen in FIGS. **26**A-E, once first exemplary cartridge **100** is placed on the rails **340***a-b* at location **2650** (shown here as an end of the row location), a push actuator **480** pushes a first cartridge **100** down the rails **340***a-b*. As best seen in FIG. **26**A, the push actuator **480** has a flat surface **485** to engage the edge of the cartridge **100**. A telescoping arm **490** extends to press the cartridge **100** down the rails **340***a-b* (FIGS. **26**B-D). As seen in FIG. **26**E, once the first cartridge **100** is in place, a second cartridge **100***b* can be lowered onto the rails **340***a-b* and pushed by the push actuator **480** along the rails **340***a-b*. The first and second cartridges **100**, **100***b* can also be pushed together along the rails **340***a-b*. In this manner, multiple cartridges **100** can be pushed simultaneously, in order to install a plurality of cartridges **100** onto the rail system **340***a-b* from an end of the row location **2650**.

[0092] In another embodiment, shown in FIGS. **27**A and **27**B, the cartridge **1500** of FIG. **15** may be mounted onto the T-shaped cartridge mounting rails **1540***a* from the end of the cartridge mounting rails **1540***a* as shown, similar to as described above with respect to FIGS. **24**A and **24**B. Once the cartridge **1500** is slid onto the end of the cartridge mounting rails **1540***a,* a push actuator **480** pushes the cartridge **1500** along the rails as shown in FIG. **24**B.

[0093] In another embodiment, the cartridge rails may be configured without the T-shape at an installation location along the cartridge mounting rails **1540***b* as is shown in FIG. **27**C. At this location along the rails, the cartridge **1500** may be lowered onto the rails as described above. Then, the push actuator **480** would slide the cartridge **1500** onto the T-shaped rails, and, from then, moved to its mounting location along the cartridge mounting rails **1540***b*. In another embodiment, shown in FIG. **27**D, the cartridge **1500***a,* shown in FIG. **17**E, could be installed onto the cartridge mounting rails **1540***c* either vertically or horizontally as discussed above. Similar to the embodiments described above, a push actuator **480** may then move the cartridge **1500***a*.

[0094] FIG. **28**A shows a side view of the cartridge **1500** of FIG. **15** mounted to the cartridge mounting rails **1540***a*. As can be seen, the arms **1538** of the struts **1522***a,b* wrap underneath T-shaped cartridge mounting rails **1540***a,* while the wheel assembly **1541** allows the cartridge **1500** to roll along the cartridge mounting rails **1540***a*. When the cartridge **1500** reaches its mounting location, fasteners **1552**, such as pins or bolts, may be inserted through mounting holes **1553** in the struts **1522***a,b* and into the cartridge mounting rails **1540***a* to secure the cartridge **1500** at its mounting location along the cartridge mounting rails **1540***a*.

[0095] As shown in a second embodiment in FIG. **28**B, a cartridge **1500***b* that utilizes struts **1522***c,d* of the kind shown in FIG. **16**C may be installed onto the T-shaped cartridge mounting rails **1540***a* in a vertical direction, similar to as shown in FIGS. **22**A-D. The cartridge **1500***b* may then roll along cartridge mounting rails **1540***a* to its mounting location. This configuration of cartridge **1500***a* has the advantage of being able to be lowered onto the cartridge mounting rails **1540***a* without having to be inserted onto the rails from the end. Similarly to the embodiment shown in FIG. **27**A, once the cartridge **1500***a* reaches its mounting location, fasteners **1552**, such as pins or bolts, are inserted through mounting holes **1553** in the struts **1522***c* and into the cartridge mounting rails **1540***a*.

[0096] In a third embodiment, shown in FIG. **28**C, a cartridge **1500***a* is configured to be installed on rectangular cross-section cartridge mounting rails **1540***c*. This cartridge **1500***a* may be installed either from the end, as described and shown with respect to cartridge **1500**, or vertically as described and shown with respect to cartridge **1500***b* of FIG. **28**B. The cartridge **1500***a* is then rolled to its mounting location, at which point fasteners **1552**, such as pins or bolts are inserted through mounting holes **1553** in the struts **1522***d* and into the cartridge mounting rails **1540***c*.

[0097] Deployment of cartridges at spaced positions along a row or at the end of each row reduces equipment and labor movement. Both rails and cartridges are designed so the cartridges can quickly be placed onto the rails and slid along the rows and moved into a final position. In this manner, each cartridge mounts one or more photovoltaic panels (e.g., one, four or eight, as shown in the Figs.) at once to a set of rails, thereby simplifying installation time and cost. A field installation **2000** is shown in FIGS. **29**A and **29**B. In such an installation, a plurality of rows of rails (e.g., **640***a-b,* **2340***a-b*) are set up, onto which cartridges (e.g., **100**, **600**, **700**, **800**, **900**, **1000**, **1100**, **1400**, **1500**, **2200**, and **2300**) can be installed in sequence, a row at a time, from spaced positions along each row. Optionally, a robotic installation system **400** can be used.

[0098] It should also be noted that the cartridges (e.g., **100**, **600**, **700**, **800**, **900**, **1000**, **1100**, **1400**, **1500**, **2200**, and **2300**) can be prewired to facilitate photovoltaic panel interconnection and the cartridges themselves can plug into one another to further reduce installation labor. It should also be noted that any other system components, such as wire harnesses, DC/DC converters, and the like could also be slid in from the ends of the rows, to further increase installation efficiency.

[0099] While embodiments have been described in detail, it should be readily understood that the invention is not limited to the disclosed embodiments. Rather the embodiments can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described. Although certain features have been described with some embodiments of the cartridge, such features can be employed in other disclosed embodiments of the cartridge as well. Accordingly, the invention is not limited by the foregoing embodiments, but is only limited by the scope of the appended claims.

What is claimed as new and desired to be protected by Letters Patent of the United States is:

1. A cartridge for mounting a plurality of photovoltaic panels thereon comprising:

a frame;

at least a first strut transversely mounted to a first side of the frame and a second side of the frame, opposite the first side,

wherein a first mounting channel is provided on one of the frame and the first strut, and a first mounting region is provided on the other of the frame and the first strut.

2. The cartridge according to claim **1**, further comprising a central beam transversely mounted to the first side of the frame and the second side of the frame,

wherein the central beam is mounted such that the first strut is provided between the central beam and a third side of the frame,

wherein a second mounting channel is provided on one of the central beam and the first strut, and a second mounting region is provided on the other of the central beam and first strut.

3. The cartridge according to claim **2**, further comprising a second strut transversely mounted to the first side of the frame and the second side of the frame, wherein the second strut is mounted such that the second strut is provided between the central beam and a fourth side of the frame,

wherein a third mounting channel is provided on one of the central beam and the second strut and a third mounting region is provided on the other of the central beam and the second strut, and

wherein a fourth mounting channel is provided on one of the frame and the second strut and a fourth mounting region is provided on the other of the frame and the second strut.

4. The cartridge according to claim **1**, wherein the frame is formed from one continuous frame blank.

5. The cartridge according to claim **1**, wherein the frame comprises:

a first side;

a second side, opposite the first side, wherein the first side and the second side are of equal lengths;

a third side;

a fourth side opposite the third side, wherein the third side and fourth side are of equal lengths.

6. The cartridge according to claim **5**, wherein the first side, second side, third side, and fourth side are of equal lengths.

7. The cartridge according to claim **1**, wherein the frame comprises a longitudinal extent and a reinforced area, wherein the reinforced area is provided along the longitudinal extent.

8. The cartridge according to claim **1**, wherein the first strut comprises a longitudinal extent and a reinforced area, wherein the reinforced area is provided along the longitudinal extent.

9. The cartridge according to claim **2**, wherein the central beam comprises a longitudinal extent and a reinforced area, wherein the reinforced area is provided along the longitudinal extent.

10. The cartridge according to claim **2**, wherein a top surface of at least one of the frame, first strut, and central beam comprise a reinforced area.

11. The cartridge according to claim **3**, wherein the first strut and the second strut are configured to attach to corresponding cartridge mounting rails associated with a support structure.

12. The cartridge according to claim **11**, wherein the frame has first and second notches corresponding to a first location and a second location where the first strut is mounted to the frame and third and fourth notches corresponding to a third location and a fourth location where the second strut is mounted to the frame, wherein the notches are configured to allow the frame to move over the cartridge mounting rails.

13. The cartridge according to claim **1**, further comprising a first photovoltaic panel mounted to the cartridge, wherein a first longitudinal side of the first photovoltaic panel is inserted into the mounting channel and a second longitudinal side of the first photovoltaic panel, opposite the first longitudinal side, rests in the mounting region.

14. The cartridge according to claim **3**, further comprising:

a first photovoltaic panel mounted to the cartridge, wherein a first longitudinal side of the first photovoltaic panel is inserted into the mounting channel and a second longitudinal side of the first photovoltaic panel, opposite the first longitudinal side, rests in the mounting region;

a second photovoltaic panel mounted to the cartridge, wherein a third longitudinal side of the second photovoltaic panel is inserted into the second mounting channel and a fourth longitudinal side of the second photovoltaic panel, opposite the third longitudinal side, rests in the second mounting region;

a third photovoltaic panel mounted to the cartridge, wherein a fifth longitudinal side of the third photovoltaic panel is inserted into the third mounting channel and a sixth longitudinal side of the third photovoltaic panel, opposite the fifth longitudinal side, rests in the third mounting region; and

a fourth photovoltaic panel mounted to the cartridge, wherein a seventh longitudinal side of the fourth photovoltaic panel is inserted into the fourth mounting channel and a eighth longitudinal side of the fourth photovoltaic panel, opposite the seventh longitudinal side, rests in the fourth mounting region.

15. The cartridge according to claim **3**, further comprising eight photovoltaic panels mounted therein.

16. The cartridge according to claim **15**, wherein:

a first longitudinal side of the first photovoltaic panel and a first longitudinal side of the second photovoltaic panel are inserted into the first mounting channel and a second longitudinal side of the first photovoltaic panel and a second longitudinal side of the second photovoltaic panel opposite their respective first longitudinal sides are secured in the first mounting region;

a first longitudinal side of the third photovoltaic panel and a first longitudinal side of the fourth photovoltaic panel are inserted into the second mounting channel and a second longitudinal side of the third photovoltaic panel and a second longitudinal side of the fourth photovoltaic panel opposite their respective first longitudinal sides are secured in the second mounting region;

a first longitudinal side of the fifth photovoltaic panel and a first longitudinal side of the sixth photovoltaic panel are inserted into the third mounting channel and a second longitudinal side of the fifth photovoltaic panel and a second longitudinal side of the sixth photovoltaic panel opposite their respective first longitudinal sides are secured in the third mounting region; and

a first longitudinal side of the seventh photovoltaic panel and a first longitudinal side of the eighth photovoltaic panel are inserted into the fourth mounting channel and a second longitudinal side of the seventh photovoltaic panel and a second longitudinal side of the eighth photovoltaic panel opposite their respective first longitudinal sides are secured in the fourth mounting region.

17. The cartridge according to claim **3**, wherein:

the first mounting region and the fourth mounting region are provided on the frame;

the first mounting channel and the second mounting channel are provided on the first strut;

the second mounting region and the third mounting region are provided on the central beam; and

the third mounting channel and the fourth mounting channel are provided on the second strut.

18. The cartridge according to claim **3**, wherein:
the first mounting channel and the fourth mounting channel are provided on the frame;
the first mounting region and the second mounting region are provided on the first strut;
the second mounting channel and the third mounting channel are provided on the central beam; and
the third mounting region and the fourth mounting region are provided on the second strut.

19. The cartridge according to claim **11**, wherein each strut is configured to move along its corresponding cartridge mounting rail.

20. The cartridge according to claim **19**, wherein each strut comprises a plurality of wheel assemblies configured to allow the cartridge to move along the cartridge mounting rails.

21. The cartridge according to claim **13**, further comprising at least one bracket for securing the first photovoltaic panel to the cartridge, wherein the at least one bracket is fastened adjacent the mounting region.

22. The cartridge according to claim **21**, wherein the at least one bracket is fastened adjacent the mounting region using at least one of screws, bolts, rivets, and welds.

23. The cartridge according to claim **1**, wherein the frame is provided a nesting channel, wherein the nesting channel is configured to allow a frame of a second cartridge to seat within the nesting channel to allow the cartridge to be stackable.

24. The cartridge according to claim **3**, wherein the central beam and struts are fastened to the frame by at least one of screws, bolts, rivets, and welds.

25. The cartridge according to claim **1**, wherein the first strut comprises a first opposed arm and a second opposed arm, wherein the first opposed arm is configured to face a first side of a mounting rail and the second opposed arm is configured to face a second side of the mounting rail opposite the first side.

26. The cartridge according to claim **1**, wherein the first strut comprises a pair of opposed arms that are configured to wrap around a T-shaped cartridge mounting rail.

27. The cartridge according to claim **25**, wherein the first strut is provided the mounting channel, and further wherein an angled portion of the first opposed arm defines a first side of the first mounting channel and is configured to allow a photovoltaic panel to be inserted into the first mounting channel at an angle.

28. The cartridge according to claim **1**, wherein the first strut is provided the first mounting channel and a second mounting channel, wherein the first mounting channel is configured to receive the first side of the photovoltaic panel and the second mounting channel is configured to receive a first side of a second photovoltaic panel.

29. The cartridge according to claim **1**, wherein the frame comprises a first height and the first strut comprises a second height less than the first height.

30. A method of constructing a cartridge for mounting a plurality of photovoltaic panels comprising:
providing a rectangular frame comprising:
a first side;
a second side, opposite the first side, wherein the first side and the second side are of equal lengths;
a third side;
a fourth side opposite the third side, wherein the third side and fourth side are of equal lengths;
transversely attaching at least a first strut to the frame, wherein the first strut is mounted to the first side of the frame and the second side of the frame;
providing a first mounting channel on one of the third side of the frame and the first strut;
providing a first mounting region on the other of the third side of the frame and the first strut, wherein a photovoltaic panel is mountable to the cartridge by inserting a first longitudinal side of the photovoltaic panel into the first mounting channel and securing a second longitudinal side of the photovoltaic panel to the first mounting region.

31. The method of claim **30**, further comprising:
providing a frame blank; and
bending the frame blank to form the rectangular frame.

32. The method of claim **30**, further comprising transversely attaching a second strut to the first side and the second side of the frame.

33. The method of claim **32**, further comprising transversely attaching a central beam to the frame, wherein the central beam is positioned between the first and second struts

34. The method according to claim **30**, further comprising inserting a photovoltaic panel into the first mounting channel.

35. The method according to claim **34**, wherein the photovoltaic panel is inserted into the first mounting channel at an angle of between approximately 30° and approximately 60°.

36. The method according to claim **34**, further comprising seating the photovoltaic panel into the first mounting region.

37. The method according to claim **33**, further comprising inserting a first side of a photovoltaic panel into a second mounting channel provided on one of the central beam and the first strut.

38. The method according to claim **37**, further comprising seating a second side of the photovoltaic panel opposite the first side into a second mounting region provided on the other of the central beam and the first strut.

39. The method according to claim **36**, further comprising fastening at least one bracket adjacent to the first mounting region in order to secure the photovoltaic panel to the cartridge.

40. The method according to claim **30**, wherein the first strut is attached to the frame by at least one of screws, bolts, rivets, and welds.

41. The method according to claim **33**, wherein the central beam is attached to the frame by at least one of screws, bolts, rivets, and welds.

42. The method according to claim **30**, further comprising notching the frame blank to allow the cartridge to travel along at least one cartridge mounting rail.

43. The method according to claim **42**, wherein the first strut is attached in alignment with the notches.

44. The method according to claim **31**, further comprising forming bend notches in the frame blank to allow the frame blank to be bent to form the frame.

45. The method according to claim **44**, further comprising welding a first end of the frame blank to a second end of the frame blank to form the rectangular frame.

46. A method of installing a cartridge for mounting photovoltaic panels onto a support structure comprising:
providing a cartridge comprising:
a frame comprising:
a first side;
a second side, opposite the first side, wherein the first side and the second side are of equal lengths;

a third side;
a fourth side opposite the third side, wherein the third side and fourth side are of equal lengths.
a first strut and second strut transversely mounted to the first side and the second side of the frame;
wherein a photovoltaic panel is mountable to the cartridge by inserting a first side of the photovoltaic panel into a first mounting channel provided on one of the first strut and the frame and securing a second side of the photovoltaic panel to a first mounting region provided on the other of the frame and the first strut;
affixing said first strut to a first cartridge mounting rail;
affixing said second strut to a second cartridge mounting rail;
sliding said cartridge to a mounting location along said cartridge mounting rails.

47. The method according to claim **46**, wherein said affixing step is accomplished by lowering said cartridge onto said cartridge mounting rail in a vertical direction.

48. The method according to claim **46**, wherein said affixing step is accomplished by sliding said cartridge onto said cartridge mounting rail in a horizontal direction.

49. The method according to claim **46**, further comprising inserting a fastener through said first strut and into said first cartridge mounting rail to secure the cartridge at the mounting location.

50. The method according to claim **46**, wherein said cartridge mounting rails have a T-shaped cross section.

51. The method according to claim **46**, wherein said cartridge mounting rails have a rectangular cross section.

52. The method according to claim **50**, wherein the struts comprise opposed arms that are configured to wrap around the top of the T-shaped cartridge mounting rails.

53. The method according to claim **50**, wherein the struts comprise opposed arms that define a generally U-shaped cross section.

54. The method according to claim **50**, wherein the struts comprise a plurality of wheel assemblies that permit the cartridge to roll along the cartridge mounting rails.

55. A system for transporting a plurality of cartridges for mounting photovoltaic panels comprising:
a first cartridge comprising:
a first frame comprising:
a first side;
a second side, opposite the first side, wherein the first side and the second side are of equal lengths;
a third side;
a fourth side opposite the third side, wherein the third side and fourth side are of equal lengths;
a nesting channel formed along the first, second, third, and fourth sides of the frame;
a first strut transversely mounted to the first side and the second side of the frame;
wherein a first mounting channel is provided on one of the first strut and the first frame, and a first mounting region is provided on the other of the first frame and the first strut; and
a second cartridge comprising:
a second frame comprising:
a fifth side;
a sixth side, opposite the fifth side, wherein the fifth side and the sixth side are of equal lengths;
a seventh side;
a eighth side opposite the seventh side, wherein the seventh side and eighth side are of equal lengths.
a second strut transversely mounted to the fifth side and the sixth side of the frame;
wherein a second mounting channel is provided on one of the second strut and the second frame, and a second mounting region is provided on the other of the second frame and the second strut;
wherein the second frame is configured to seat onto the nesting channel of the first frame to facilitate stacking of the first and second cartridges.

56. The system of claim **55**, wherein the fifth, sixth, seventh, and eighth sides of the second frame comprise longitudinal extents with a reinforced area provided along the longitudinal extents of each of the sides.

57. The system of claim **56**, wherein the reinforced area is provided along a bottom portion of the fifth, sixth, seventh, and eighth sides of the second frame and is configured to seat onto the nesting channel of the first frame.

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