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(54) Title: PREFABRICATED BUILDING SYSTEMS WITH BUILT-UP STRUCTURAL ELEMENTS

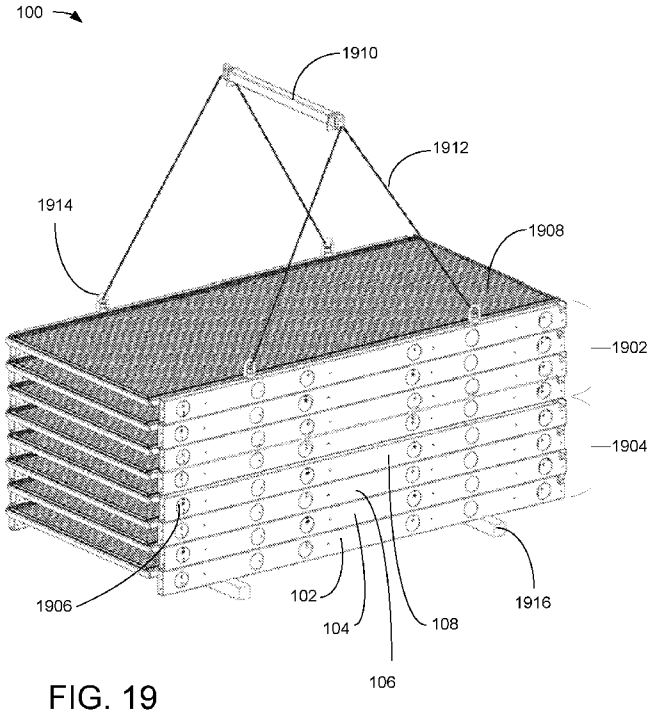

FIG. 19

(57) Abstract: A built-up structural element includes a pair of steel hollow structural sections, each having a hollow and generally rectangular cross-sectional shape, a plurality of openings, and a plurality of bolt holes distinct from the openings, wherein the steel hollow structural sections are stacked together in a stacked configuration, and a plurality of bolts extending through the plurality of bolt holes and securing the pair of steel hollow structural sections together in the stacked configuration. A built-up structural element includes a pair of steel hollow structural sections, each having a hollow and generally rectangular cross-sectional shape, a plurality of openings, and a plurality of bolt holes distinct from the openings, wherein the steel hollow structural sections are coupled to one another using a plurality of bolts extending through the plurality of bolt holes.

[Continued on next page]

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PREFABRICATED BUILDING SYSTEMS WITH BUILT-UP STRUCTURAL ELEMENTS

BACKGROUND

Technical Field

The present disclosure relates to prefabricated building systems, including built-up structural components of prefabricated building systems.

The present disclosure also relates to rapidly-deployable rugged building structures, including light-weight foldable prefabricated building frames. The present disclosure also relates to foldable sectional frames having tubular columns and rafters of generally rectangular cross-section and having castellated holes on opposing long sides of the rectangular tubular beams.

Description of the Related Art

A wide variety of prefabricated building systems are commercially available. Nevertheless, there is room for improvement in the strength, durability, and efficiency of such systems. There is also room for improvement in terms of modularization and transportability of such systems.

A wide variety of structural components are commercially available for use as columns, beams, girders, joists, and other similar structural elements. Such products can be made from a wide variety of materials, including wood or other natural materials, steel, aluminum, or other metallic materials, or plastic, polymeric, or other materials. Standardized structural steel components, as one example, have traditionally been fabricated in the form of an elongated beam having a constant profile or cross-sectional shape along its length. Such components can be advantageous because they can be fabricated consistently and repeatedly relatively efficiently, such as by well-established hot and/or cold rolling processes.

Such standardized structural steel components suffer from drawbacks, however, in that their standardization limits the degree to which they can be customized. Therefore, efforts have continued to be made to provide structural steel components that are tailored, and therefore more efficient, for specific use cases. Built-up steel components, which include a plurality of individual steel elements coupled to one another, such as by welding or riveting, represent one type of such efforts.

BRIEF SUMMARY

A method of fabricating a built-up structural element may be summarized as comprising: obtaining a pair of steel hollow structural sections, each steel hollow structural section having a uniform cross-sectional profile over an entirety of a longitudinal length thereof; for each of the pair of steel hollow structural sections, cutting a plurality of openings in the steel hollow structural section to vary the cross-sectional profile of the steel hollow structural section over the longitudinal length thereof; for each of the pair of steel hollow structural sections, cutting a plurality of bolt holes distinct from the plurality of openings in the steel hollow structural section along the longitudinal length thereof; stacking the pair of steel hollow structural sections together to form a stacked configuration in which the plurality of bolt holes of each steel hollow structural section align with each other; and bolting the pair of steel hollow structural sections together via the plurality of bolt holes to secure the pair of steel hollow structural sections together in the stacked configuration.

The method may further comprise: obtaining a complementary pair of steel hollow structural sections, each of the complementary pair of steel hollow structural sections having a uniform cross-sectional profile over an entirety of a longitudinal length thereof; for each of the complementary pair of steel hollow structural sections, cutting a plurality of openings in the steel hollow structural section to vary the cross-sectional profile of the steel hollow structural section over the longitudinal length thereof; for each of the complementary pair of steel hollow structural sections, cutting a plurality of bolt holes distinct from the plurality of openings in the steel hollow structural section along the longitudinal length thereof; stacking the complementary pair of steel hollow structural sections together to form a stacked configuration in which the plurality of bolt holes of each of the complementary pair of steel hollow structural sections align with each other; bolting the complementary pair of steel hollow structural sections together via the plurality of bolt holes to secure the complementary pair of steel hollow structural sections together in the stacked configuration; and coupling the pair of steel hollow structural sections in the stacked configuration to the complementary pair of steel hollow structural sections in the stacked configuration via one or more spanning members.

The one or more spanning members may include cladding and/or struts. The method may further comprise, after fabricating the built-up structural element, using the fabricated built-up structural element to fabricate a sectional foldable prefabricated building. Bolting the pair of steel hollow structural sections together via the plurality of bolt holes may include using the openings to access the bolt holes.

A built-up structural element may be summarized as comprising: a pair of steel hollow structural sections, each having a hollow and generally rectangular cross-sectional shape, a plurality of openings, and a plurality of bolt holes distinct from the openings, wherein the steel hollow structural sections are stacked together in a stacked configuration; and a plurality of bolts extending through the plurality of bolt holes and securing the pair of steel hollow structural sections together in the stacked configuration.

The built-up structural element may further comprise: a pair of complementary steel hollow structural sections, each having a hollow and generally rectangular cross-sectional shape, a plurality of openings, and a plurality of bolt holes distinct from the openings, and wherein the complementary steel hollow structural sections are stacked together in a stacked configuration; a plurality of bolts extending through the plurality of bolt holes and securing the complementary pair of steel hollow structural sections together in the stacked configuration; and one or more spanning members extending between the pair of steel hollow structural sections and the pair of complementary steel hollow structural sections.

The built-up structural element may be symmetrical. The built-up structural element may be a component of a sectional foldable prefabricated building. The built-up structural element may be a wall frame of a sectional foldable prefabricated building. The steel hollow structural sections may be columns of a sectional foldable prefabricated building. The built-up structural element may be a roof frame of a sectional foldable prefabricated building. The steel hollow structural sections may be beams of a sectional foldable prefabricated building.

A method of fabricating a building may be summarized as comprising: fabricating a first steel hollow structural section; fabricating a second steel hollow structural section; coupling the first and second steel hollow structural sections to one another via one or more spanning members to form a first structural assembly; shipping the first structural assembly to an installation location in a first package; fabricating a third steel hollow structural section; fabricating a fourth steel hollow structural section; shipping the third and fourth steel hollow structural sections to the installation location in a second package distinct from the first package; stacking the first and third steel hollow structural sections together at the installation location; bolting the first and third steel hollow structural sections together at the installation location; stacking the second and fourth steel hollow structural sections together at the installation location; and bolting the second and fourth steel hollow structural sections together at the installation location. The one or more spanning members may include cladding.

The method may further comprise: fabricating a fifth steel hollow structural section; fabricating a sixth steel hollow structural section; coupling the fifth and sixth steel hollow

structural sections to one another via spanning members to form a second structural assembly; shipping the second structural assembly to the installation location in the first package; fabricating a seventh steel hollow structural section; fabricating an eighth steel hollow structural section; shipping the seventh and eighth steel hollow structural sections to the installation location in the second package; stacking the fifth and seventh steel hollow structural sections together at the installation location; bolting the fifth and seventh steel hollow structural sections together at the installation location; stacking the sixth and eighth steel hollow structural sections together at the installation location; and bolting the sixth and eighth steel hollow structural sections together at the installation location. The spanning members may include cladding.

A method of fabricating a built-up structural element may be summarized as comprising: obtaining a pair of steel hollow structural sections, each steel hollow structural section having a uniform cross-sectional profile over an entirety of a longitudinal length thereof; for each of the pair of steel hollow structural sections, cutting a plurality of openings in the steel hollow structural section to vary the cross-sectional profile of the steel hollow structural section over the longitudinal length thereof; for each of the pair of steel hollow structural sections, cutting a plurality of bolt holes distinct from the plurality of openings in the steel hollow structural section along the longitudinal length thereof; and coupling the pair of steel hollow structural sections together using a plurality of bolts extending through the bolt holes.

Coupling the pair of steel hollow structural sections together may include bolting a first one of the pair of steel hollow structural sections to infill framing and bolting a second one of the pair of steel hollow structural sections to the infill framing. The method may further comprise: obtaining a complementary pair of steel hollow structural sections, each of the complementary pair of steel hollow structural sections having a uniform cross-sectional profile over an entirety of a longitudinal length thereof; for each of the complementary pair of steel hollow structural sections, cutting a plurality of openings in the steel hollow structural section to vary the cross-sectional profile of the steel hollow structural section over the longitudinal length thereof; for each of the complementary pair of steel hollow structural sections, cutting a plurality of bolt holes distinct from the plurality of openings in the steel hollow structural section along the longitudinal length thereof; coupling the complementary pair of steel hollow structural sections together using a plurality of bolts extending through the bolt holes; and coupling the pair of steel hollow structural sections to the complementary pair of steel hollow structural sections via one or more spanning members. Coupling the pair of steel hollow structural sections together may include bolting a first one of the pair of steel hollow structural sections to a first set of infill framing and bolting a second one of the pair of steel hollow structural sections to the first set of

infill framing; and coupling the complementary pair of steel hollow structural sections together may include bolting a first one of the complementary pair of steel hollow structural sections to a second set of infill framing and bolting a second one of the complementary pair of steel hollow structural sections to the second set of infill framing. The one or more spanning members may include cladding and/or struts. Coupling the pair of steel hollow structural sections to the complementary pair of steel hollow structural sections via one or more spanning members may include: coupling a first one of the pair of steel hollow structural sections to a first one of the complementary pair of steel hollow structural sections via one or more first spanning members; and coupling a second one of the pair of steel hollow structural sections to a second one of the complementary pair of steel hollow structural sections via one or more second spanning members. Coupling the pair of steel hollow structural sections together may include using the openings to access the bolt holes.

A built-up structural element may be summarized as comprising: a pair of steel hollow structural sections, each having a hollow and generally rectangular cross-sectional shape, a plurality of openings, and a plurality of bolt holes distinct from the openings; and a plurality of bolts extending through the plurality of bolt holes and securing the pair of steel hollow structural sections together.

The built-up structural element may further comprise: infill framing; wherein a first one of the pair of steel hollow structural sections is bolted to the infill framing and a second one of the pair of steel hollow structural sections is bolted to the infill framing. The built-up structural element may further comprise: a pair of complementary steel hollow structural sections, each having a hollow and generally rectangular cross-sectional shape, a plurality of openings, and a plurality of bolt holes distinct from the openings; a plurality of bolts extending through the plurality of bolt holes and securing the complementary pair of steel hollow structural sections together; and one or more spanning members extending between the pair of steel hollow structural sections and the pair of complementary steel hollow structural sections.

The built-up structural element may further comprise: a first set of infill framing; wherein a first one of the pair of steel hollow structural sections is bolted to the first set of infill framing and a second one of the pair of steel hollow structural sections is bolted to the first set of infill framing; and a second set of infill framing; wherein a first one of the complementary pair of steel hollow structural sections is bolted to the second set of infill framing and a second one of the complementary pair of steel hollow structural sections is bolted to the second set of infill framing. The one or more spanning members may include: first spanning members that couple a first one of the pair of steel hollow structural sections to a first one of the complementary pair of

steel hollow structural sections; and second spanning members that couple a second one of the pair of steel hollow structural sections to a second one of the complementary pair of steel hollow structural sections.

A method of fabricating a building may be summarized as comprising: fabricating a first steel hollow structural section; fabricating a second steel hollow structural section; coupling the first and second steel hollow structural sections to one another via one or more spanning members to form a first structural assembly; shipping the first structural assembly to an installation location in a first package; fabricating a third steel hollow structural section; fabricating a fourth steel hollow structural section; shipping the third and fourth steel hollow structural sections to the installation location in a second package distinct from the first package; coupling the first and third steel hollow structural sections together at the installation location using bolts; and coupling the second and fourth steel hollow structural sections together at the installation location using bolts.

The one or more spanning members may include cladding. The method may further comprise: prior to shipping the third and fourth steel hollow structural sections to the installation location in a second package distinct from the first package, coupling the third and fourth steel hollow structural sections to one another via one or more additional spanning members to form a second structural assembly. Coupling the first and third steel hollow structural sections together at the installation location using bolts may include bolting the first steel hollow structural section to infill framing and bolting the second steel hollow structural section to the infill framing. Coupling the first and third steel hollow structural sections together at the installation location using bolts may include bolting the first steel hollow structural section to a first set of infill framing and bolting the third steel hollow structural section to the first set of infill framing; and coupling the second and fourth steel hollow structural sections together at the installation location using bolts may include bolting the second steel hollow structural section to a second set of infill framing and bolting the fourth steel hollow structural section to the second set of infill framing.

The method may further comprise: fabricating a fifth steel hollow structural section; fabricating a sixth steel hollow structural section; coupling the fifth and sixth steel hollow structural sections to one another via spanning members to form a second structural assembly; shipping the second structural assembly to the installation location in the first package; fabricating a seventh steel hollow structural section; fabricating an eighth steel hollow structural section; shipping the seventh and eighth steel hollow structural sections to the installation location in the second package; coupling the fifth and seventh steel hollow structural sections

together at the installation location using bolts; and coupling the sixth and eighth steel hollow structural sections together at the installation location using bolts. The spanning members may include cladding.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Figure 1 illustrates a perspective view of a foldable prefabricated building section frame.

Figure 2 illustrates a front view of the frame of Figure 1.

Figure 3 illustrates an interior elevation view of the frame of Figure 1.

Figure 4 illustrates a top view of the frame of Figure 1.

Figure 5 illustrates a side view of the frame of Figure 1.

Figure 6 illustrates a cross-sectional view, through a portion of section AA-AA illustrated in Figure 5, of a bottom portion of a column of the frame of Figure 1.

Figure 7 illustrates a cross-sectional view, through section BB-BB illustrated in Figure 5, of a portion of the frame of Figure 1.

Figure 8 illustrates a cross-sectional view, through section CC-CC illustrated in Figure 5, of a portion of the frame of Figure 1.

Figure 9 illustrates a cross-sectional view, through section DD-DD illustrated in Figure 5, of a first embodiment of a base plate and a girt of the frame of Figure 1.

Figure 10 illustrates a cross-sectional view, through section DD-DD illustrated in Figure 5, of a second embodiment of a base plate and a girt of the frame of Figure 1.

Figure 11 illustrates an elevation view of a roof ridge of the frame of Figure 1.

Figure 12 illustrates an interior elevation view of a roof ridge of the frame of Figure 1.

Figure 13 illustrates an interior elevation view of a haunch brace of the frame of Figure 1.

Figure 14 illustrates an interior elevation view of a ridge brace of the frame of Figure 1.

Figure 15 illustrates a haunch plate of the frame of Figure 1.

Figure 16 illustrates a haunch plate of the frame of Figure 1.

Figure 17 illustrates a perspective view of a first embodiment of a base plate engaged with a bottom end of a column of the frame of Figure 1.

Figure 18 illustrates a perspective view of a second embodiment of a base plate engaged with a bottom end of a column of the frame of Figure 1.

Figure 19 illustrates a perspective view of a stack of components configured for assembly into two of the frames of Figure 1.

Figure 20 illustrates a perspective view of a built-up structural element.

Figure 21 illustrates a perspective view of the built-up structural element of Figure 20 with components thereof removed to illustrate other features of the structural element.

Figure 22 illustrates a different perspective view of components of the built-up structural element of Figure 20 at a larger scale to illustrate other features of the structural element.

Figure 23 illustrates a perspective view of the built-up structural element of Figure 20 with components thereof removed to illustrate other features of the structural element.

Figure 24 illustrates a perspective view of the built-up structural element of Figure 20 with additional components thereof removed to illustrate other features of the structural element.

Figure 25 illustrates a perspective view of the built-up structural element of Figure 20 with components thereof removed to illustrate other features of the structural element.

Figure 26 illustrates a perspective view of the built-up structural element of Figure 20 with additional components thereof removed to illustrate other features of the structural element.

Figure 27 illustrates a first view of a first hollow steel section or hollow structural section (HSS) portion of the built-up structural element of Figure 20.

Figure 28 illustrates a second view of the first hollow steel section or hollow structural section (HSS) portion of Figure 27.

Figure 29 illustrates a third view of the first hollow steel section or hollow structural section (HSS) portion of Figure 27.

Figure 30 illustrates a first view of a second hollow steel section or hollow structural section (HSS) portion of the built-up structural element of Figure 20.

Figure 31 illustrates a second view of the second hollow steel section or hollow structural section (HSS) portion of Figure 30.

Figure 32 illustrates a third view of the second hollow steel section or hollow structural section (HSS) portion of Figure 30.

Figure 33 illustrates a bolt assembly, a plurality of which can be used to couple the components of the built-up structural element of Figure 20 to one another.

Figure 34 illustrates a building.

Figure 35 illustrates a section of the building of Figure 34.

Figure 36 illustrates a section of a building corresponding to that of Figure 35.

Figure 37 illustrates a side view of the building section of Figure 36.

Figure 38 illustrates a perspective view of the building section of Figure 36.

Figure 39 illustrates an exterior panel portion of the building section of Figure 36.

Figure 40 illustrates a truss portion of the building section of Figure 36.

Figure 41 illustrates an exterior panel portion of the building section of Figure 36.

Figure 42 illustrates a truss portion of the building section of Figure 36.

Figure 43 illustrates a portion of the exterior panel portion of Figure 41.

Figure 44 illustrates a portion of the exterior panel portion of Figure 41.

Figure 45 illustrates a portion of the exterior panel portion of Figure 41.

Figure 46 illustrates a portion of the exterior panel portion of Figure 41.

DETAILED DESCRIPTION

In the following description, certain specific details are set forth in order to provide a thorough understanding of various disclosed embodiments. However, one skilled in the relevant art will recognize that embodiments may be practiced without one or more of these specific details, or with other methods, components, materials, etc. In other instances, well-known structures associated with the technology have not been shown or described in detail to avoid unnecessarily obscuring descriptions of the embodiments.

Figure 1 is a perspective view illustrating a foldable prefabricated building section frame 100. The improved foldable prefabricated building section frame 100 includes a first wall frame 102, a first roof frame 104, a second roof frame 106, and a second wall frame 108, sequentially connected by means which can secure the frame in the folded or in the erected configuration, as shown. First wall frame 102 includes two opposed spaced apart parallel columns 110 and 112 connected by four bolted-on girts 114. Column 110 has castellated holes 116, 118, 166, and 168 on the exterior side for providing weight reduction and tool access, and which provide fastener access for securing the girts 114. Each castellated hole 116, 118, 166, and 168 has a substantially circular perimeter and a flat side that is a chord of the substantially circular perimeter. The flat side is oriented parallel to a long side of the column 110 or 112, and is the same for rafters 124, 126, 144, and 146. Column 112 has castellated holes 120 on its interior side that are not aligned to the castellated holes 116, 118, 166, and 168 of column 110. Castellated holes 116, 118, 166, and 168 are generally aligned in a linear array on each wide side of each column 110 and 112 and each wide side of each rafter 144 and 146. In various embodiments, the array is not linear.

First roof frame 104 includes two opposed spaced apart parallel rafters 124 and 126. The tops of columns 110 and 112 are connected to rafters 124 and 126, respectively. Rafters 124 and 126 are connected by bolted-on purlins 164 and 131. Haunch braces 122 and 134 provide additional stabilization of the structure by rigidly extending from column 110 to rafter 124 and from column 112 to rafter 126, respectively. Rafter 124 illustrates exterior castellated holes 128. Rafter 126 illustrates interior castellated holes 132.

Second roof frame 106 includes two opposed spaced apart parallel rafters 144 and 146 that are connected to rafters 124 and 126, respectively, via ridge plates 136 and 138, respectively. Ridge brace 142 further stabilizes the rafters 124 and 146, while ridge brace 140 stabilizes the rafters 126 and 144. Rafters 144 and 146 are connected by bolted-on purlins 162 and 154. Rafter 146 shows exterior castellated holes 160. Rafter 144 shows interior castellated holes 148.

Second wall frame 108 includes two opposed spaced apart parallel columns 164 and 170 connected by four bolted-on girts 158. Rafters 146 and 144 connect to columns 164 and 170. Haunch brace 152 stabilizes the joint between rafter 146 and column 164 while haunch brace 150 stabilizes the joint between rafter 144 and column 170.

Ridge plates 136 and 138 allow the roof frames 104 and 106 to fold for transport with the top sides of the rafters 124 and 126 to abut top sides of rafters 146 and 144, respectively. Corner joints allow the wall frames 102 and 108 to fold to abut their interior surfaces to undersides of roof frames 104 and 106, respectively.

In additional embodiments, more or fewer purlins and girts may be used and more or fewer castellated holes may be used. The lengths of the columns and the lengths of the rafters may be approximately equal to provide best storage and shipping efficiency. The castellated holes have the benefit of reducing weight of the frame 100 without substantially reducing the strength. The castellated holes also assist in ease of manufacture, and therefore, reduced labor costs. The castellated holes also provide tool access for fastening frames 100 together, side-by-side, to form a building frame.

Figure 2 illustrates a front elevation view of the improved foldable prefabricated building section frame 100. Castellated holes 202 and 204 provide fastener tool operation access for securing bolted-on purlins 131 and 162.

Figure 3 illustrates an interior elevation view of the improved foldable prefabricated building section frame 100. Haunch plate bolts 302 connecting column 112 to rafter 126 are illustrated in Figure 3. Haunch plate bolts 304 connecting column 170 to rafter 144 are also illustrated in Figure 3. Interior castellated holes 306 and 310 are also illustrated in Figure 3. Girt ends 308 and 326 in column 112 provide connectivity for the girts 114.

Ridge brace 140 is shown in three sections: first end section 312, second end section 316, and a middle section, which may be a sleeve 314. Girt ends 318 and 158 and castellated hole 320 in column 170 are illustrated in Figure 3.

Figure 4 illustrates a top plan view of the foldable prefabricated building section frame 100. A different perspective on the girt ends 130 is shown in Figure 4. The position of the ridge plates 136 and 138 on the interior surfaces of rafters is also shown in Figure 4.

Figure 5 illustrates a side elevation or end view of the improved foldable prefabricated building section frame 100. Girts 114 are bolted into the columns 110 and 112 and purlins 131 are bolted into the rafters 124 and 126. Haunch brace 134 is secured to column 112 via bolts 502. Haunch brace 122 is secured to column 110 via bolts 504.

Figure 6 illustrates a detailed longitudinal cross-section, taken along section AA-AA illustrated in Figure 5, of a bottom portion of a column of the improved foldable prefabricated building section frame 100. Base plate 602 rests on a concrete footing 610, and is bolted into that concrete footing 610 by bolts 612. Vertical base plate flange 604 is bolted by bolts 606 to the interior surface 618 the column (e.g., column 110). Bolts 608 hold a girt 114 in place. Holes 614 and 616 are for packaging.

Figure 7 illustrates a cross-sectional view, taken along section BB-BB illustrated in Figure 5, of the improved foldable prefabricated building section frame 100. The cross-section of the column 110 is the same for all columns and slightly larger than for rafters.

Figure 8 illustrates a cross-sectional view, taken along section CC-CC illustrated in Figure 5, of the improved foldable prefabricated building section frame 100. Figure 8 illustrates castellated hole 166 and girt 114. Girt bolt heads 802 are illustrated in Figure 8.

Figure 9 illustrates a cross-sectional view, taken along line DD-DD in Figure 5 and through column 110, of a first base plate 602 and a girt 114 of the improved foldable prefabricated building section frame 100. Baseplate 602 extends underneath column 110. The external portion of base plate 602 has an outer vertical flange 902 and an inner vertical flange 620 guarding bolts 904 that extend through baseplate 602 and into concrete footing 610 (see Figure 6). Inner vertical flange 620 is bolted to column 110 via bolt 918 and nut 914 and to interior vertical flange 910 by bolts 908 and 918 with nuts 906 and 914, respectively. The internal portion of base plate 602 has the interior vertical flange 910 and an opposed vertical flange 604 guarding bolts 612 that extend through baseplate 602 and into concrete footing 610 (see Figure 6). Interior vertical flange 910 abuts an internal surface of column 110. Opposed vertical flange 604 abuts an opposing inner surface 618 of column 110. Opposed vertical flange 604 is bolted to column 110 via bolts 606. Girt 114 is bolted to column 110 via bolts 608.

Figure 10 illustrates a cross-sectional view, taken along line DD-DD in Figure 5 and through column 110, of a second base plate 1004 and a girt 114 of the improved foldable prefabricated building section frame 100. Base plate 1004 extends underneath a portion of column 110 and has four vertical flanges 1006, 1008, 1014, and 1016 extending therefrom. External portion 1002 of baseplate 1004 supports opposed spaced apart vertical flanges 1006 and 1008 guarding bolts 1010 that extend through base plate 1004 and into a concrete footing.

Vertical flange 1014 abuts an inside surface 618 of column 110 and vertical flange 1016 abuts an opposing inside surface 618 of column 110. Vertical flanges 1014 and 1016 have beveled top edges to assist in sliding column 110 down onto baseplate 1004 during building construction. Bolts 1020 and 1012 extend through baseplate 1004 and into concrete footing 610. The concrete footing 610 may be, in some cases, a concrete slab large enough to support all columns and, in other cases, may be discrete footings, as needed. Bolt 1018 fastens column 110 to baseplate 1004 via vertical flange 1016. Bolts 608 fasten girt 114 to column 110.

Figure 11 illustrates an exterior elevation view of a roof ridge 1104 of the improved foldable prefabricated building section frame 110. Ridge brace sleeve 314 has two fasteners 1102 and 1104, to secure the ridge brace 142 in place during construction. Ridge plate 136 has two holes 1108 for receiving lifting apparatus during erection of the frame 100.

Figure 12 illustrates an interior elevation view of a roof ridge 1106 of the improved foldable prefabricated building section frame 100. Bolts 1206 and 1208 are loosened, with bolts 1202 and 1204 removed, to pivot rafters 144 and 124 during storage and transportation. Once erected by lifting using holes 1210 and 1108 and a lifting apparatus, bolts 1202 and 1204 are inserted, and all bolts 1202, 1204, 1206, and 1208 are tightened.

Purlin end 1224 has flanges 1212 with fastener openings for four bolts 1214. Purlin end 1226 has opposing flanges 1218 with fastener openings for four bolts 1220.

Figure 13 illustrates an interior elevation view of the haunch brace 134 of the improved foldable prefabricated building section frame 100. Haunch brace 134 is disconnected during shipping and then secured to column 112 by two bolts 502 during erection of the frame 100.

Figure 14 illustrates an interior elevation view of the ridge brace of the improved foldable prefabricated building section frame 100. The first ridge brace end section 312 is secured to rafter 126 using two bolts 1402. During building construction one bolt 1402 is used as a pivot and the same is done with second ridge brace end section 316. When the walls and roof panels are properly positioned, the sleeve 314, riding on one of the ridge brace end sections 312 or 316, is slid into position, and all ridge brace bolts 1402 are fastened.

Figure 15 illustrates a longitudinal cross-sectional view of the haunch plate 304 of the improved foldable prefabricated building section frame 100. Haunch plate 304 is fastened against the interior surface 1512 of tubular rafter 144 via three bolts 1504 and is fastened against the interior surface 1510 of tubular column 170 via four bolts 1502. Haunch plate 304 has openings for seven bolts 1502 and 1504. One of the bolts 1504 and one of the bolts 1502 are used as pivot points during transport and erection of the building, with the other five bolts

omitted until the wall and roof panels are correctly positioned. Openings 1506 are for securing bolted-on purlin 154. Bolts 1508 secure the top girt 158.

Figure 16 illustrates a side view of the haunch plate 304 of the improved foldable prefabricated building section frame 100. The open end of tubular rafter 144 provides tool access to secure the haunch plate 304.

Figure 17 illustrates a perspective view of a first base plate 602 engaged to a first bottom end of the column 110 of the improved foldable prefabricated building section frame 100. Bight 1706 provides tool access to connect column 110 to baseplate 602. Bolt 914 has a long shaft 1704 to serve as an anchor bolt 914. Opening 1702 may be used to connect a second column, installed immediately beside column 110 to vertical flange 902 with bolt 918 doing double duty to connect the second column to vertical flange 620 and to column 110.

Figure 18 illustrates a perspective view of a second base plate 1004 engaged to a second bottom end of the column 110 of the improved foldable prefabricated building section frame 100. Anchor bolt 1010 has a long shaft 1802, as do all of the anchor bolts described herein. Vertical flanges 1006 and 1008 may be used to receive a second column at a right angle to column 110 and to secure that second column to baseplate 1004.

Figure 19 illustrates a perspective view of a shipping stack of two of the improved foldable prefabricated building section frames 100, with panels 1908 installed. Foldable building sections 1902 and 1904 are held together via packaging bolts 1906 and are lifted by a crane using a spreader bar 1910, cables 1912, and attachment hardware 1914. Dunnage 1916 provides access to fork lifts.

Figure 20 illustrates a perspective view of a built-up structural element 2000, which can be comparable to, and which can replace, the first wall frame 102. Thus, the built-up structural element 2000 can be oriented, in use, vertically, and can function as a structural column. As illustrated in Figure 20, the built-up structural element 2000 includes a first individual built-up beam or column 2002, which may be comparable to the column 110, a second individual built-up beam or column 2004, which may be comparable to the column 112, and cladding 2006, which may cover an exterior surface of the built-up structural element 2000. As also illustrated in Figure 20, the built-up structural element 2000 includes a central longitudinal axis 2008 that extends along a length of the built-up structural element 2000, in a direction parallel to lengths of the first and second columns 2002 and 2004, and in a direction perpendicular to a rectangular inner profile of the built-up structural element 2000 defined by an inner surface of each of the first and second columns 2002, 2004, and the cladding 2006. Figure 21 illustrates the same perspective view of the built-up structural element 2000 as in Figure 20 with the cladding 2006

removed to reveal a plurality of struts 2010, which can be comparable to and can replace the girts 114. Figure 22 illustrates a different perspective view of some features of the built-up structural element 2000 at a larger scale.

Figure 23 illustrates the same perspective view of the built-up structural element 2000 as in Figures 20 and 21, with the cladding 2006 and struts 2010 removed. As illustrated in Figure 23, the first column 2002 and the second column 2004 are each built-up columns including respective first and second individual column elements. In particular, the first built-up column 2002 includes a respective first individual column element 2002a, which may be an outer individual column element 2002a, in the sense that it carries the cladding 2006 or the cladding 2006 is directly coupled to it. The first built-up column 2002 also includes a respective second individual column element 2002b, which may be an inner individual column element 2002b, in the sense that it does not carry the cladding 2006 or the cladding 2006 is not directly coupled to it. When a building is fully assembled and in use, the outer individual column element 2002a is located outside of the inner individual column element 2002b, in the sense that the outer individual column element 2002a is closer to an external environment surrounding the building and the inner individual column element 2002b is closer to the inner environment within the building.

Similarly, the second built-up column 2004 includes a respective first individual column element 2004a, which may be an outer individual column element 2004a, in the sense that it carries the cladding 2006 or the cladding 2006 is directly coupled to it. The second built-up column 2004 also includes a respective second individual column element 2004b, which may be an inner individual column element 2004b, in the sense that it does not carry the cladding 2006 or the cladding 2006 is not directly coupled to it. When a building is fully assembled and in use, the outer individual column element 2004a is located outside of the inner individual column element 2004b, in the sense that the outer individual column element 2004a is closer to an external environment surrounding the building and the inner individual column element 2004b is closer to the inner environment within the building.

In some embodiments, the first built-up column 2002 and the second built-up column 2004 can be mirror images of one another. Specifically, the first built-up column 2002 can be a mirror image of the second built-up column 2004 across a plane that includes the central longitudinal axis 2008 and that extends directly inward and outward, that is, outward toward the external environment surrounding the building and inward toward the inner environment within the building. That is, such a plane extends perpendicular to an axis extending directly from the first built-up column 2002 to the second built-up column 2004.

Figure 24 illustrates the same perspective view of the same components as in Figure 23, but with the first and second outer individual column elements 2002a and 2004a removed, to illustrate additional features of the first and second inner individual column elements 2002b and 2004b. Figure 25 illustrates a different perspective view of the same components as in Figure 23. Figure 26 illustrates the same perspective view of the same components as in Figure 25, but with the first and second inner individual column elements 2002b and 2004b removed, to illustrate additional features of the first and second outer individual column elements 2002a and 2004a.

As illustrated in Figures 24 and 26 in particular, each of the first and second outer individual column elements 2002a and 2004a and the first and second inner individual column elements 2002b and 2004b can comprise a metallic, e.g., steel, HSS (hollow structural section or hollow steel section) component. Such terminology is well understood in the art. For clarity, however, such components are typically generally tubular, and typically have generally square or rectangular cross-sectional shapes, with opposing elements forming paired web and paired flange portions of the component. As illustrated in Figures 23 and 25 in particular, each of the first and second outer individual column elements 2002a and 2004a and the first and second inner individual column elements 2002b and 2004b can be oriented such that a long axis of its cross-sectional shape is oriented along an inward-outward axis, that is, such that short sides of the HSS components engage, abut, and/or contact one another.

Figure 27 illustrates an inner surface of the first outer individual column element 2002a, which, when the built-up structural element 2000 is assembled, faces toward, contacts, and/or engages with an outer surface of the first inner individual column element 2002b. As illustrated in Figure 27, the inner surface of the first, outer individual column element 2002a (and the corresponding web or flange thereof) has a plurality of apertures, cutouts, or openings 2012 formed therein. Each of the openings 2012 can have an overall circular, oval, elliptical, or oblong shape, or can have a "stadium" shape including a rectangle with semicircles at opposite ends thereof, which may also be referred to as a discorectangle or an obround. For example, the inner surface of the first outer individual column element 2002a can include twelve openings 2012 arranged in a line extending from a first end of the column element 2002a to a second, opposite end of the column element 2002a. Each of the openings 2012 may have the same dimensions, such as long and short axes, as one another.

As further illustrated in Figure 27, the inner surface of the first outer individual column element 2002a (and the corresponding web or flange thereof) includes a plurality of openings, apertures, or bolt holes 2014 that extend through the inner surface of the first outer individual column element 2002a. As illustrated in Figure 27, the inner surface of the first outer individual

column element 2002a includes a first line of bolt holes 2014a that extends along a first side thereof and a second line of bolt holes 2014b that extends along a second, opposite side thereof.

As further illustrated in Figure 27, the bolt holes 2014 include a plurality of paired bolt holes, where each pair of bolt holes includes a first bolt hole 2014a in the first line and a second bolt hole 2014b in the second line that is adjacent to the first bolt hole 2014, that is, as close as possible given the distance between the first and second lines of bolt holes 2014. Further, the bolt holes 2014 are arranged to at least partially alternate with the openings 2012 along the length of the first outer individual column element 2002a. For example, from the first end to the second end of the first outer individual column element 2002a, the inner surface thereof includes four sets of paired bolt holes 2014, then a single opening 2012, then a single set of paired bolt holes 2014, then a single opening 2012, then a single set of paired bolt holes 2014, then a single opening 2012, then a single set of paired bolt holes 2014, then a single opening 2012, then a single set of paired bolt holes 2014, then a single opening 2012, then a single set of paired bolt holes 2014, then a single opening 2012, then a single set of paired bolt holes 2014, then a single opening 2012, then five sets of paired bolt holes 2014, then a single opening 2012, then a single set of paired bolt holes 2014, then a single opening 2012, then a single set of paired bolt holes 2014, then a single opening 2012, then five sets of paired bolt holes 120.

As illustrated in Figures 28 and 29, opposing long side surfaces of the first outer individual column element 2002a (and the corresponding webs or flanges thereof) have a plurality of apertures, cutouts, or openings 2012 formed therein. Each of the openings 2012 can have an overall circular, oval, elliptical, or oblong shape, or can have a "stadium" shape including a rectangle with semicircles at opposite ends thereof, which may also be referred to as a discorectangle or an obround. Each of the openings 2012 may have the same dimensions, such as long and short axes, as one another. In some implementations, the openings 2012 formed in these surfaces can provide access to the interior of the first outer individual column element 2002a, to allow an operator to install and secure nuts and bolts to the first outer individual column element 2002a, as described elsewhere herein. As further illustrated in Figures 28 and 29, these surfaces of the first outer individual column element 2002a (and the corresponding webs or flanges thereof) include a plurality of openings, apertures, or bolt holes 2014 that extend through such surfaces.

Figure 30 illustrates an outer surface of the first inner individual column element 2002b, which, when the built-up structural element 2000 is assembled, faces toward, contacts, and/or

engages with the inner surface of the first outer individual column element 2002a. As illustrated in Figure 30, the outer surface of the first, inner individual column element 2002b (and the corresponding web or flange thereof) has a plurality of apertures, cutouts, or openings 2012 formed therein. Each of the openings 2012 can have an overall circular, oval, elliptical, or oblong shape, or can have a "stadium" shape including a rectangle with semicircles at opposite ends thereof, which may also be referred to as a discorectangle or an obround. For example, the outer surface of the first inner individual column element 2002b can include twelve openings 2012 arranged in a line extending from a first end of the column element 2002b to a second, opposite end of the column element 2002b. Each of the openings 2012 may have the same dimensions, such as long and short axes, as one another.

As further illustrated in Figure 30, the outer surface of the first inner individual column element 2002b (and the corresponding web or flange thereof) includes a plurality of openings, apertures, or bolt holes 2014 that extend through the outer surface of the first inner individual column element 2002b. As illustrated in Figure 30, the outer surface of the first inner individual column element 2002b includes a first line of bolt holes 2014a that extends along a first side thereof and a second line of bolt holes 2014b that extends along a second, opposite side thereof.

As further illustrated in Figure 30, the bolt holes 2014 include a plurality of paired bolt holes, where each pair of bolt holes includes a first bolt hole 2014a in the first line and a second bolt hole 2014b in the second line that is adjacent to the first bolt hole 2014, that is, as close as possible given the distance between the first and second lines of bolt holes 2014. Further, the bolt holes 2014 are arranged to at least partially alternate with the openings 2012 along the length of the first inner individual column element 2002b. For example, from the first end to the second end of the first inner individual column element 2002b, the outer surface thereof includes four sets of paired bolt holes 2014, then a single opening 2012, then a single set of paired bolt holes 2014, then a single opening 2012, then a single set of paired bolt holes 2014, then a single opening 2012, then a single set of paired bolt holes 2014, then a single opening 2012, then a single set of paired bolt holes 2014, then a single opening 2012, then a single set of paired bolt holes 2014, then a single opening 2012, then a single set of paired bolt holes 2014, then a single opening 2012, then a single set of paired bolt holes 2014, then a single opening 2012, then five sets of paired bolt holes 2014, then a single opening 2012, then a single set of paired bolt holes 2014, then a single opening 2012, then a single set of paired bolt holes 2014, then a single opening 2012, then five sets of paired bolt holes 120. Thus, the pattern of openings 2012 and bolt holes 2014 in the outer surface of the first inner individual column element 2002b can match or be a mirror image of the

pattern of openings 2012 and bolt holes 2014 in the inner surface of the first outer individual column element 2002a.

As illustrated in Figures 31 and 32, opposing long side surfaces of the first inner individual column element 2002b (and the corresponding webs or flanges thereof) have a plurality of apertures, cutouts, or openings 2012 formed therein. Each of the openings 2012 can have an overall circular, oval, elliptical, or oblong shape, or can have a "stadium" shape including a rectangle with semicircles at opposite ends thereof, which may also be referred to as a discorectangle or an obround. Each of the openings 2012 may have the same dimensions, such as long and short axes, as one another. Alternatively, the openings 2012 may have different dimensions, such as long and short axes, than one another. In some implementations, the openings 2012 formed in these surfaces can provide access to the interior of the first inner individual column element 2002b, to allow an operator to install and secure nuts and bolts to the first inner individual column element 2002b, as described elsewhere herein. As further illustrated in Figures 31 and 32, these surfaces of the first inner individual column element 2002b (and the corresponding webs or flanges thereof) include a plurality of openings, apertures, or bolt holes 2014 that extend through such surfaces.

As noted elsewhere herein, the first built-up column 2002 and the second built-up column 2004 can be mirror images of one another. Thus, in the same manner, the first outer individual column element 2002a can be a mirror image of the second outer individual column element 2004a and the first inner individual column element 2002b can be a mirror image of the second inner individual column element 2004b.

Figure 33 illustrates a bolt assembly 2020, a plurality of which can be used to couple the components of the built-up structural element 2000 to one another. As illustrated in Figure 33, the bolt assembly 2020 includes a threaded bolt 2022, a threaded nut 2024 threaded onto the threaded bolt 2022, and a washer 2026 in a captive position between the threaded nut 2024 and a head portion of the threaded bolt 2022.

A method of fabricating, building, or assembling the built-up structural element 2000 may include first fabricating the first individual built-up beam or column 2002 and the second individual built-up beam or column 2004. Building each of the first individual built-up beam or column 2002 and the second individual built-up beam or column 2004 may include first obtaining standard HSS sections. Such standard HSS sections may be fabricated in accordance with generally known, standard techniques, such as hot rolling and/or cold rolling techniques. The method may then include cutting the openings 2012 and bolt holes 2014 into the standard HSS sections. Such cutting may be performed using CNC thermal cutting techniques to remove

the desired material from the webs and flanges of the HSS sections. Such cutting may reduce the overall weight of the HSS sections by at least 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, or 45%, and/or up to 20%, 25%, 30%, 35%, 40%, or 45%.

Building each of the first individual built-up beam or column 2002 and the second individual built-up beam or column 2004 may then include bolting the HSS sections to one another top-to-bottom in pairs, such as in the configuration described elsewhere herein to form an especially deep yet lightweight built-up beam or column. In some examples, bolting the HSS sections to one another in this manner may include using one of the bolt assemblies 2020 described herein with each of the bolt holes 2014 in each of the HSS sections, that is, such that each of the bolt assemblies 2020 extends through one of the bolt holes 2014 in an inner surface of an outer individual built-up beam or column (e.g., 2002a or 2004a) and one of the bolt holes 2014 in an outer surface of an inner individual built-up beam or column (e.g., 2002b or 2004b). In some examples, 48 of the bolt assemblies 2020 are used to couple an outer individual built-up beam or column (e.g., 2002a or 2004a) to an inner individual built-up beam or column (e.g., 2002b or 2004b).

Building the built-up structural element 2000 may then include bolting, welding, or otherwise coupling the cladding 2006 to the first and second built-up beams or columns 2002 and 2004, such as in the configuration described elsewhere herein.

As described elsewhere herein, the built-up structural element 2000 can be comparable to, and can replace, the first wall frame 102, the first individual built-up beam or column 2002 can be comparable to, and can replace, the column 110, the second individual built-up beam or column 2004 can be comparable to, and can replace, the column 112, and the struts 2010 can be comparable to, and can replace, the girts 114. In some alternative embodiments, the built-up structural element 2000, or components and features thereof, can be comparable to, and can replace, the first roof frame 104, the first individual built-up beam or column 2002, or components and features thereof, can be comparable to, and can replace, the rafter 124, the second individual built-up beam or column 2004, or components and features thereof, can be comparable to, and can replace, the rafter 126, and the struts 2010, or components and features thereof, can be comparable to, and can replace, the purlins 131. In other alternative embodiments, the built-up structural element 2000, or components and features thereof, can be comparable to, and can replace, the second roof frame 106, the first individual built-up beam or column 2002, or components and features thereof, can be comparable to, and can replace, the rafter 144, the second individual built-up beam or column 2004, or components and features thereof, can be comparable to, and can replace, the rafter 146, and the struts 2010, or components

and features thereof, can be comparable to, and can replace, the purlins 162. In some embodiments, the built-up structural element 2000 can be comparable to, and can replace, the second wall frame 108, the first individual built-up beam or column 2002 can be comparable to, and can replace, the column 170, the second individual built-up beam or column 2004 can be comparable to, and can replace, the column 164, and the struts 2010 can be comparable to, and can replace, the girts 158.

The systems and methods described herein allow deep, lightweight structural elements to be expeditiously and accurately assembled in the field. In some implementations, the components described herein may be shipped in a disassembled or partially disassembled configuration to reduce shipping costs by allowing for high-density packaging. For example, in some embodiments, the first, outer individual column element 2002a and the second, outer individual column element 2004a can be coupled to one another, such as, at least in part, by the cladding 2006, such that the cladding 2006 is directly coupled to both of the first, outer individual column element 2002a and the second, outer individual column element 2004a, in a final, assembled configuration. Such an assembly can be packaged with other comparable or identical assemblies in a relatively space-efficient or volume-efficient manner because they are not coupled to the first, inner individual column element 2002b and the second, inner individual column element 2004b (e.g., ten of such assemblies can be packaged together in a single package for shipment to an installation location). The first, inner individual column element 2002b and the second, inner individual column element 2004b can then be packaged together, and with other comparable or identical components, in a relatively space-efficient or volume-efficient manner because they are not coupled to the first, outer individual column element 2002a, the second, outer individual column element 2004a, or the cladding 2006. Such packaged components can then be shipped independently of one another, or in distinct packages within a single shipment, to an installation location.

In other implementations, the beam components may be shipped in an assembled configuration to reduce on-site installation time. Because the systems described herein may be bolted, they are recoverable to allow disassembly and relocation after assembly and use. Because the systems described herein are bolted, an installer can break the weight of individual lifts during installation into smaller increments to reduce required equipment size to complete a given span. Because individual components of the structures described herein are relatively small and light, the manufacturing equipment for processing, lifting, and handling the components is reduced, reducing the overall cost of manufacturing, or effectively increasing an available beam depth given available manufacturing equipment.

Figures 34-46 illustrate additional embodiments that have similarities to the embodiments described previously, especially those illustrated in Figures 20-33. In particular, Figures 34-46 illustrate embodiments of a panelized building that can be built as a truss, where the panels of the building can be assembled at a first location, such as at a factory, packed in a relatively compact configuration for shipping and transport, which may be referred to as a "flat-pack" configuration, and then shipped to a second location, such as an installation location, and rapidly assembled into a completed building at the second location. Because such panels can be coupled to one another primarily with bolts, such buildings can also be rapidly disassembled at the second location, re-packed into the flat-pack configuration, and shipped to a third location, which may be another installation location, and then rapidly assembled into a completed building at the third location. In some embodiments, such assembled buildings may have a castellated tube steel exterior panel frame, a bolted-together tube steel lower chord, and infill framing. The features of the embodiments illustrated in Figured 34-46 can be combined with the features of the embodiments described and illustrated elsewhere herein.

Figure 34 illustrates an example of a fully assembled building 3000. As seen in Figure 34, the building 3000 is made up of a series of individual building sections 3002a, 3002b, 3002c, etc., where the building sections 3002 are identical or substantially identical to one another and arranged adjacent to one another along a long axis of the building 3000, from an opening 3004 at a first end of the building 3000 to a second end of the building opposite the opening 3004 along the long axis of the building 3000. Figure 35 illustrates one embodiment of a truss structure of each of the building sections 3002, with dimensions overlaid to illustrated scale. For example, each of the building sections 3002 can include a first wall frame 3006 at a first side thereof, a second wall frame 3008 at a second side thereof opposite to the first side thereof, a first roof frame 3010 at the first side thereof and coupled to a top end of the first wall frame 3006, and a second roof frame 3012 at the second side thereof and coupled to a top end of the second wall frame 3008.

Each of the first wall frame 3006, the second wall frame 3008, the first roof frame 3010, and the second roof frame 3012 can have structural similarities to one another. For example, they can each be formed as built-up structural elements composed of an exterior panel portion, which carries cladding, an interior or lower chord panel portion, and infill framing that couples the exterior panel portion to the interior panel portion. Thus, these components can each comprise three-dimensional truss structures, as seen in the drawings. The first and second wall frames 3006, 3008 and the first and second roof frames 3010, 3012 may therefore be described below, at least to the extent they have corresponding features, collectively.

As further illustrated in Figure 35, each of the first and second wall frames 3006, 3008 can have an overall height, such as at an exterior surface of the wall frames 3006, 3008, of 58 feet, 5 and 5/16 of an inch tall. In various embodiments, this height can be between 50 and 70 feet, or between 55 and 65 feet. As further illustrated in Figure 35, each building section 3002 can have an overall height, such as at an exterior surface of the roof frames 3010, 3012, and at a central portion of the building section where ends of the roof frames 3010, 3012 are coupled to one another, of 73 feet, 5 and 7/16 of an inch tall. In various embodiments, this height can be between 60 and 80 feet, or between 65 and 75 feet. As further illustrated in Figure 35, each building section 3002 can enclose an interior space having a height that increases from the periphery thereof to the center thereof. For example, the interior space can have an overall height, such as adjacent to the first and second wall frames 3006, 3008, of 50 feet, or between 40 and 60 feet, and can have an overall height, such as at a center thereof where the first and second roof frames 3010, 3012 are coupled to one another, of 63 feet, 3 and 15/16 of an inch tall, or between 50 and 70 feet. As further illustrated in Figure 35, each building section 3002 can have an overall width, such as from an exterior surface of the wall frame 3006 to an exterior surface of the wall frame 3008, of 180 feet, or between 160 and 200 feet, or between 170 and 190 feet. The interior space can have an overall width, such as at a bottom of the interior space or along a ground and/or floor surface, of 172 feet, or between 160 and 180 feet, and can have an overall width, such as at a location above the ground and/or floor surface, of 160 feet or between 150 and 170 feet.

Figure 36 illustrates a perspective view of another embodiment of a building section 3002. Figure 37 illustrates a side view of the building section 3002 as illustrated in Figure 36. Figure 38 illustrates another perspective view of the building section 3002 as illustrated in Figure 36, but with exterior cladding removed to reveal additional details of the truss structure. Figure 39 illustrates an exterior panel portion 3014 of the first wall frame 3006, which carries cladding. Figure 40 illustrates a close-up perspective view of the first wall frame 3006 with the cladding removed, revealing the truss structure of an interior panel portion 3016 of the first wall frame 3006 and of infill framing 3018 that couples the exterior panel portion 3014 to the interior panel portion 3016. Figure 41 illustrates an exterior panel portion 3020 of the first roof frame 3010, which carries cladding. Figure 42 illustrates a close-up perspective view of the first roof frame 3010 with the cladding removed, revealing the truss structure of an interior panel portion 3022 of the first roof frame 3010 and of infill framing 3024 that couples the exterior panel portion 3020 to the interior panel portion 3022. In some embodiments, the building 3000 and each of its building sections 3002 can be symmetrical about a central vertical plane thereof that extends

along the length of the building 3000 from its first end, at the opening 3004, to its second end opposite the opening 3004. Thus, while Figures 39 and 40 illustrate features of the first wall frame 3006, they also illustrate corresponding features of the second wall frame 3008, and while Figures 41 and 42 illustrate features of the first roof frame 3010, they also illustrate corresponding features of the second wall frame 3012.

In some embodiments, the wall frames 3006, 3008, including their exterior panel portions (e.g., 3014), and/or the roof frames 3010, 3012, including their exterior panel portions (e.g., 3020), can each be made up of a plurality of smaller (e.g., shorter) individual components. For example, Figure 43 illustrates a terminal end portion 3026 of one such individual component 3028 of the exterior panel portion 3020 of the first roof frame 3010, from the same perspective as seen in Figure 41, and Figure 44 illustrates a terminal end portion 3030 of another such individual component 3032 of the exterior panel portion 3020 of the first roof frame 3010, from the same perspective as seen in Figure 41. For example, the terminal end portion 3026 of the individual component 3028 may be configured to be coupled to the terminal end portion 3030 of the individual component 3032 when the building 3000 is fully assembled. Nevertheless, the individual component 3028 may be separated from the individual component 3032 to allow the various components of the building section 3002 to be packed more efficiently for transport.

Figure 45 illustrates another perspective view of the terminal end portion 3026 the individual component 3028, and Figure 46 illustrates another perspective view of the terminal end portion 3030 of the individual component 3032. In some embodiments, all or substantially all on-site assembly of the building 3000 and/or of its building sections 3002 can be performed at an installation location by bolting components to one another. Figures 45 and 46 illustrate that each of the individual components 3028, 3032 of the first roof frame 3010 can include a pair of HSS (hollow structural section or hollow steel section) components 3034. Terminal end portions of the HSS components 3034 can have plates 3036 coupled thereto, such as by welding at a factory, where the plates 3036 span across open ends of the respective HSS components 3034 and have bolt holes formed therethrough. Thus, the first and second individual components 3028 and 3032 can be coupled to one another by bolts extending through the bolt holes of the respective plates 3036. Such bolt holes can be accessed, for example, using openings in the HSS components 3034 as described elsewhere herein.

The features of the embodiments illustrated in Figured 34-46 can be combined with the features of the embodiments described and illustrated elsewhere herein. The first wall frame 3006 can be comparable to, and can replace, the first wall frame 102 and/or the built-up structural element 2000. Thus, the first wall frame 3006 can be oriented, in use, vertically, and can

function as a structural column. The first wall frame 3006 includes a first individual built-up beam or column at a first side thereof, which may be comparable to the column 110, a second individual built-up beam or column at a second side thereof opposite to the first side thereof, which may be comparable to the column 112, and the cladding, which may cover an exterior surface thereof.

The first and second individual built-up beams or columns are each built-up columns including respective first and second individual column elements. In particular, the first built-up column includes a respective first individual column element, which may be an outer individual column element, in the sense that it is a component of the exterior panel portion 3014 and carries the cladding, or the cladding is directly coupled to it. The first built-up column also includes a respective second individual column element, which may be an inner individual column element, in the sense that it is a component of the interior panel portion 3016 and does not carry the cladding, or the cladding is not directly coupled to it. The first built-up column also includes a portion of the infill framing 3018, which structurally couples the first individual column element to the second individual column element.

Similarly, the second built-up column includes a respective first individual column element, which may be an outer individual column element, in the sense that it is a component of the exterior panel portion 3014 and carries the cladding, or the cladding is directly coupled to it. The second built-up column also includes a respective second individual column element, which may be an inner individual column element, in the sense that it is a component of the interior panel portion 3016 and does not carry the cladding, or the cladding is not directly coupled to it. The second built-up column also includes a portion of the infill framing 3018, which structurally couples the first individual column element to the second individual column element. Each of the first and second outer individual column elements and the first and second inner individual column elements can comprise a metallic, e.g., steel, HSS (hollow structural section or hollow steel section) component.

As illustrated in the drawings, the first individual column element of the first built-up column, which is a component of the exterior panel portion 3014, and the first individual column element of the second built-up column, which is a component of the exterior panel portion 3014, can be coupled to one another by a plurality of struts. Similarly, as illustrated in the drawings, the second individual column element of the first built-up column, which is a component of the interior panel portion 3016, and the second individual column element of the second built-up column, which is a component of the interior panel portion 3016, can be coupled to one another by a plurality of struts.

A method of fabricating, building, or assembling the first wall frame 3006 may include first fabricating the exterior panel portion 3014, the interior panel portion 3016, and the infill framing 3018. Building each of these components may include first obtaining standard HSS sections. Such standard HSS sections may be fabricated in accordance with generally known, standard techniques, such as hot rolling and/or cold rolling techniques. The method may then include cutting openings and/or and bolt holes into the standard HSS sections, as described elsewhere herein. Such cutting may be performed using CNC thermal cutting techniques to remove the desired material from the webs and flanges of the HSS sections. Such cutting may reduce the overall weight of the HSS sections by at least 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, or 45%, and/or up to 20%, 25%, 30%, 35%, 40%, or 45%.

Building these components may then include bolting the HSS sections to struts to form the exterior panel portion 3014 and the interior panel portion 3016, and/or bolting components of the infill framing 3018 to one another, such as in the configurations described elsewhere herein. In some examples, bolting the components to one another in this manner may include using one of the bolt assemblies 2020 described herein with each of the bolt holes in each of the HSS sections.

As described elsewhere herein, the first wall frame 3006 can be comparable to, and can replace, the first wall frame 102 and/or the built-up structural element 2000. Similarly, the first roof frame 3010 can be comparable to, and can replace, the first roof frame 104 and/or the built-up structural element 2000. Similarly, the second roof frame 3012 can be comparable to, and can replace, the second roof frame 106 and/or the built-up structural element 2000. Similarly, the second wall frame 3008 can be comparable to, and can replace, the second wall frame 108 and/or the built-up structural element 2000. The first and second roof frames 3010, 3012, and the second wall frame 3008, can include any of the features described herein for the first wall frame 3006.

The systems and methods described herein with respect to Figures 34-46 allow deep, lightweight structural elements to be expeditiously and accurately assembled in the field. In some implementations, the components described herein may be shipped in a disassembled or partially disassembled configuration to reduce shipping costs by allowing for high-density packaging. For example, in some embodiments, the exterior panel portion 3014 can be packaged with other comparable or identical assemblies in a relatively space-efficient or volume-efficient manner because they are not coupled to the infill framing 3018 and/or to the interior panel portion 3016. Similarly, the interior panel portion 3016 can be packaged with other comparable or identical assemblies in a relatively space-efficient or volume-efficient manner because they are

not coupled to the infill framing 3018 and/or to the exterior panel portion 3014. Similarly, the infill framing 3018 can be packaged with other comparable or identical components in a relatively space-efficient or volume-efficient manner because they are not coupled to the exterior panel portion 3014 and/or to the interior panel portion 3016. Such packaged components can then be shipped independently of one another, or in distinct packages within a single shipment, to an installation location.

As another example, in some embodiments, the exterior panel portion 3020 can be packaged with other comparable or identical assemblies in a relatively space-efficient or volume-efficient manner because they are not coupled to the infill framing 3024 and/or to the interior panel portion 3022. Similarly, the interior panel portion 3022 can be packaged with other comparable or identical assemblies in a relatively space-efficient or volume-efficient manner because they are not coupled to the infill framing 3024 and/or to the exterior panel portion 3020. Similarly, the infill framing 3024 can be packaged with other comparable or identical components in a relatively space-efficient or volume-efficient manner because they are not coupled to the exterior panel portion 3020 and/or to the interior panel portion 3022. Such packaged components can then be shipped independently of one another, or in distinct packages within a single shipment, to an installation location.

Because the systems described herein may be bolted, they are recoverable to allow disassembly and relocation after assembly and use. Because the systems described herein are bolted, an installer can break the weight of individual lifts during installation into smaller increments to reduce required equipment size to complete a given span. Because individual components of the structures described herein are relatively small and light, the manufacturing equipment for processing, lifting, and handling the components is reduced, reducing the overall cost of manufacturing, or effectively increasing an available beam depth given available manufacturing equipment.

Aspects of the various embodiments described above can be combined to provide further embodiments. These and other changes can be made to the embodiments in light of the above-detailed description. In general, in the following claims, the terms used should not be construed to limit the claims to the specific embodiments disclosed in the specification and the claims, but should be construed to include all possible embodiments along with the full scope of equivalents to which such claims are entitled.

This application claims the benefit of priority to U.S. Provisional Application No. 63/347,448, filed May 31, 2022, and 63/356,762, filed June 29, 2022, which are hereby incorporated by reference in their entirety.

CLAIMS

1. A method of fabricating a built-up structural element, comprising:

obtaining a pair of steel hollow structural sections, each steel hollow structural section having a uniform cross-sectional profile over an entirety of a longitudinal length thereof;

for each of the pair of steel hollow structural sections, cutting a plurality of openings in the steel hollow structural section to vary the cross-sectional profile of the steel hollow structural section over the longitudinal length thereof;

for each of the pair of steel hollow structural sections, cutting a plurality of bolt holes distinct from the plurality of openings in the steel hollow structural section along the longitudinal length thereof;

stacking the pair of steel hollow structural sections together to form a stacked configuration in which the plurality of bolt holes of each steel hollow structural section align with each other; and

bolting the pair of steel hollow structural sections together via the plurality of bolt holes to secure the pair of steel hollow structural sections together in the stacked configuration.

2. The method of claim 1, further comprising:

obtaining a complementary pair of steel hollow structural sections, each of the complementary pair of steel hollow structural sections having a uniform cross-sectional profile over an entirety of a longitudinal length thereof;

for each of the complementary pair of steel hollow structural sections, cutting a plurality of openings in the steel hollow structural section to vary the cross-sectional profile of the steel hollow structural section over the longitudinal length thereof;

for each of the complementary pair of steel hollow structural sections, cutting a plurality of bolt holes distinct from the plurality of openings in the steel hollow structural section along the longitudinal length thereof;

stacking the complementary pair of steel hollow structural sections together to form a stacked configuration in which the plurality of bolt holes of each of the complementary pair of steel hollow structural sections align with each other;

bolting the complementary pair of steel hollow structural sections together via the plurality of bolt holes to secure the complementary pair of steel hollow structural sections together in the stacked configuration; and

coupling the pair of steel hollow structural sections in the stacked configuration to the complementary pair of steel hollow structural sections in the stacked configuration via one or more spanning members.

3. The method of claim 2 wherein the one or more spanning members includes cladding.

4. The method of claim 2 wherein the one or more spanning members includes struts.

5. The method of claim 1, further comprising, after fabricating the built-up structural element, using the fabricated built-up structural element to fabricate a sectional foldable prefabricated building.

6. The method of claim 1 wherein bolting the pair of steel hollow structural sections together via the plurality of bolt holes includes using the openings to access the bolt holes.

7. A built-up structural element, comprising:

a pair of steel hollow structural sections, each having a hollow and generally rectangular cross-sectional shape, a plurality of openings, and a plurality of bolt holes distinct from the openings, wherein the steel hollow structural sections are stacked together in a stacked configuration; and

a plurality of bolts extending through the plurality of bolt holes and securing the pair of steel hollow structural sections together in the stacked configuration.

8. The built-up structural element of claim 7, further comprising:

a pair of complementary steel hollow structural sections, each having a hollow and generally rectangular cross-sectional shape, a plurality of openings, and a plurality of bolt holes distinct from the openings, and wherein the complementary steel hollow structural sections are stacked together in a stacked configuration;

a plurality of bolts extending through the plurality of bolt holes and securing the complementary pair of steel hollow structural sections together in the stacked configuration; and

one or more spanning members extending between the pair of steel hollow structural sections and the pair of complementary steel hollow structural sections.

9. The built-up structural element of claim 8 wherein the built-up structural element is symmetrical.

10. The built-up structural element of claim 7, wherein the built-up structural element is a component of a sectional foldable prefabricated building.

11. The built-up structural element of claim 7, wherein the built-up structural element is a wall frame of a sectional foldable prefabricated building.

12. The built-up structural element of claim 7, wherein the steel hollow structural sections are columns of a sectional foldable prefabricated building.

13. The built-up structural element of claim 7, wherein the built-up structural element is a roof frame of a sectional foldable prefabricated building.

14. The built-up structural element of claim 7, wherein the steel hollow structural sections are beams of a sectional foldable prefabricated building.

15. A method of fabricating a building, comprising:

fabricating a first steel hollow structural section;

fabricating a second steel hollow structural section;

coupling the first and second steel hollow structural sections to one another via one or more spanning members to form a first structural assembly;

shipping the first structural assembly to an installation location in a first package;

fabricating a third steel hollow structural section;

fabricating a fourth steel hollow structural section;

shipping the third and fourth steel hollow structural sections to the installation location in a second package distinct from the first package;

stacking the first and third steel hollow structural sections together at the installation location;

bolting the first and third steel hollow structural sections together at the installation location;

stacking the second and fourth steel hollow structural sections together at the installation location; and

bolting the second and fourth steel hollow structural sections together at the installation location.

16. The method of claim 15 wherein the one or more spanning members includes cladding.

17. The method of claim 15, further comprising:

fabricating a fifth steel hollow structural section;

fabricating a sixth steel hollow structural section;

coupling the fifth and sixth steel hollow structural sections to one another via spanning members to form a second structural assembly;

shipping the second structural assembly to the installation location in the first package;

fabricating a seventh steel hollow structural section;

fabricating an eighth steel hollow structural section;

shipping the seventh and eighth steel hollow structural sections to the installation location in the second package;

stacking the fifth and seventh steel hollow structural sections together at the installation location;

bolting the fifth and seventh steel hollow structural sections together at the installation location;

stacking the sixth and eighth steel hollow structural sections together at the installation location; and

bolting the sixth and eighth steel hollow structural sections together at the installation location.

18. The method of claim 16 wherein the spanning members include cladding.

19. A method of fabricating a built-up structural element, comprising:

obtaining a pair of steel hollow structural sections, each steel hollow structural section having a uniform cross-sectional profile over an entirety of a longitudinal length thereof;

for each of the pair of steel hollow structural sections, cutting a plurality of openings in the steel hollow structural section to vary the cross-sectional profile of the steel hollow structural section over the longitudinal length thereof;

for each of the pair of steel hollow structural sections, cutting a plurality of bolt holes distinct from the plurality of openings in the steel hollow structural section along the longitudinal length thereof; and

coupling the pair of steel hollow structural sections together using a plurality of bolts extending through the bolt holes.

20. The method of claim 19 wherein coupling the pair of steel hollow structural sections together includes bolting a first one of the pair of steel hollow structural sections to infill framing and bolting a second one of the pair of steel hollow structural sections to the infill framing.

21. The method of claim 19, further comprising:

obtaining a complementary pair of steel hollow structural sections, each of the complementary pair of steel hollow structural sections having a uniform cross-sectional profile over an entirety of a longitudinal length thereof;

for each of the complementary pair of steel hollow structural sections, cutting a plurality of openings in the steel hollow structural section to vary the cross-sectional profile of the steel hollow structural section over the longitudinal length thereof;

for each of the complementary pair of steel hollow structural sections, cutting a plurality of bolt holes distinct from the plurality of openings in the steel hollow structural section along the longitudinal length thereof;

coupling the complementary pair of steel hollow structural sections together using a plurality of bolts extending through the bolt holes; and

coupling the pair of steel hollow structural sections to the complementary pair of steel hollow structural sections via one or more spanning members.

22. The method of claim 21, wherein:

coupling the pair of steel hollow structural sections together includes bolting a first one of the pair of steel hollow structural sections to a first set of infill framing and bolting a second one of the pair of steel hollow structural sections to the first set of infill framing; and

coupling the complementary pair of steel hollow structural sections together includes bolting a first one of the complementary pair of steel hollow structural sections to a second set of infill framing and bolting a second one of the complementary pair of steel hollow structural sections to the second set of infill framing.

23. The method of claim 21 wherein the one or more spanning members includes cladding.

24. The method of claim 21 wherein the one or more spanning members includes struts.

25. The method of claim 21 wherein coupling the pair of steel hollow structural sections to the complementary pair of steel hollow structural sections via one or more spanning members includes:

coupling a first one of the pair of steel hollow structural sections to a first one of the complementary pair of steel hollow structural sections via one or more first spanning members; and

coupling a second one of the pair of steel hollow structural sections to a second one of the complementary pair of steel hollow structural sections via one or more second spanning members.

26. The method of claim 19 wherein coupling the pair of steel hollow structural sections together includes using the openings to access the bolt holes.

27. A built-up structural element, comprising:

a pair of steel hollow structural sections, each having a hollow and generally rectangular cross-sectional shape, a plurality of openings, and a plurality of bolt holes distinct from the openings; and

a plurality of bolts extending through the plurality of bolt holes and securing the pair of steel hollow structural sections together.

28. The built-up structural element of claim 27, further comprising:

infill framing;

wherein a first one of the pair of steel hollow structural sections is bolted to the infill framing and a second one of the pair of steel hollow structural sections is bolted to the infill framing.

29. The built-up structural element of claim 27, further comprising:

a pair of complementary steel hollow structural sections, each having a hollow and generally rectangular cross-sectional shape, a plurality of openings, and a plurality of bolt holes distinct from the openings;

a plurality of bolts extending through the plurality of bolt holes and securing the complementary pair of steel hollow structural sections together; and

one or more spanning members extending between the pair of steel hollow structural sections and the pair of complementary steel hollow structural sections.

30. The built-up structural element of claim 29, further comprising:

a first set of infill framing;

wherein a first one of the pair of steel hollow structural sections is bolted to the first set of infill framing and a second one of the pair of steel hollow structural sections is bolted to the first set of infill framing; and

a second set of infill framing;

wherein a first one of the complementary pair of steel hollow structural sections is bolted to the second set of infill framing and a second one of the complementary pair of steel hollow structural sections is bolted to the second set of infill framing.

31. The built-up structural element of claim 29 wherein the one or more spanning members include:

first spanning members that couple a first one of the pair of steel hollow structural sections to a first one of the complementary pair of steel hollow structural sections; and

second spanning members that couple a second one of the pair of steel hollow structural sections to a second one of the complementary pair of steel hollow structural sections.

32. A method of fabricating a building, comprising:

fabricating a first steel hollow structural section;

fabricating a second steel hollow structural section;

coupling the first and second steel hollow structural sections to one another via one or more spanning members to form a first structural assembly;

shipping the first structural assembly to an installation location in a first package;

fabricating a third steel hollow structural section;

fabricating a fourth steel hollow structural section;

shipping the third and fourth steel hollow structural sections to the installation location in a second package distinct from the first package;

coupling the first and third steel hollow structural sections together at the installation location using bolts; and

coupling the second and fourth steel hollow structural sections together at the installation location using bolts.

33. The method of claim 32 wherein the one or more spanning members includes cladding.

34. The method of claim 32, further comprising:

prior to shipping the third and fourth steel hollow structural sections to the installation location in a second package distinct from the first package, coupling the third and fourth steel hollow structural sections to one another via one or more additional spanning members to form a second structural assembly.

35. The method of claim 32 wherein coupling the first and third steel hollow structural sections together at the installation location using bolts includes bolting the first steel hollow structural section to infill framing and bolting the second steel hollow structural section to the infill framing.

36. The method of claim 32 wherein:

coupling the first and third steel hollow structural sections together at the installation location using bolts includes bolting the first steel hollow structural section to a first set of infill framing and bolting the third steel hollow structural section to the first set of infill framing; and

coupling the second and fourth steel hollow structural sections together at the installation location using bolts includes bolting the second steel hollow structural section to a second set of infill framing and bolting the fourth steel hollow structural section to the second set of infill framing.

37. The method of claim 32, further comprising:

fabricating a fifth steel hollow structural section;

fabricating a sixth steel hollow structural section;

coupling the fifth and sixth steel hollow structural sections to one another via spanning members to form a second structural assembly;

shipping the second structural assembly to the installation location in the first package;

fabricating a seventh steel hollow structural section;

fabricating an eighth steel hollow structural section;

shipping the seventh and eighth steel hollow structural sections to the installation location in the second package;

coupling the fifth and seventh steel hollow structural sections together at the installation location using bolts; and

coupling the sixth and eighth steel hollow structural sections together at the installation location using bolts.

38. The method of claim 37 wherein the spanning members include cladding.

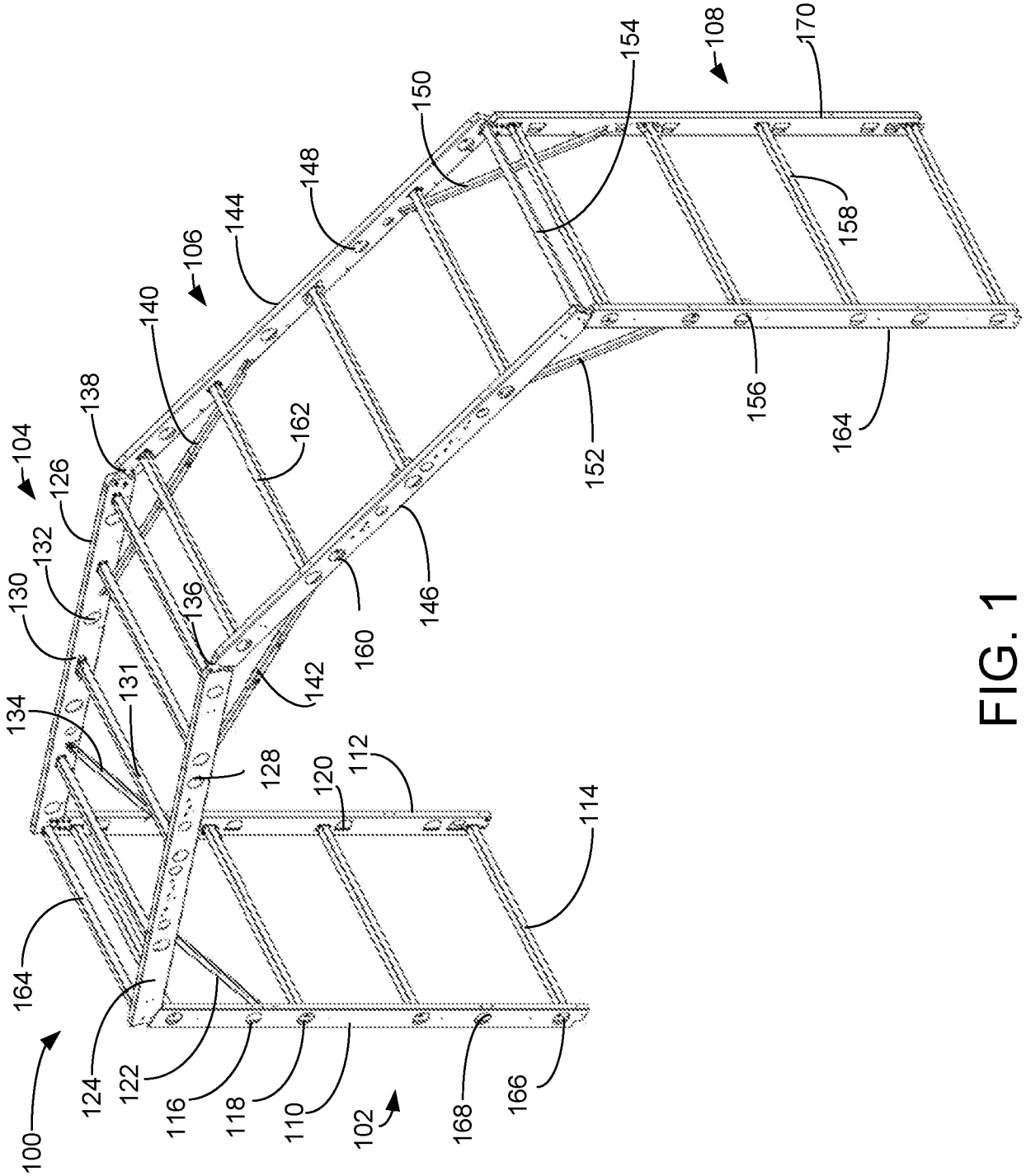
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FIG. 1

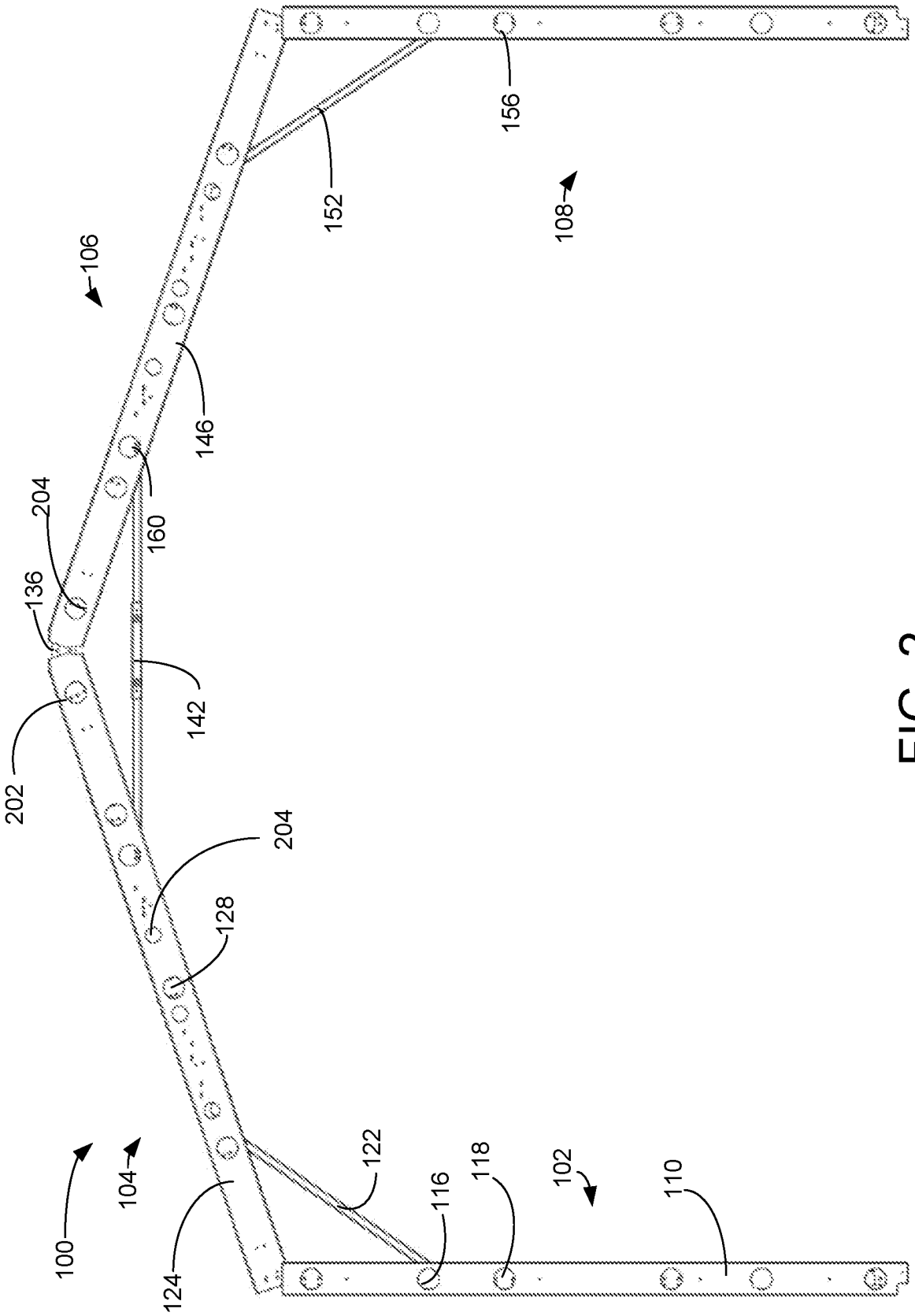
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FIG. 2

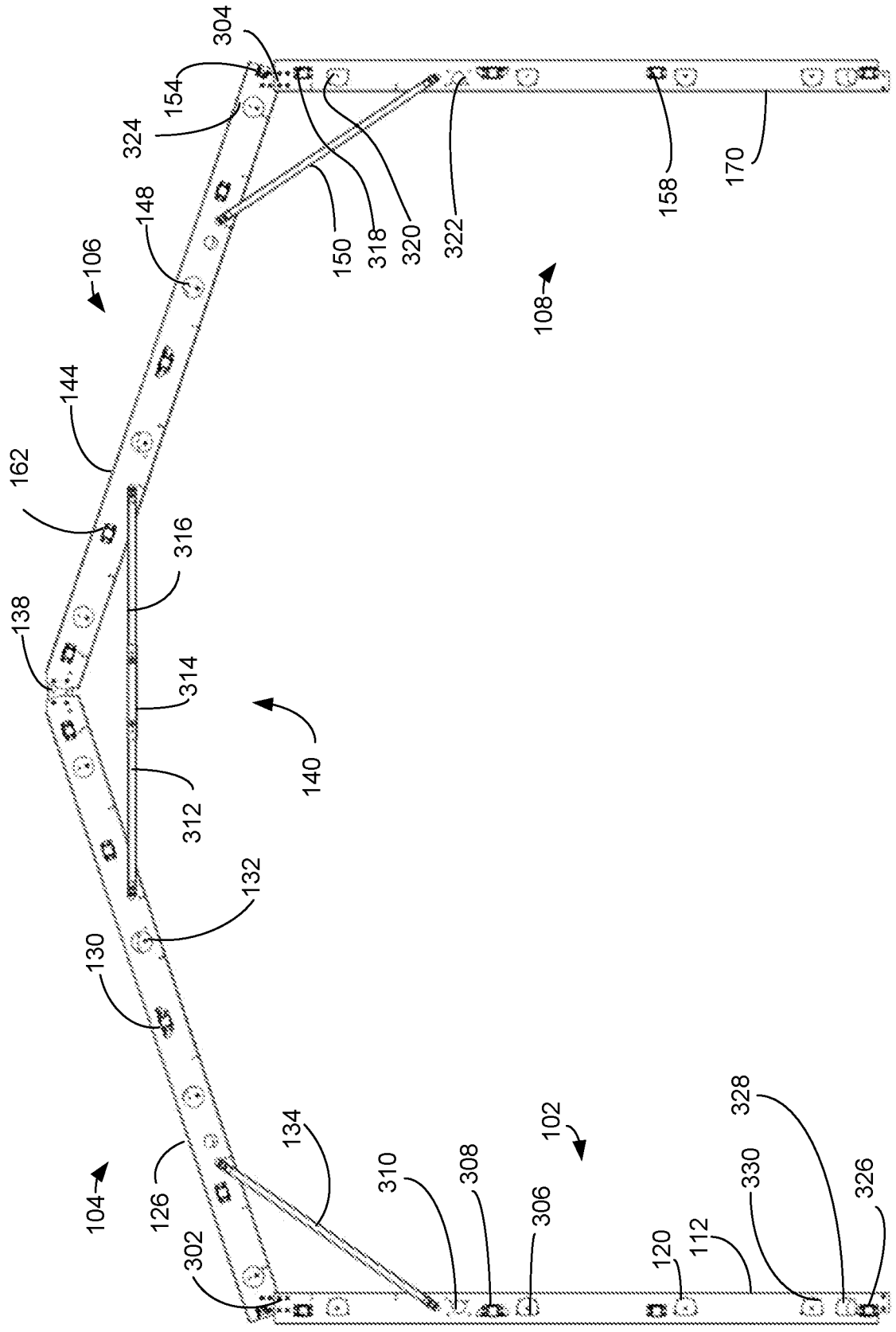
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FIG. 3

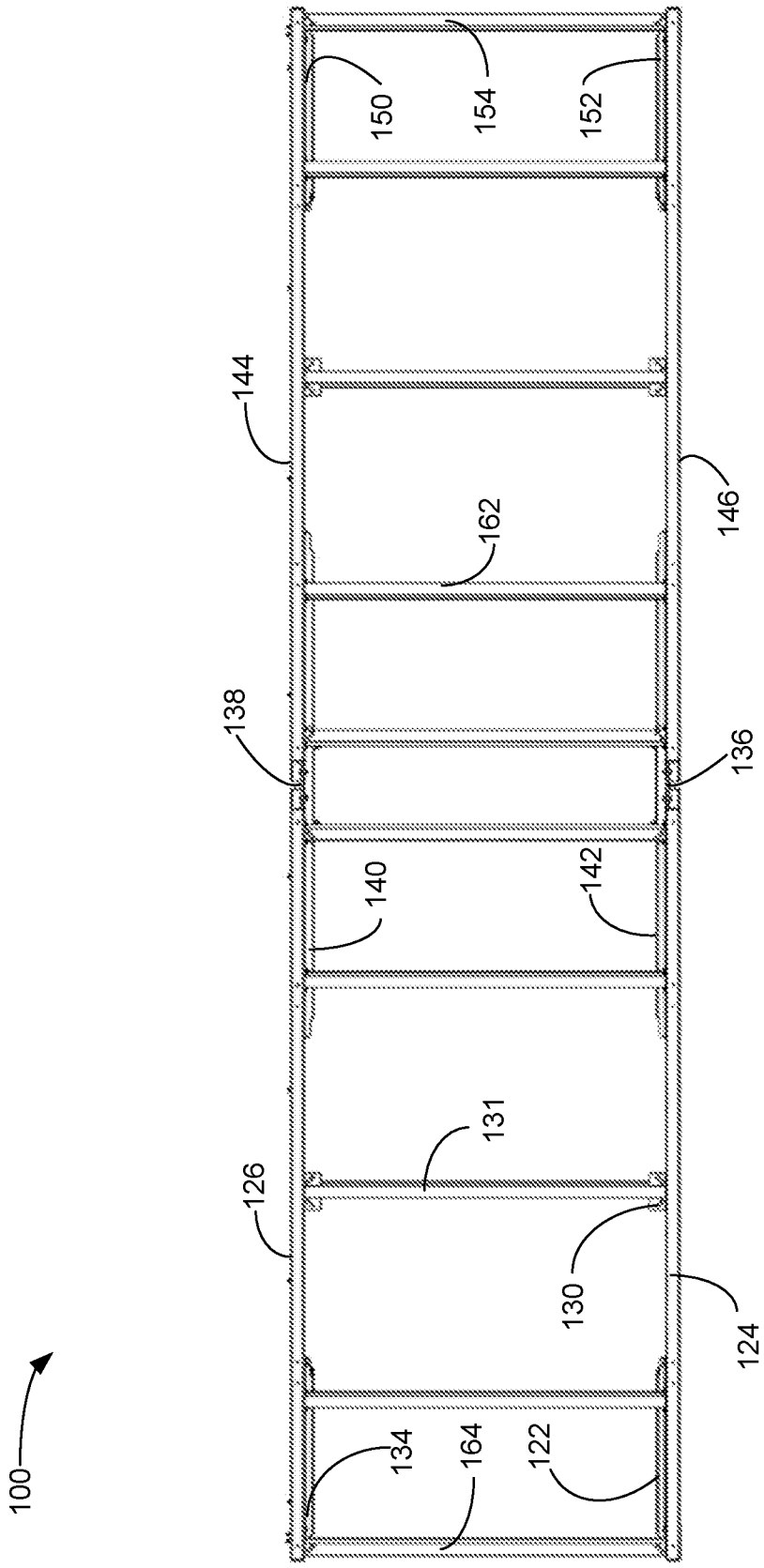
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FIG. 4

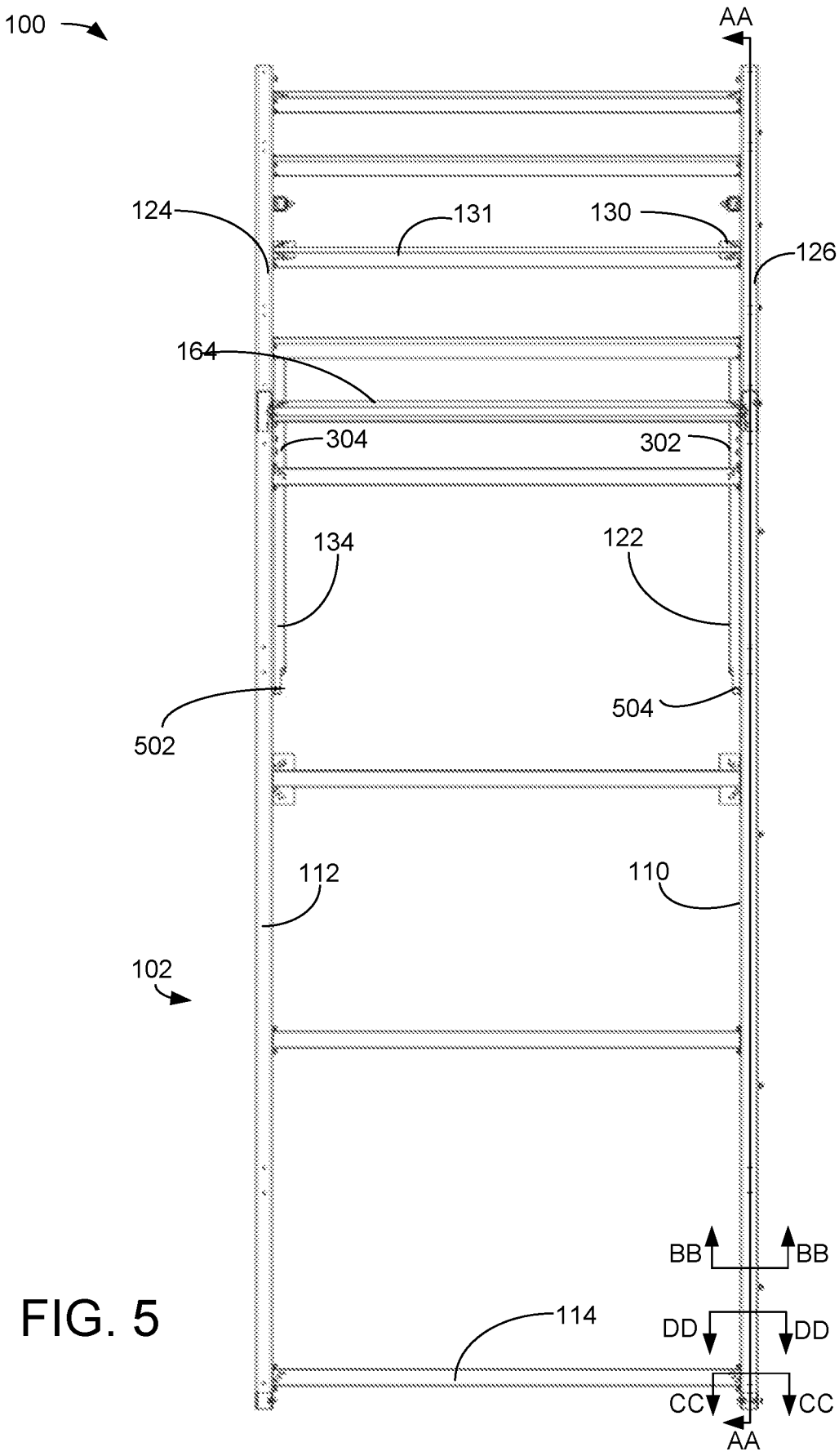
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FIG. 5

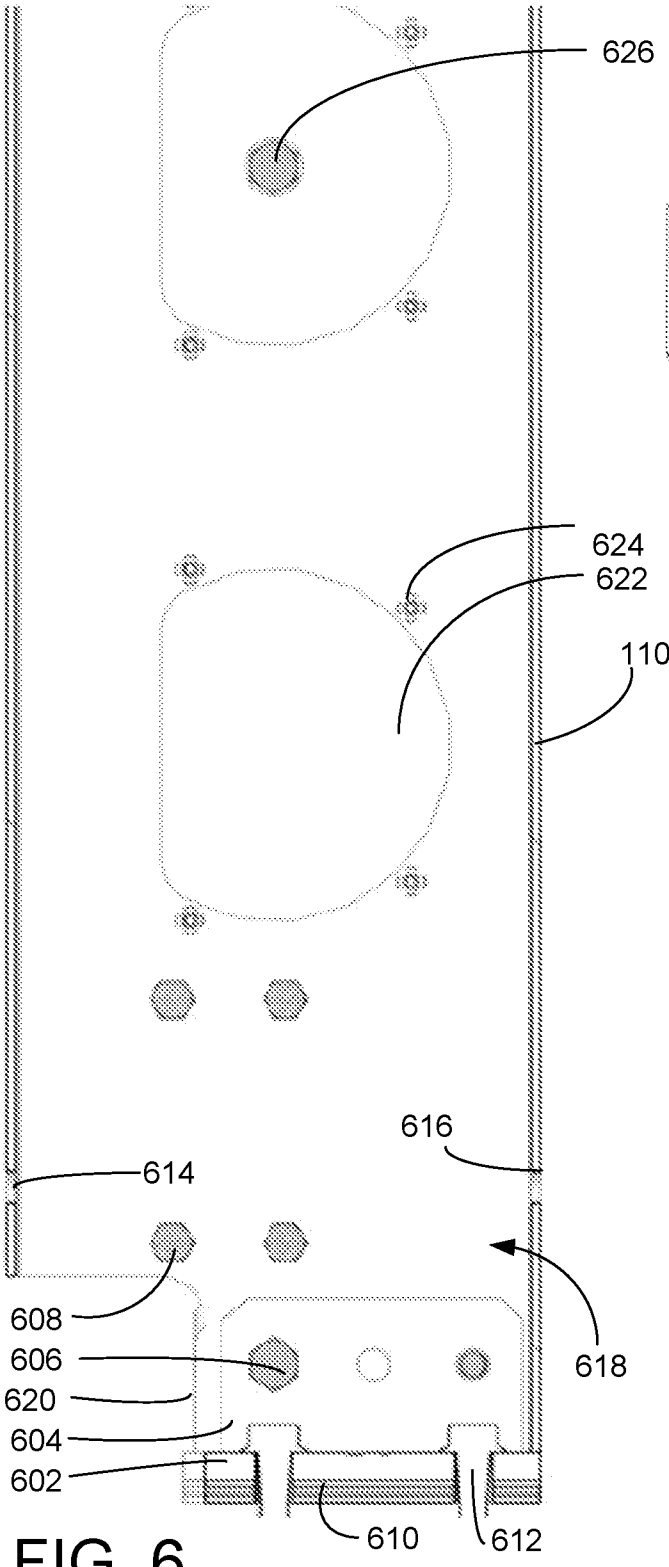

FIG. 6

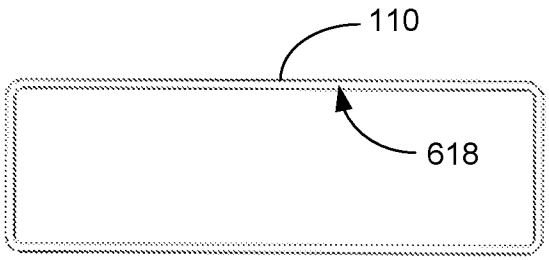

FIG. 7

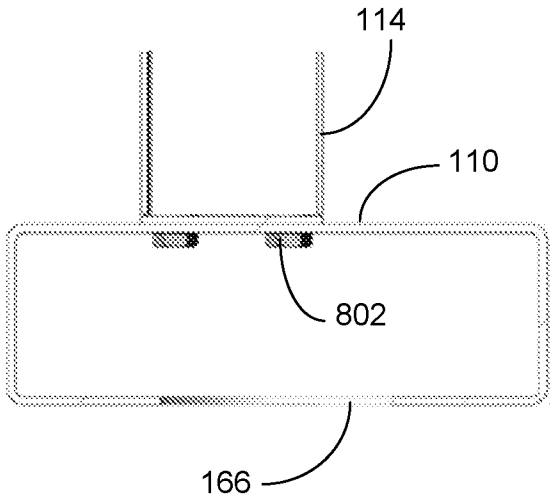

FIG. 8

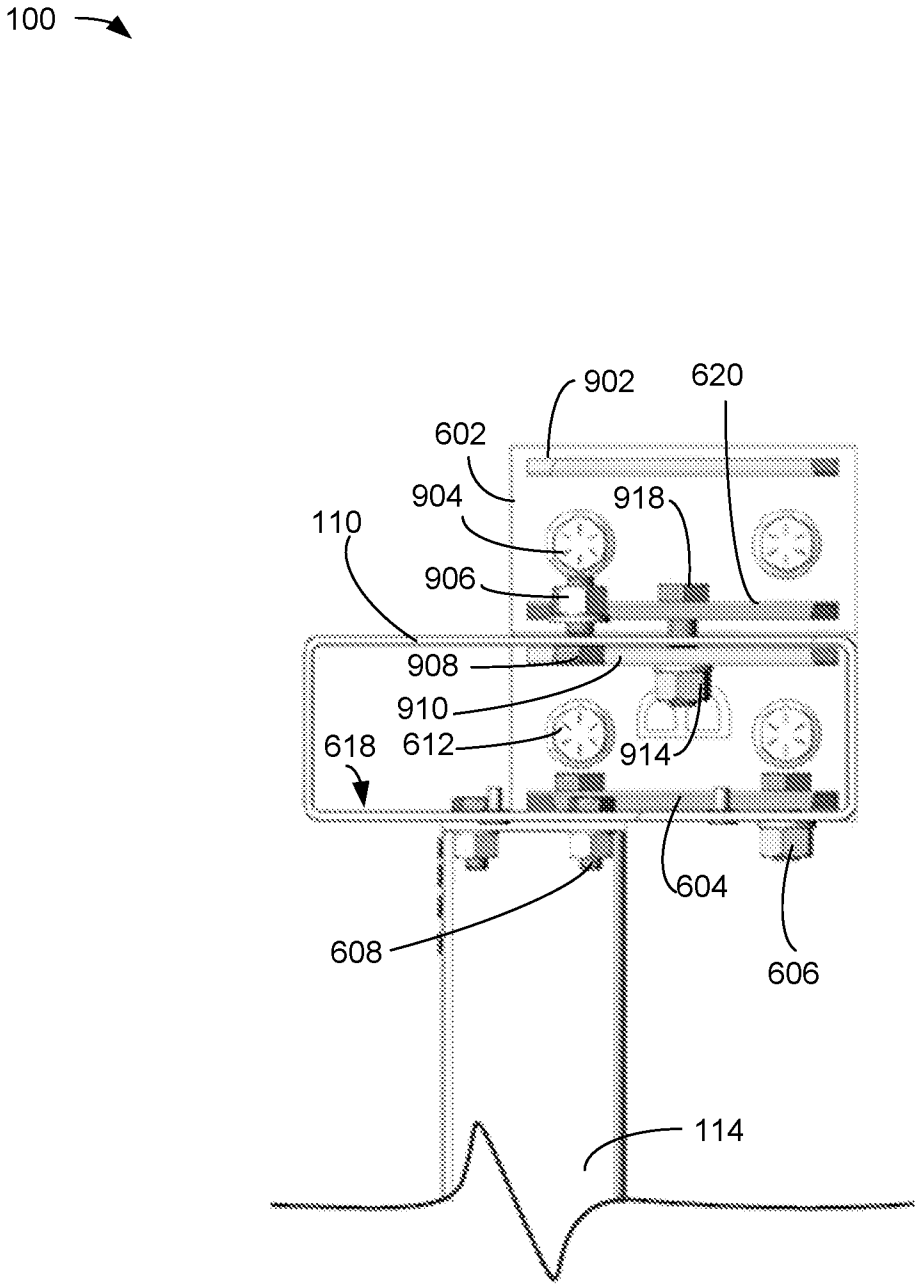
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FIG. 9

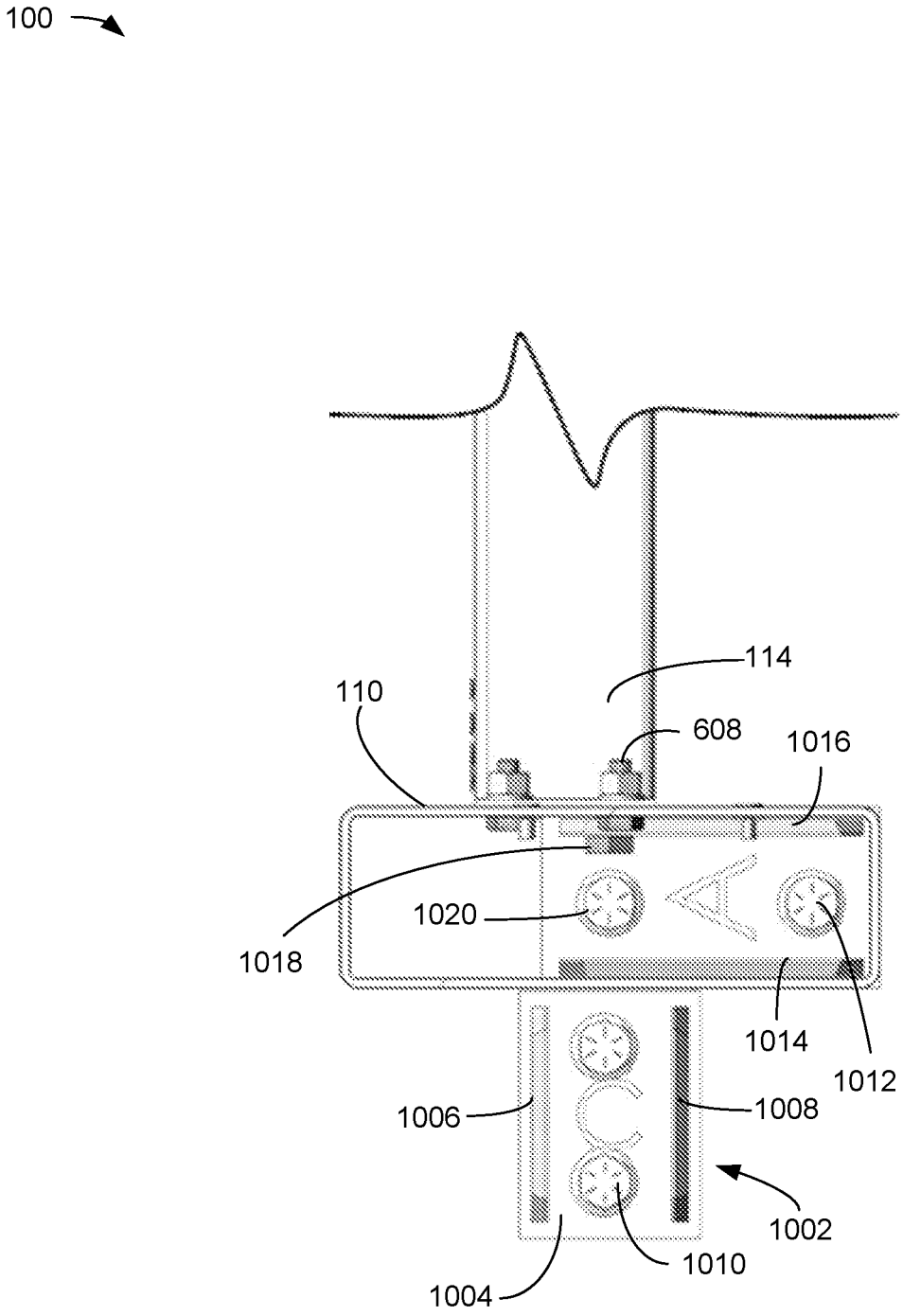
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FIG. 10

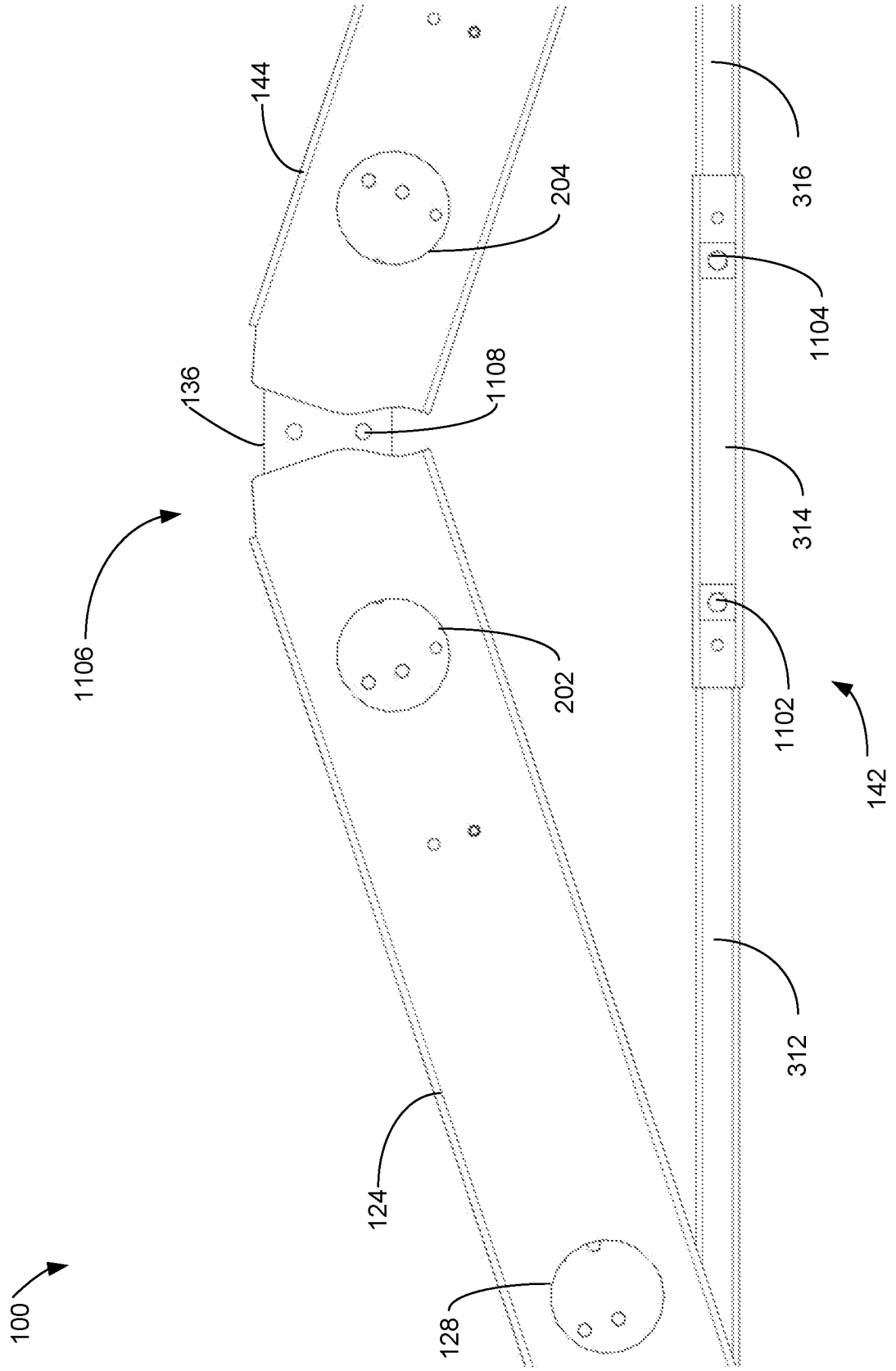

FIG. 11

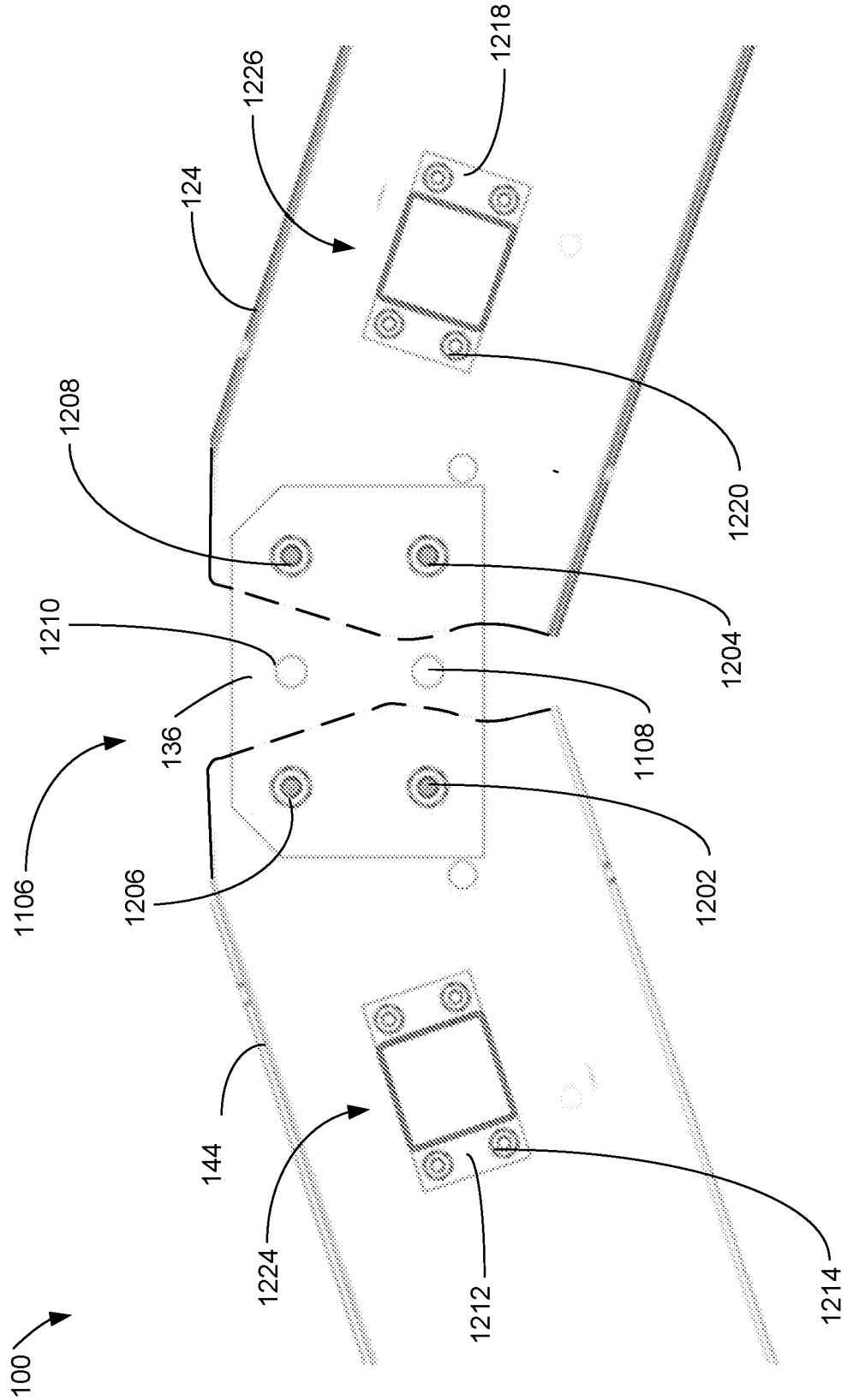
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FIG. 12

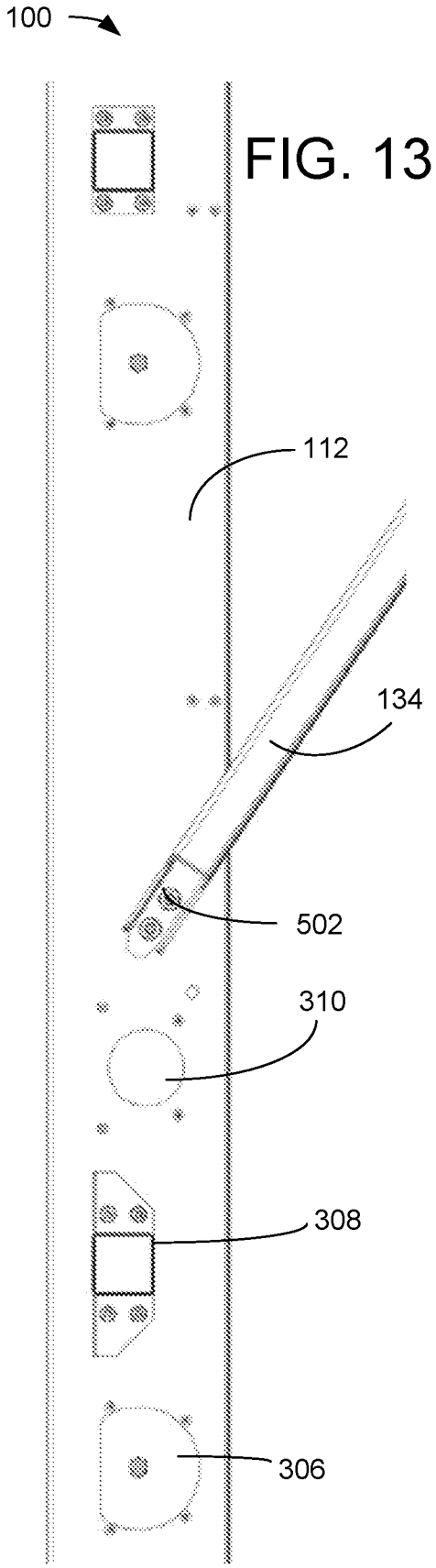

FIG. 13

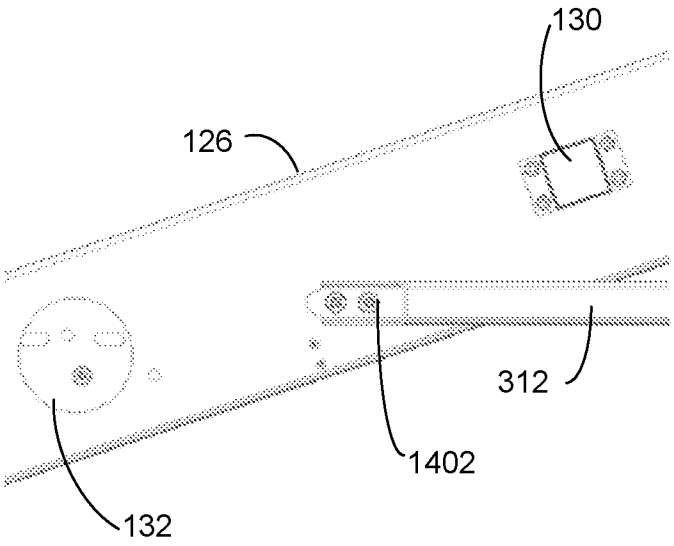

FIG. 14

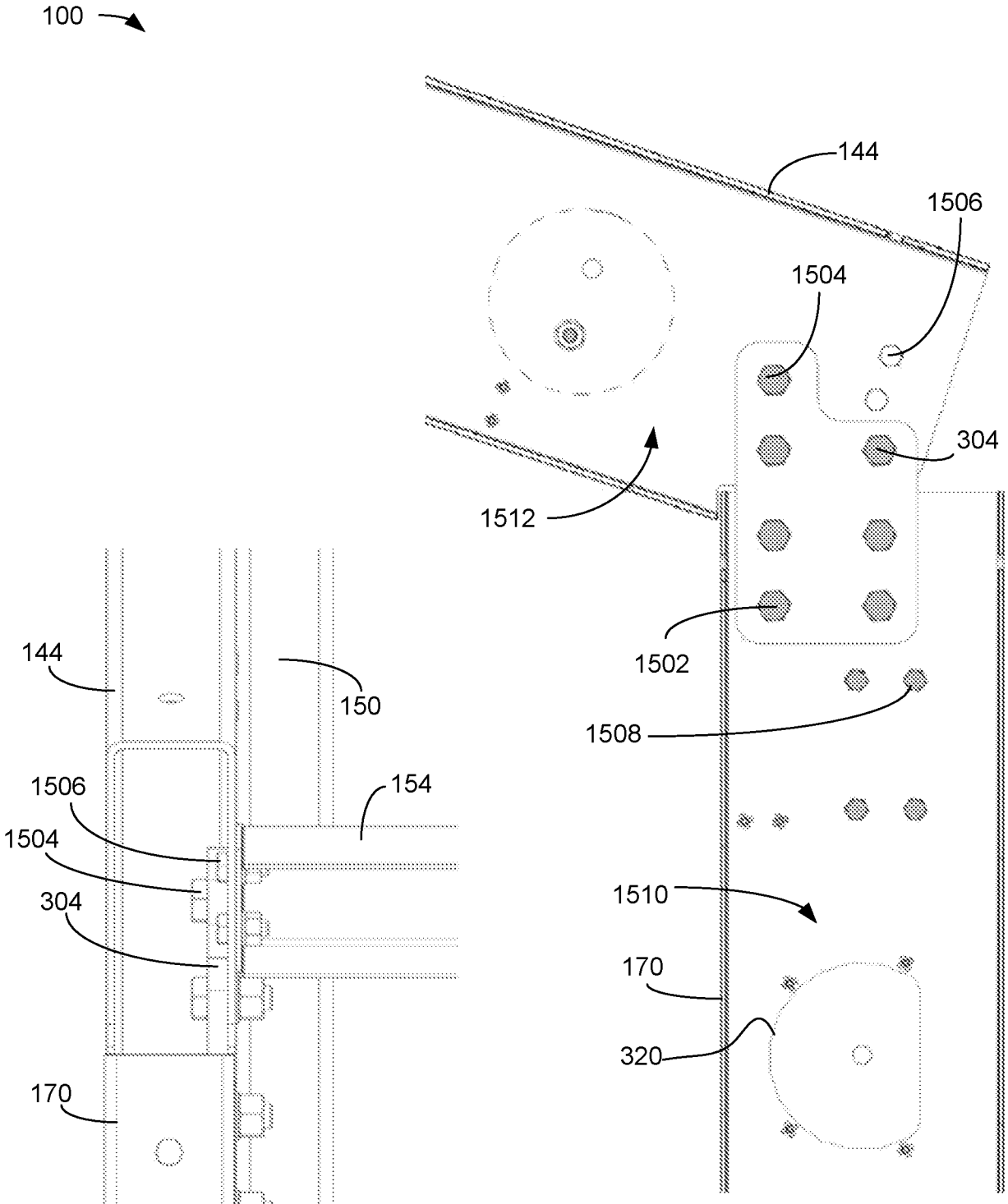
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FIG. 15

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FIG. 16

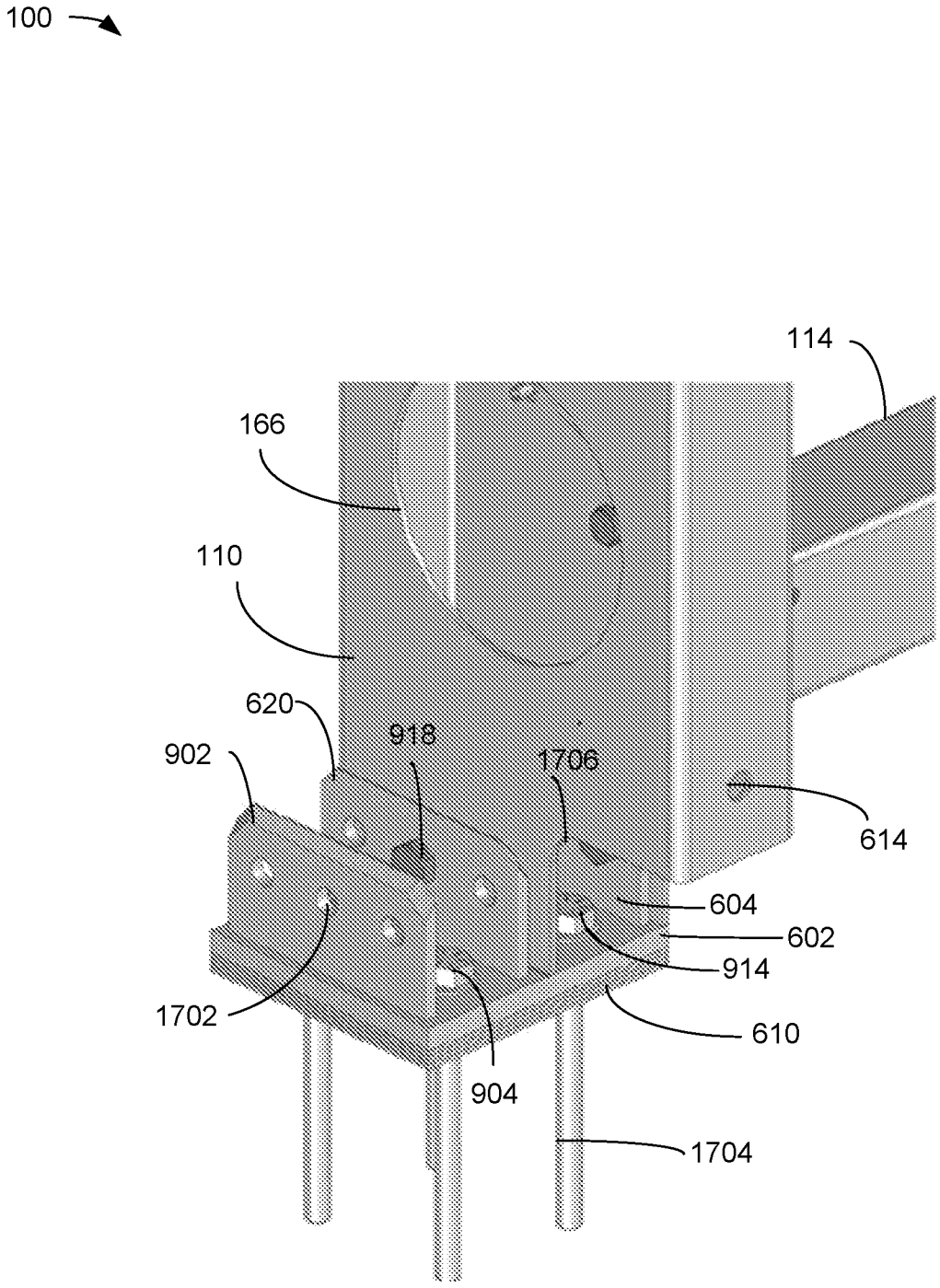
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FIG. 17

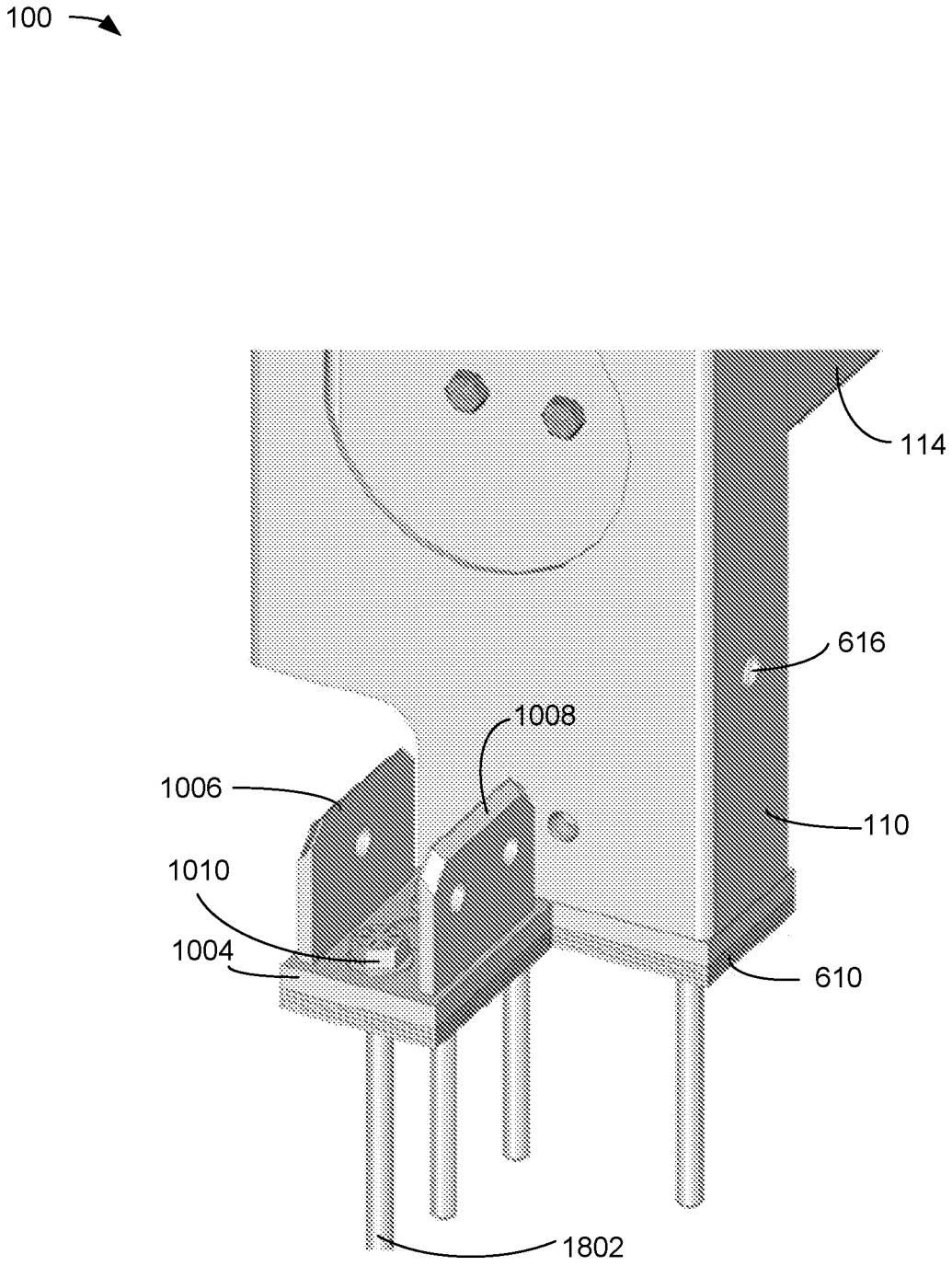

FIG. 18

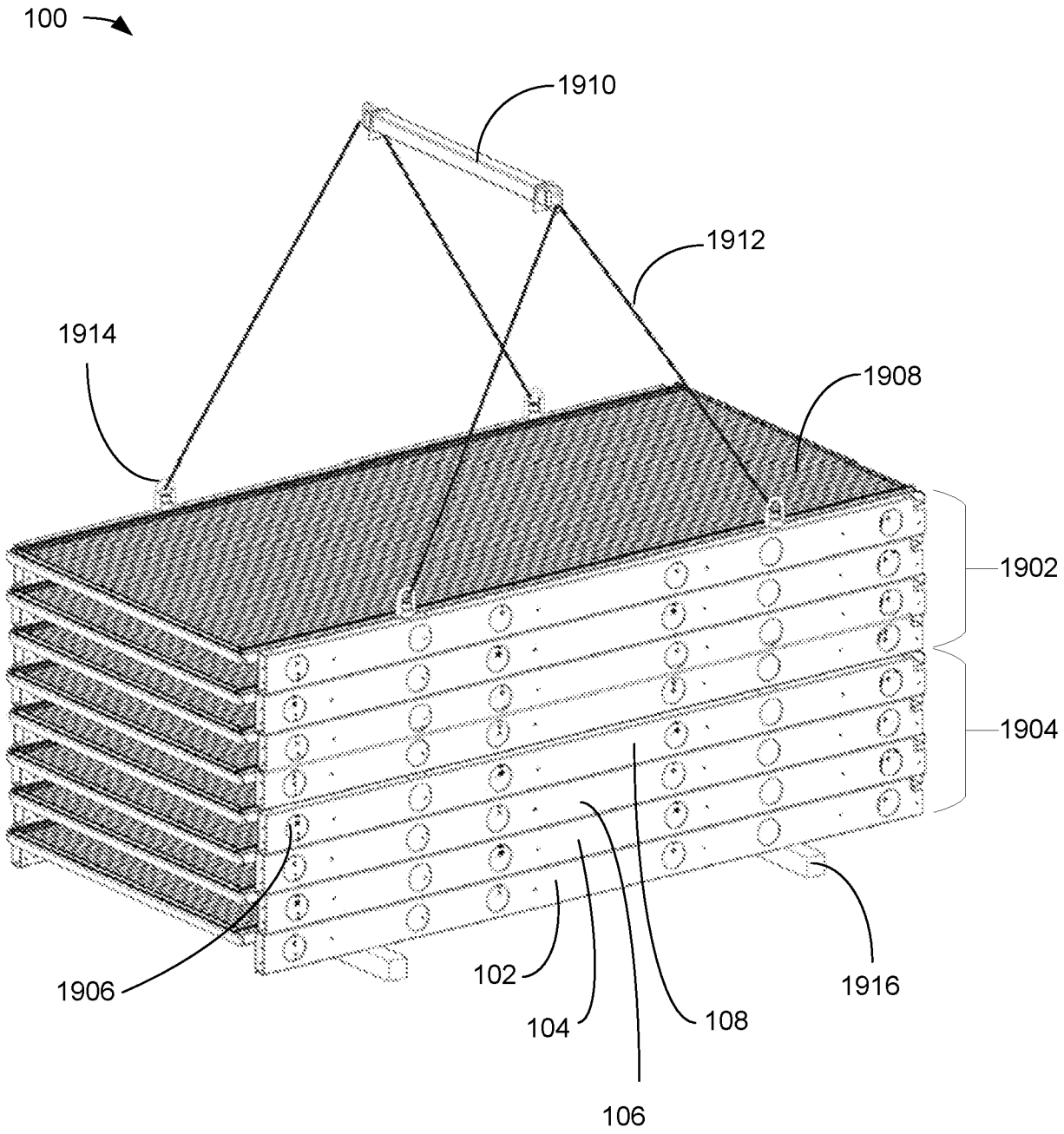

FIG. 19

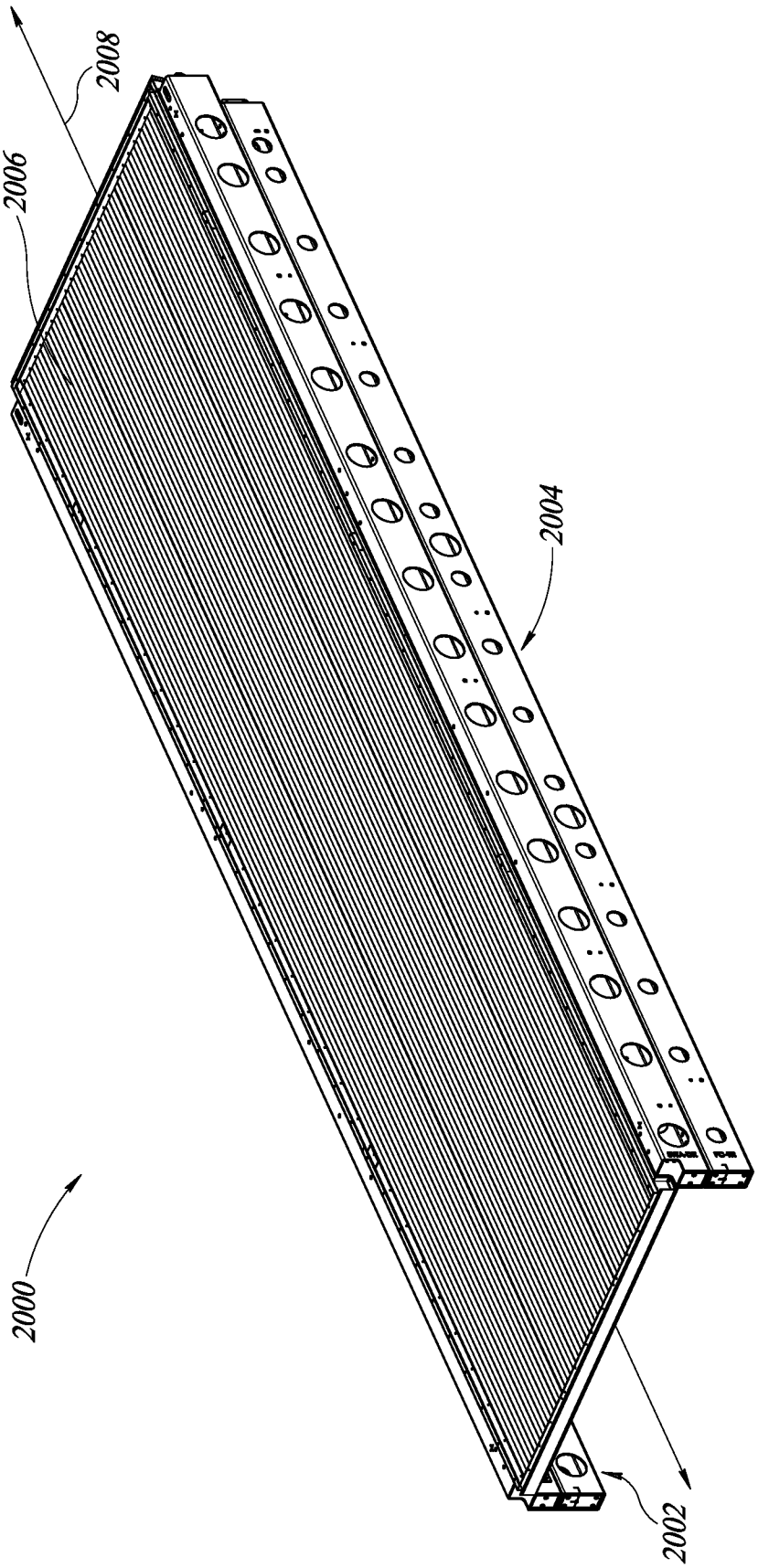

FIG. 20

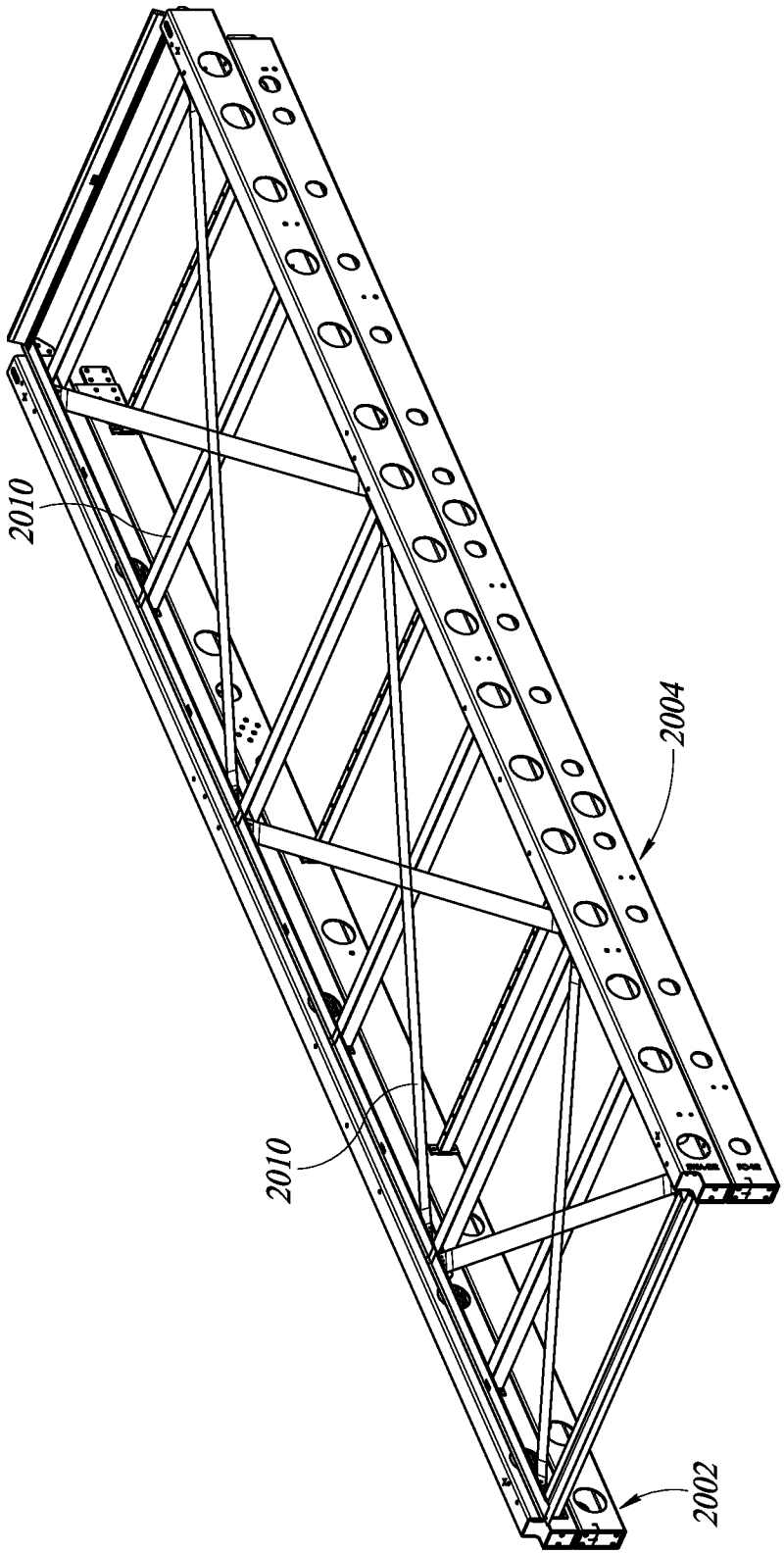

FIG. 21

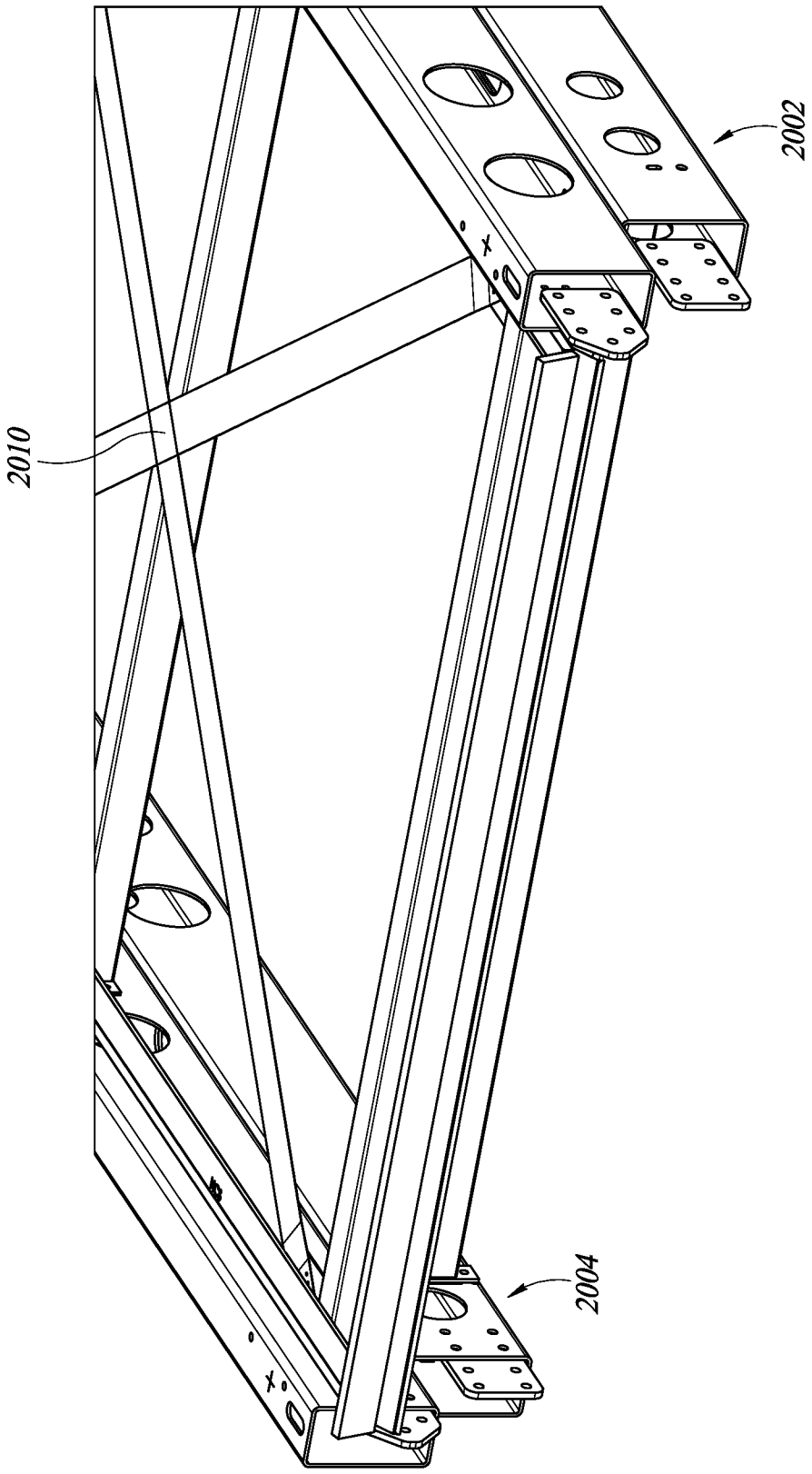

FIG. 22

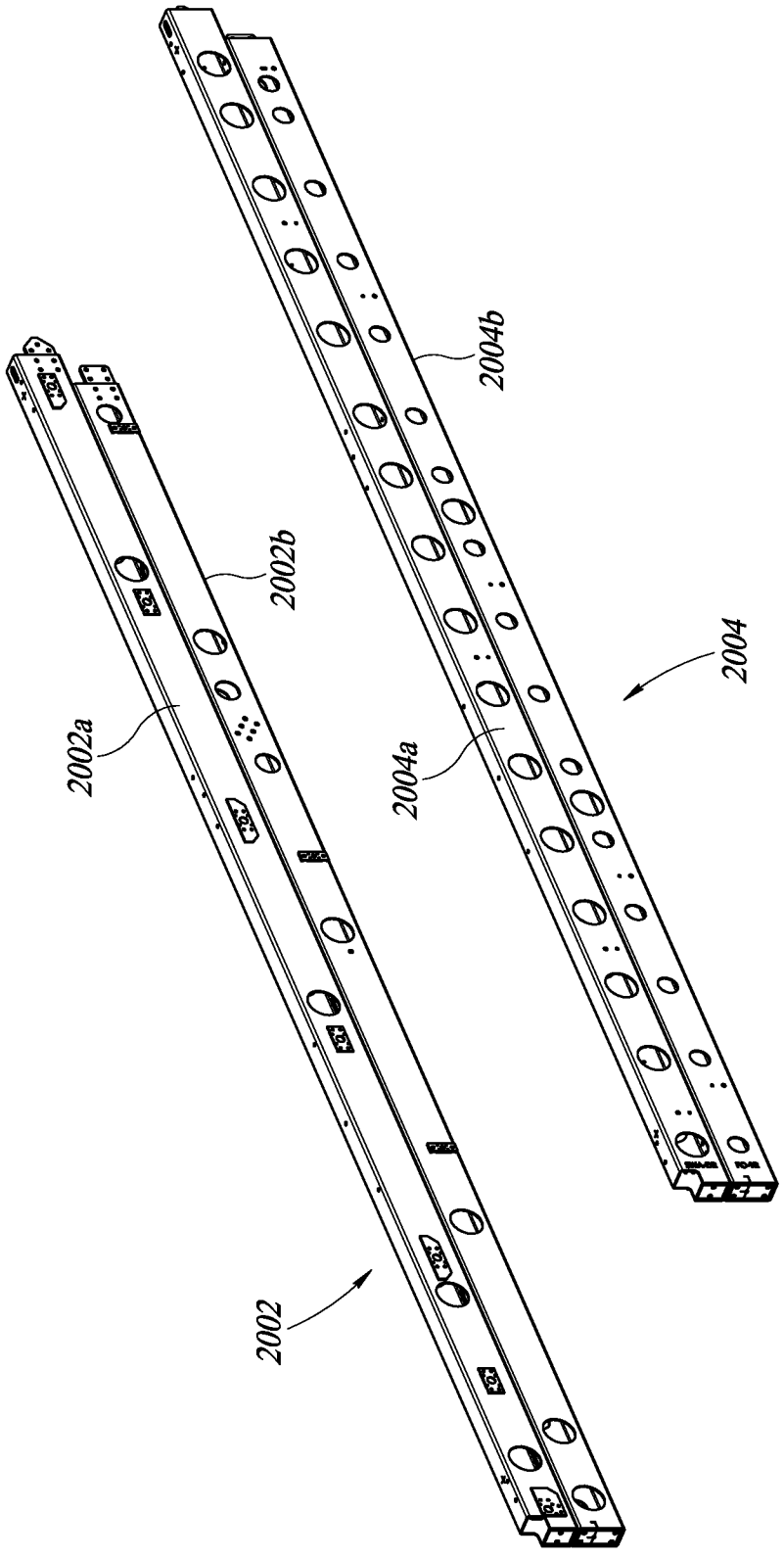

FIG. 23

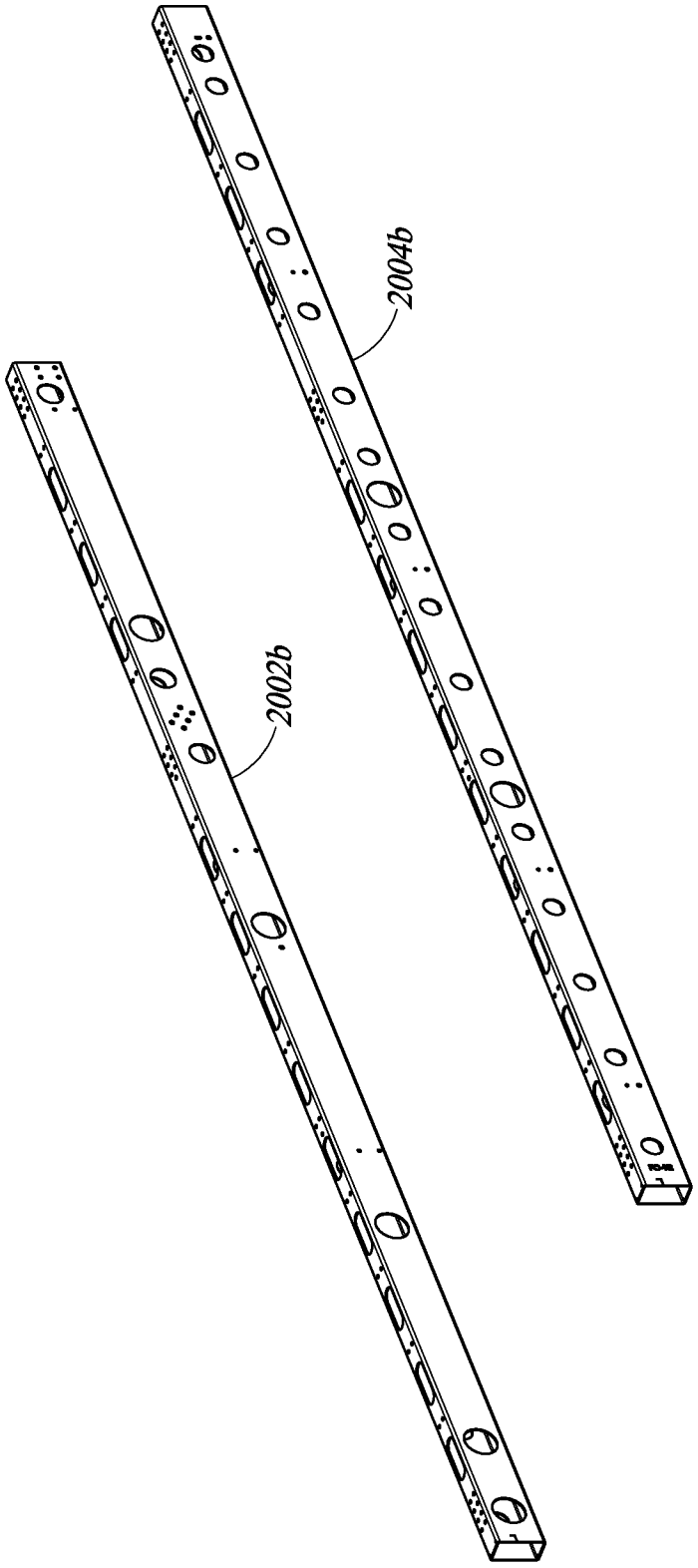

FIG. 24

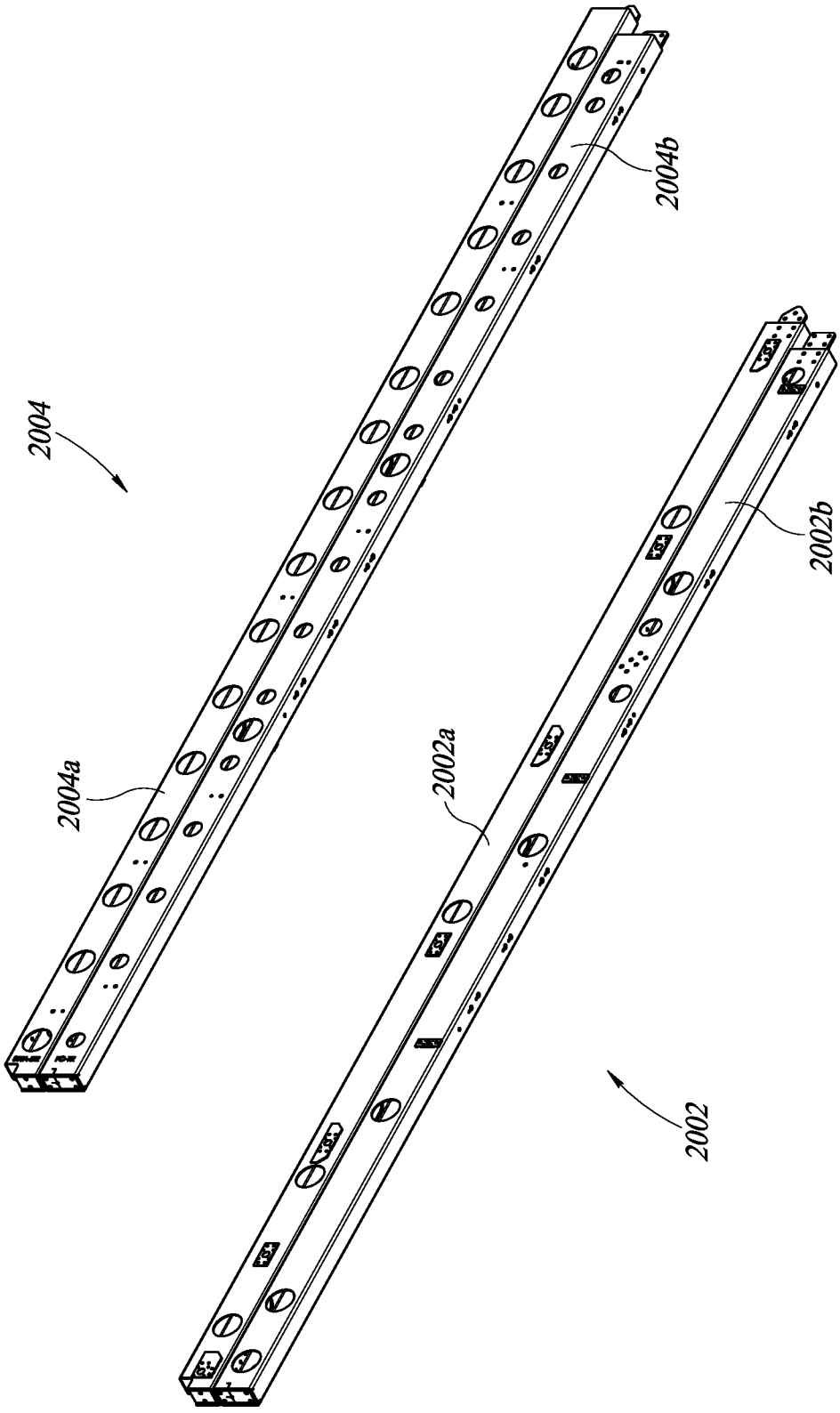

FIG. 25

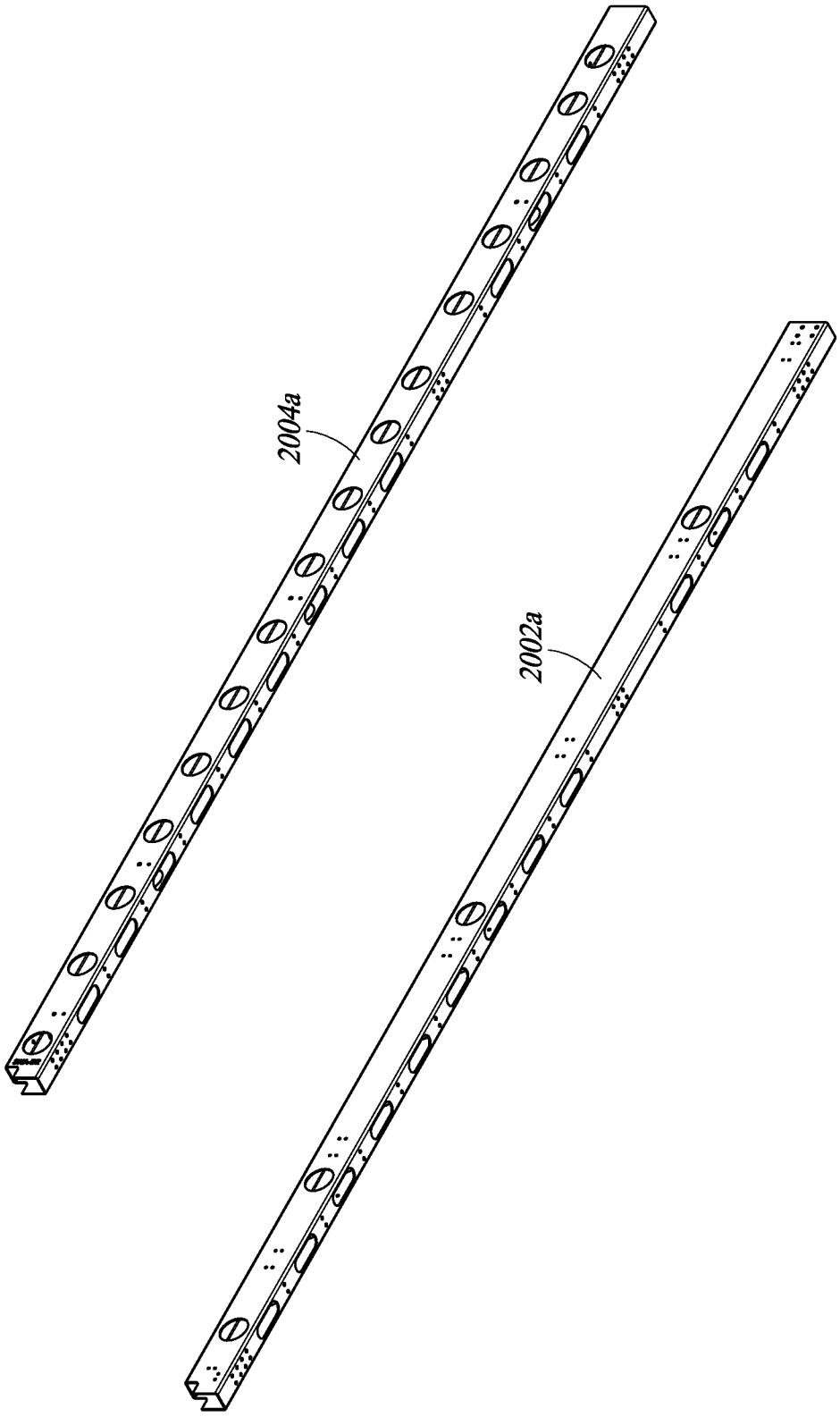

FIG. 26

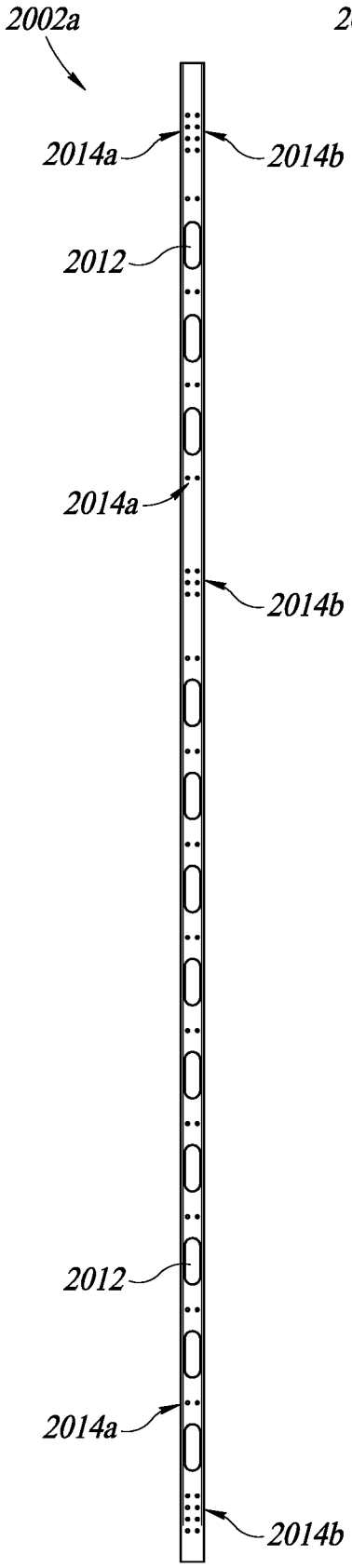

FIG. 27

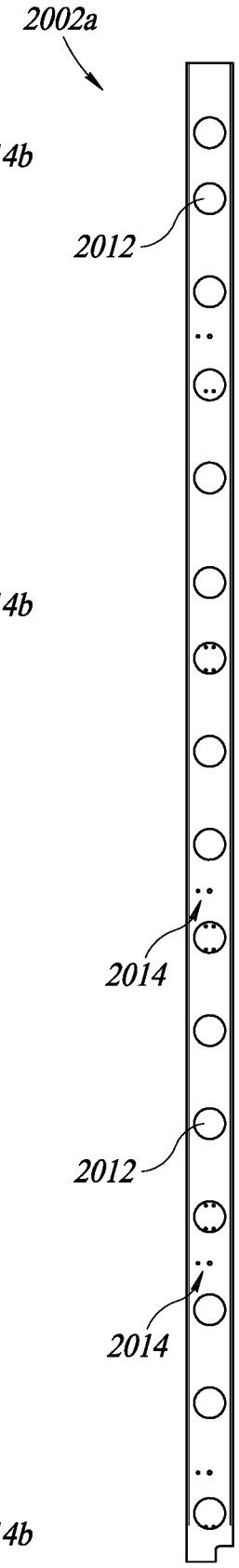

FIG. 28

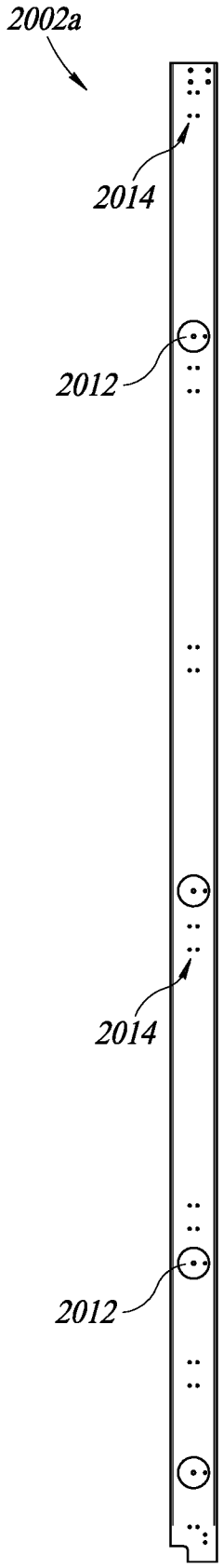

FIG. 29

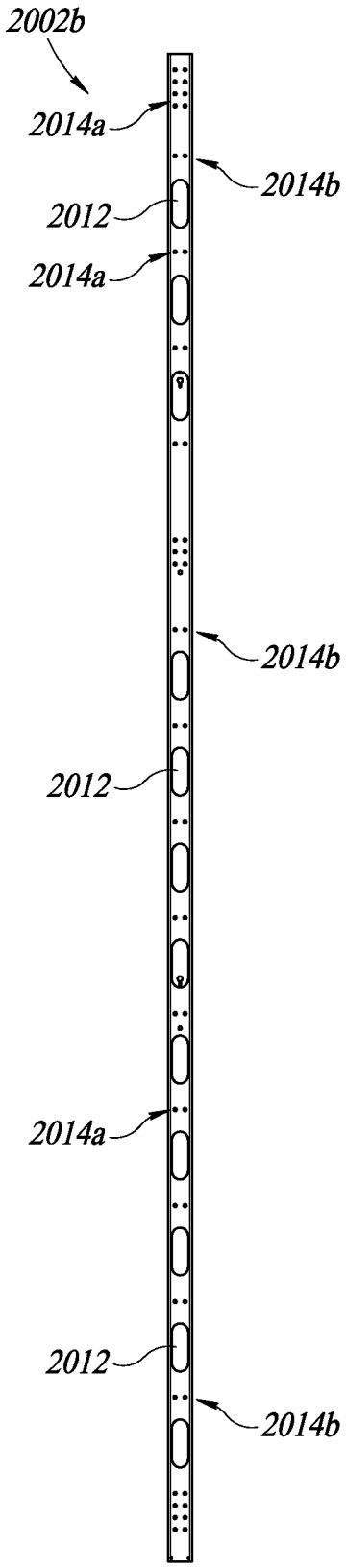

FIG. 30

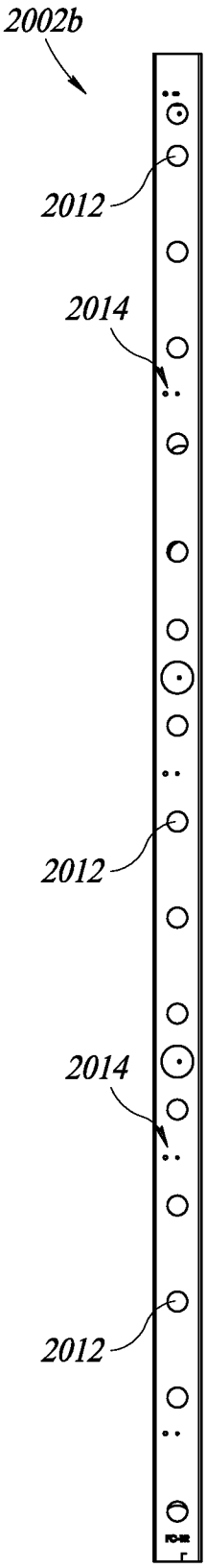

FIG. 31

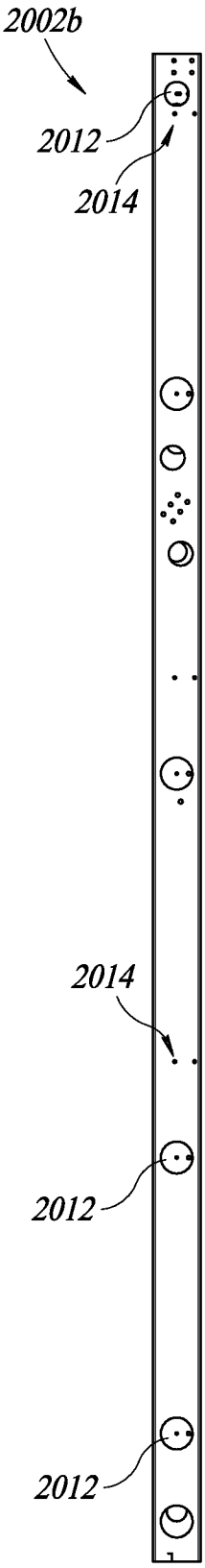

FIG. 32

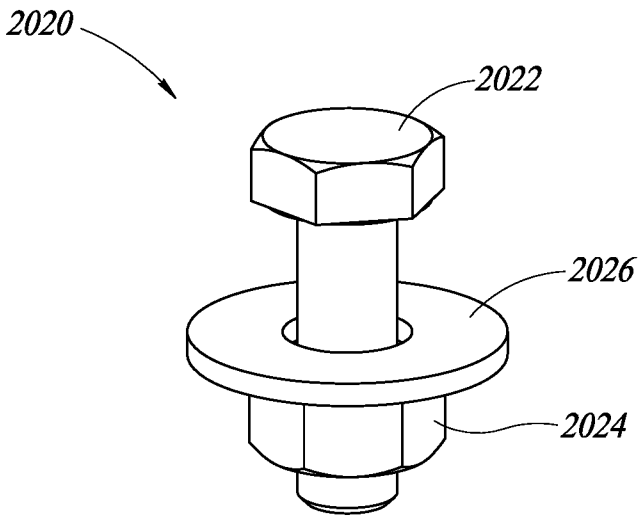

FIG. 33

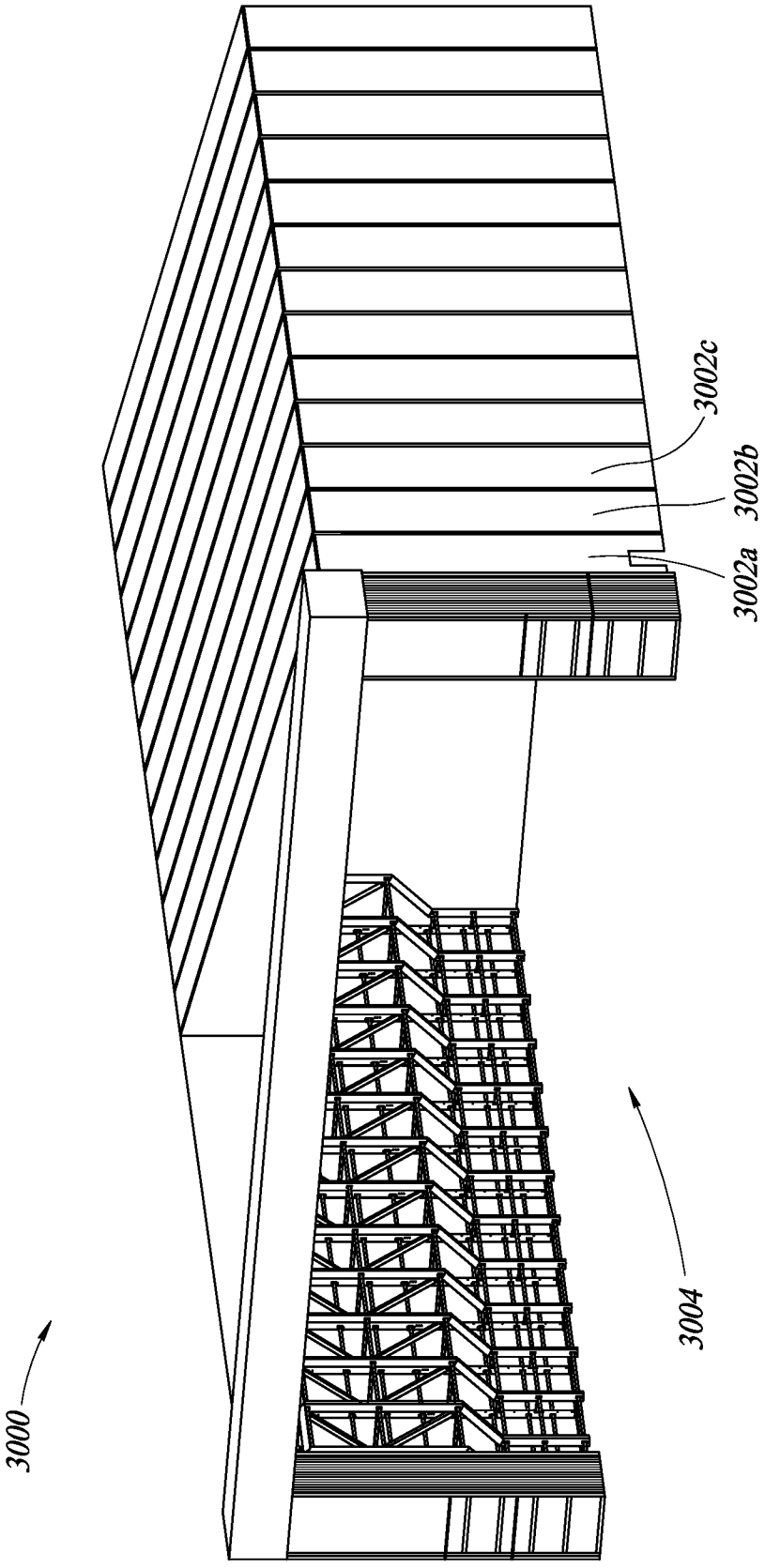

FIG. 34

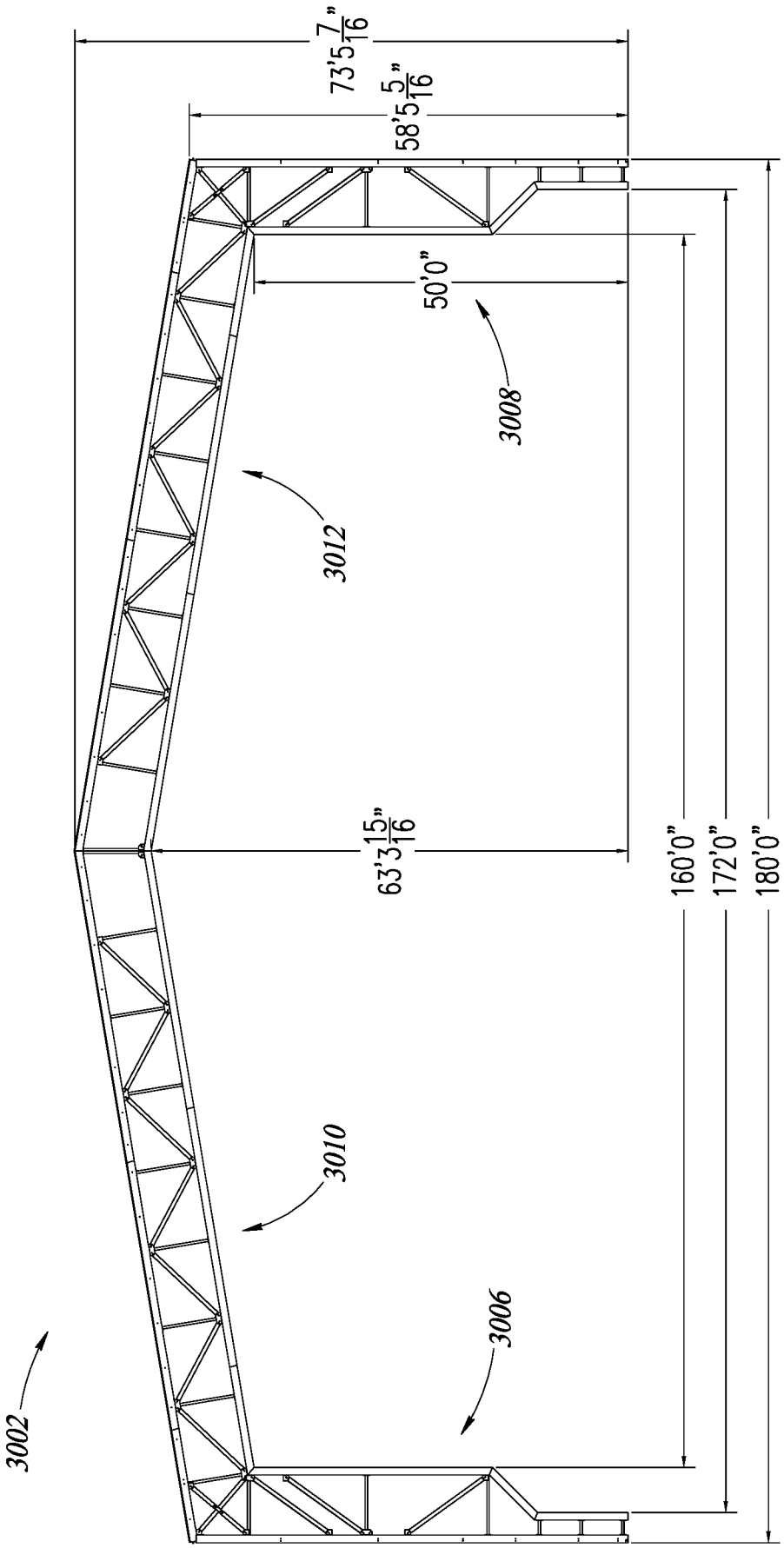
73'5 7/16"
58'5 5/16"
50'0"
3008
3012
63'3 15/16"
160'0"
172'0"
180'0"
3010
3006
3002

FIG. 35

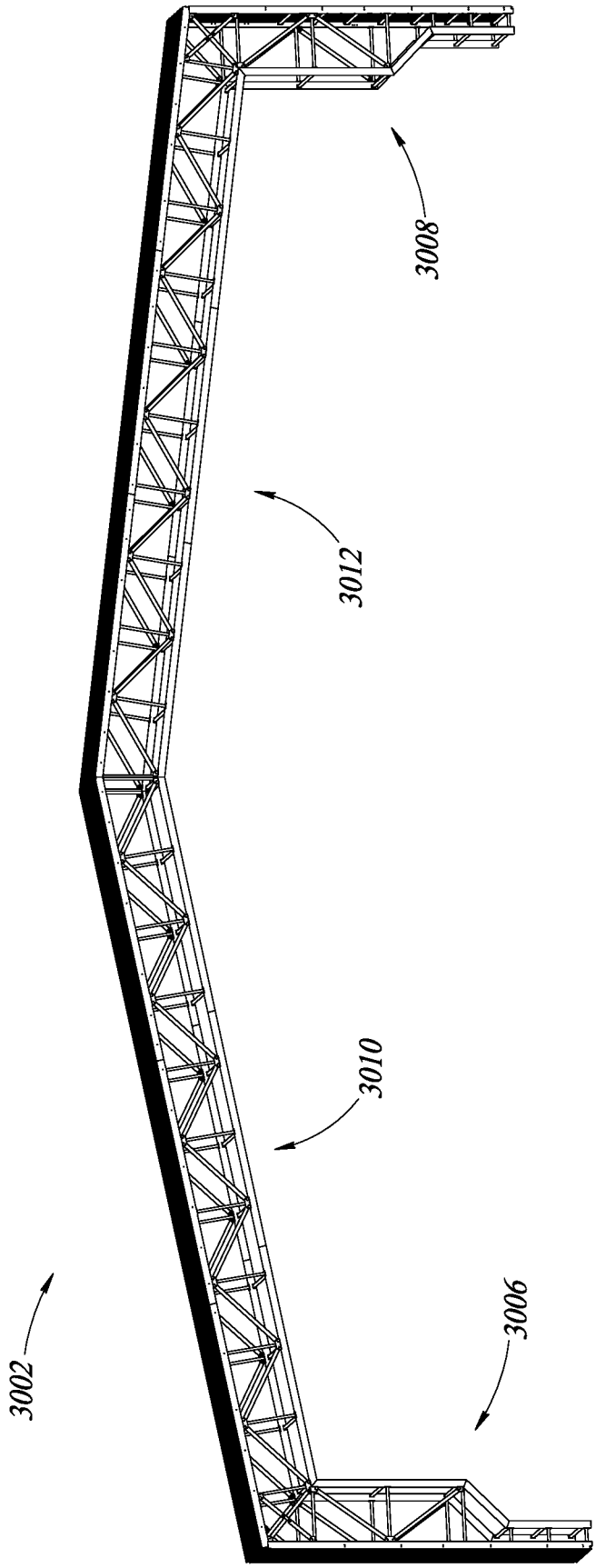

FIG. 36

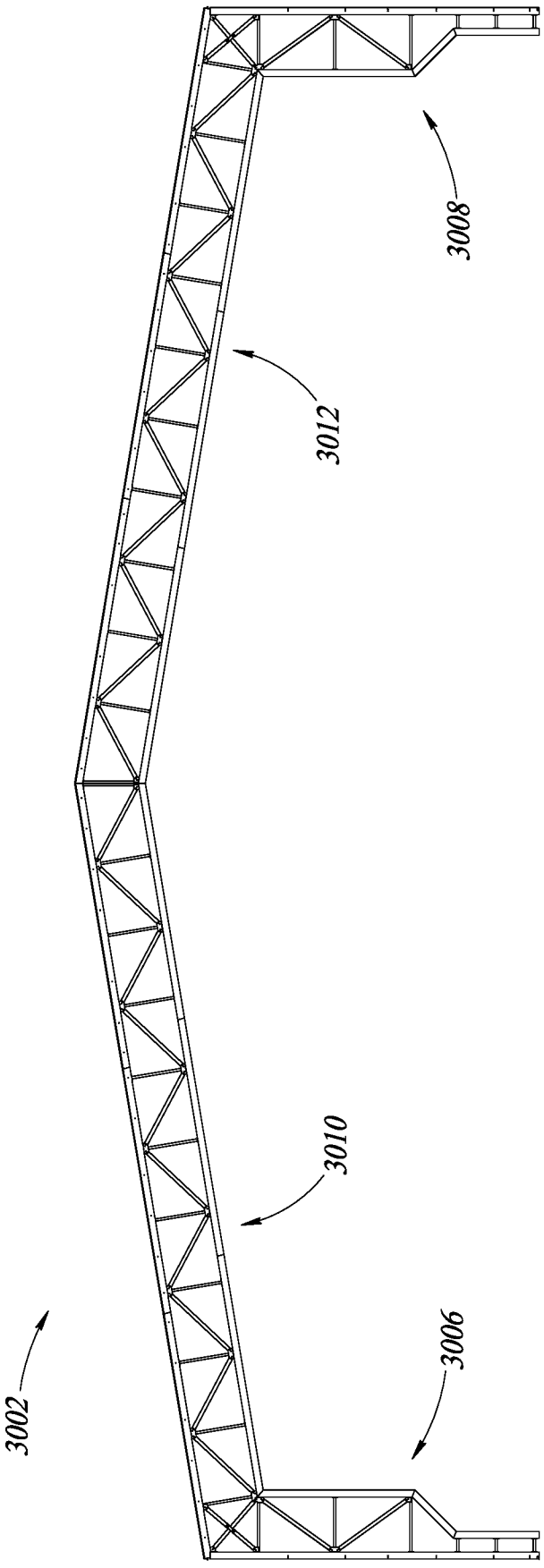

FIG. 37

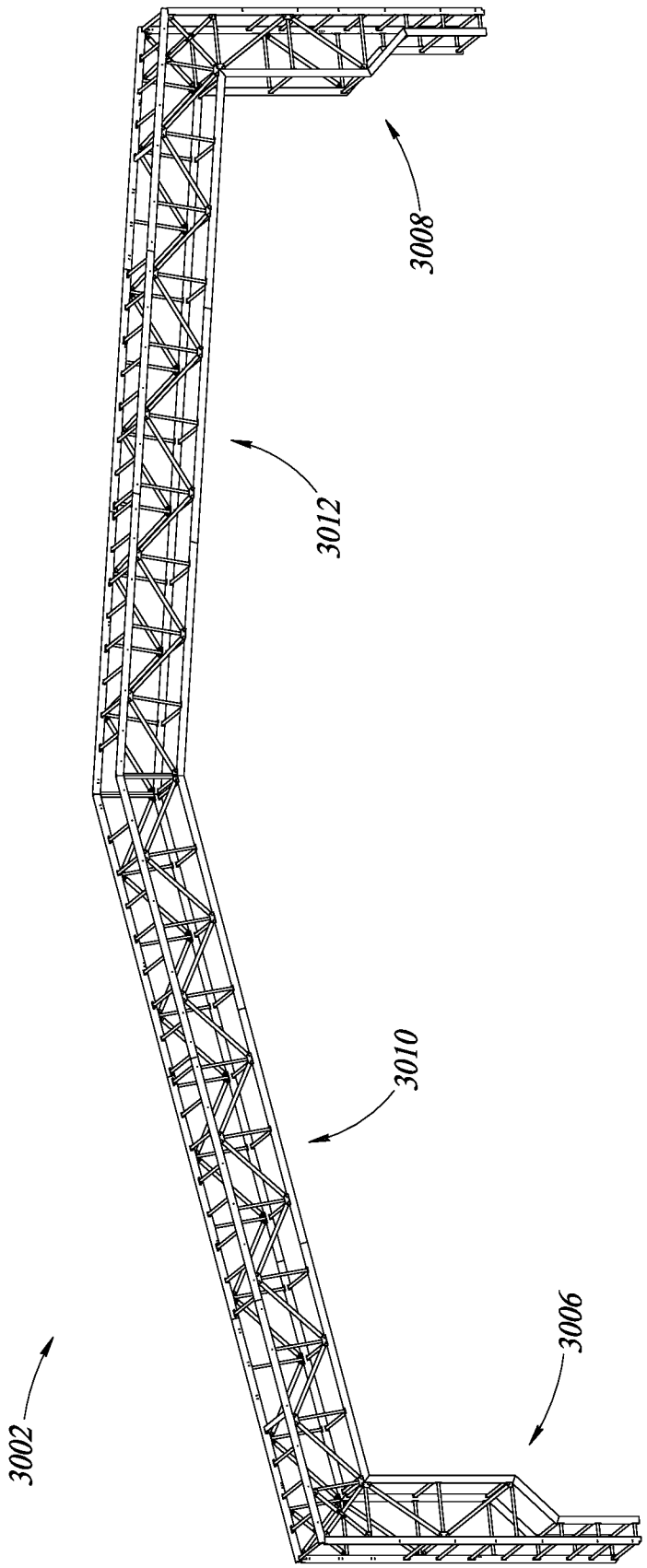

FIG. 38

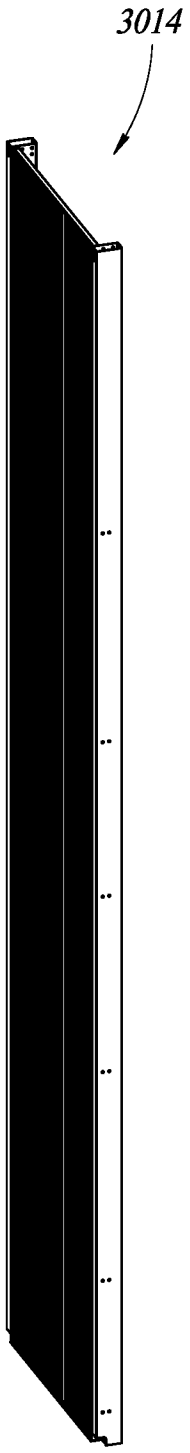

FIG. 39

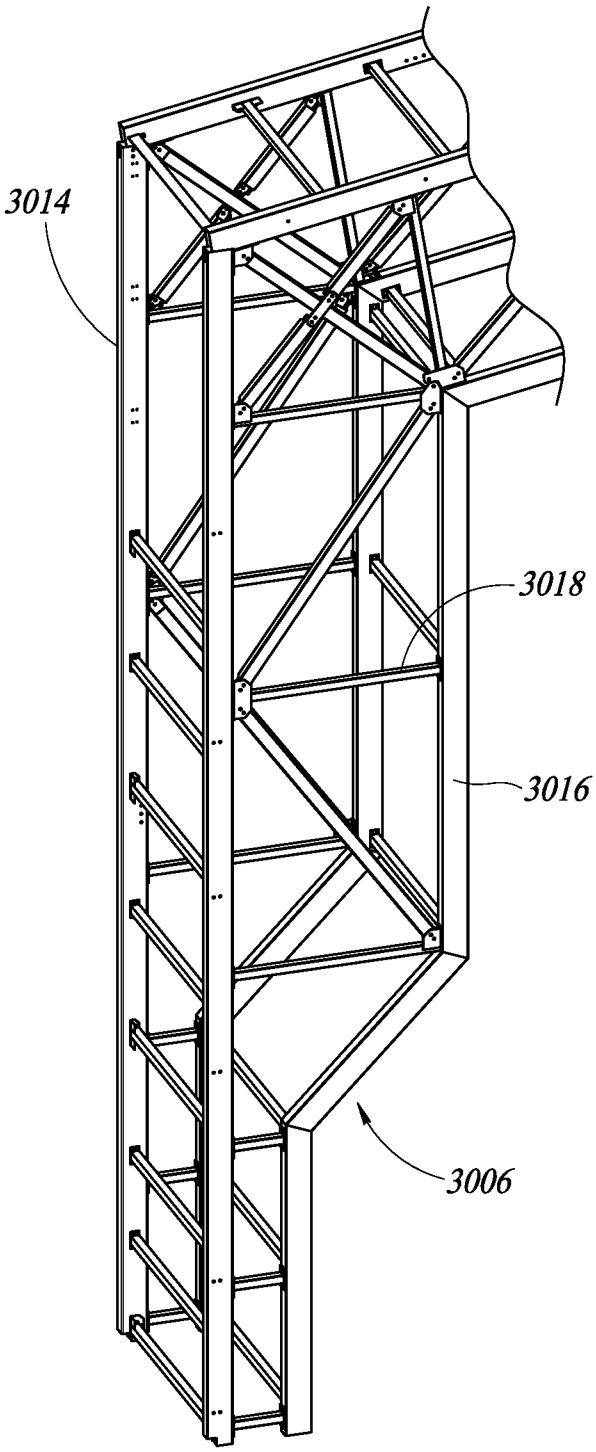

FIG. 40

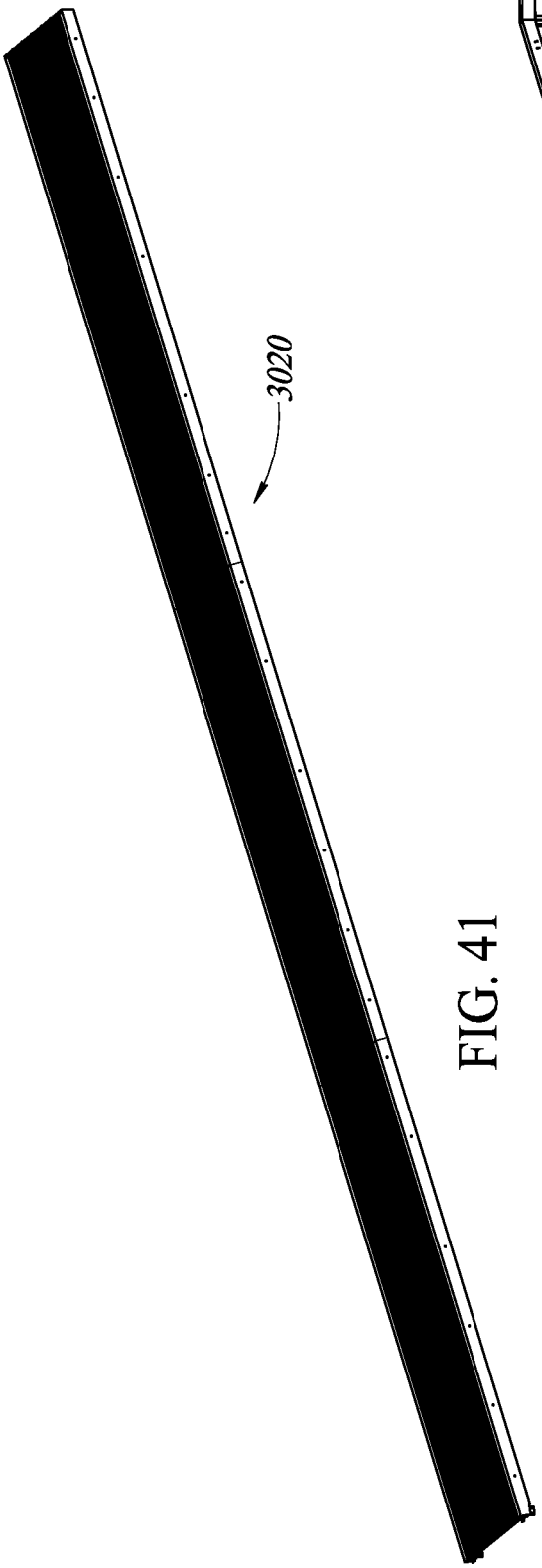

FIG. 41

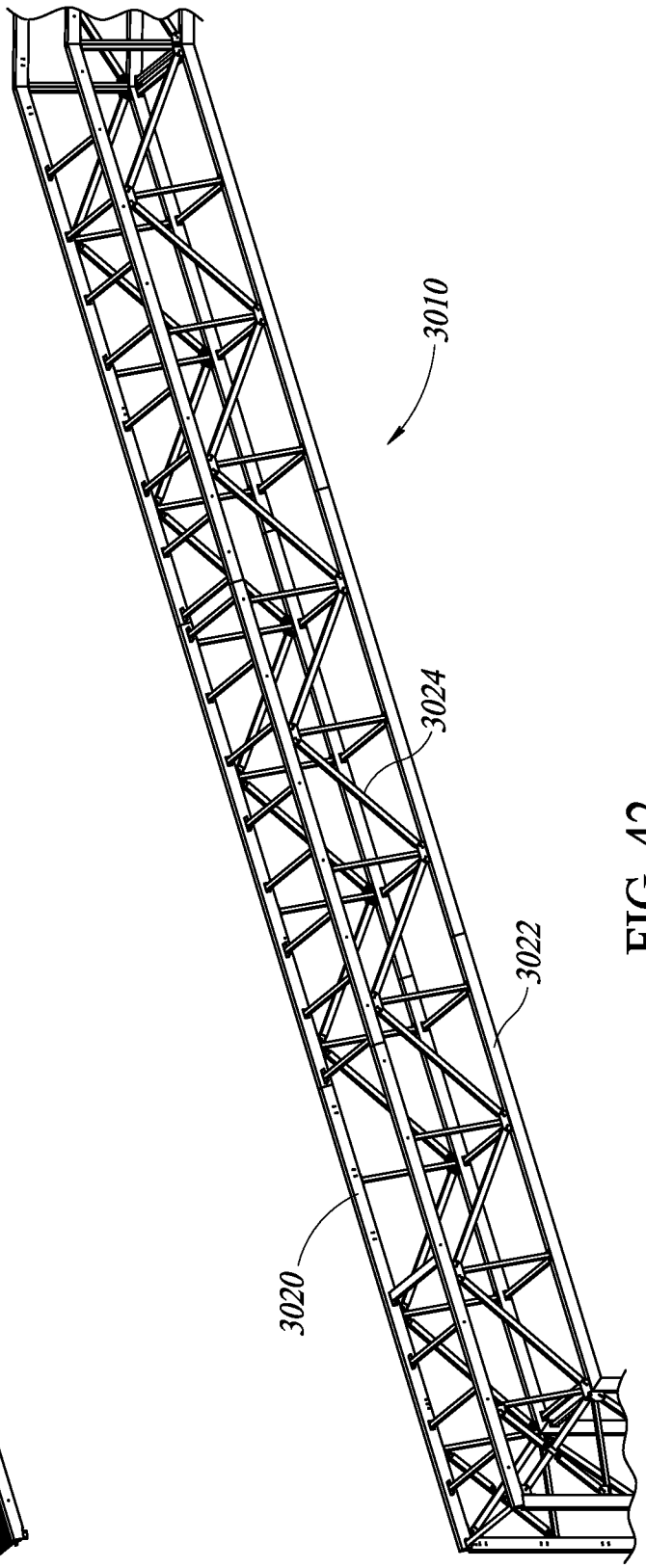

FIG. 42

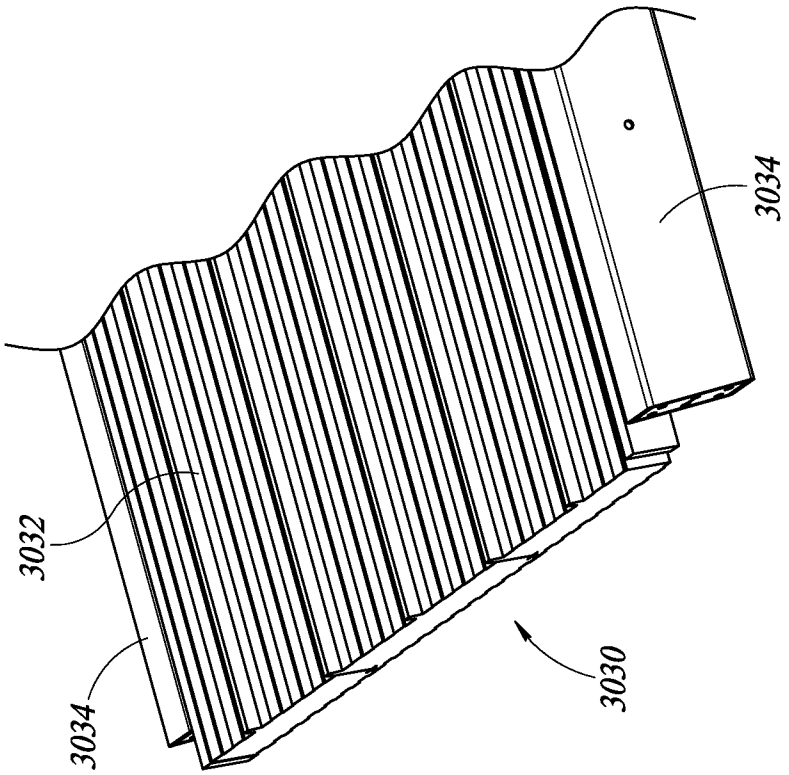

FIG. 44

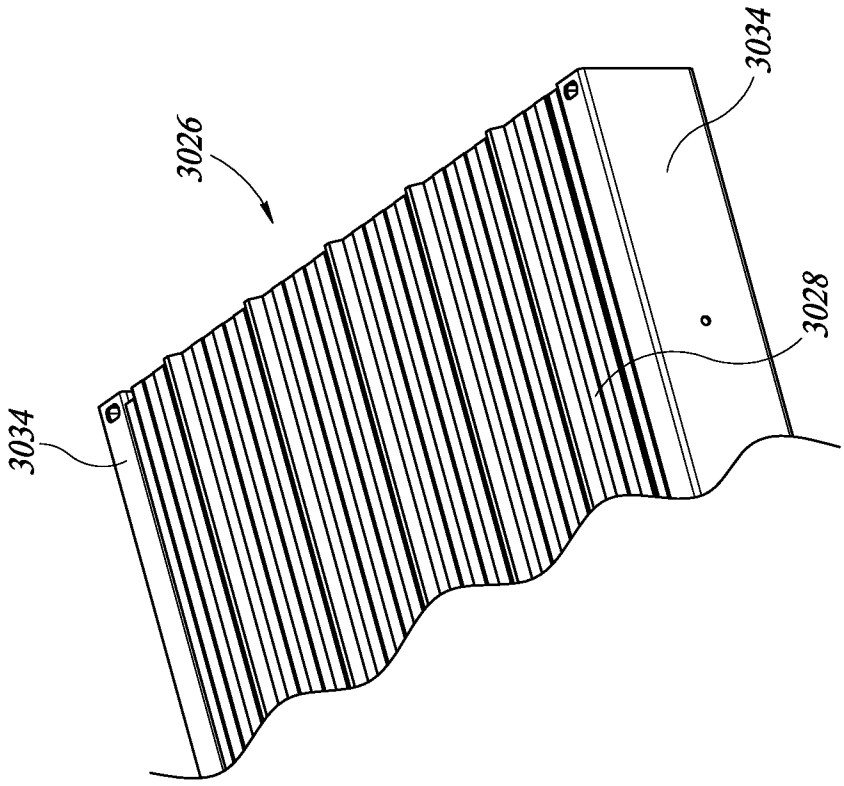

FIG. 43

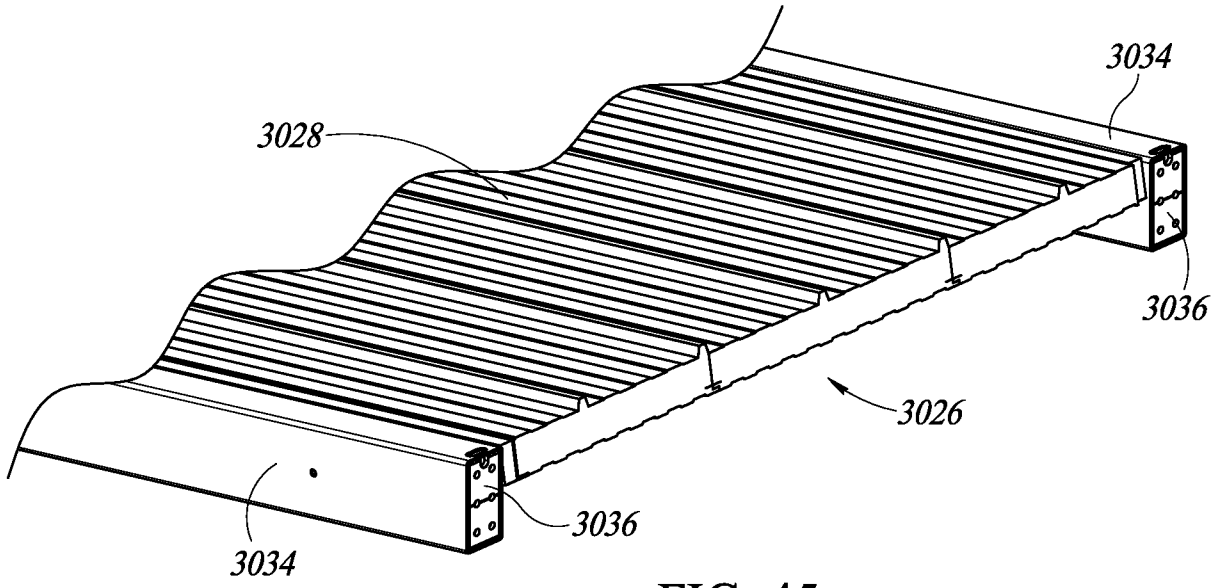

FIG. 45

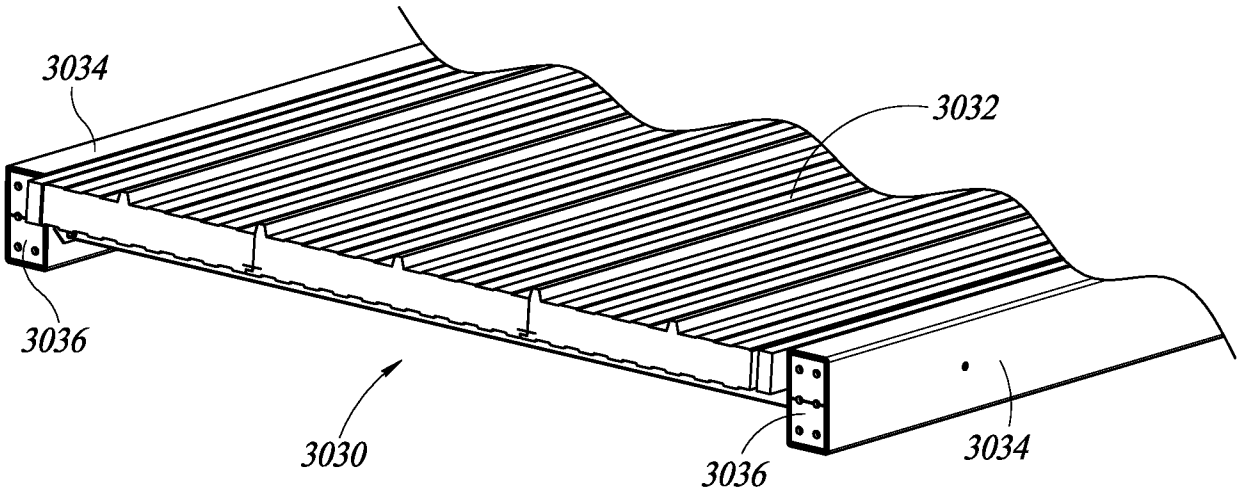

FIG. 46

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2023/023830

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - INV. - E04B 1/24; E04B 1/344 (2023.01)
ADD. - E04B 1/348; E04B 1/58 (2023.01)

CPC - INV. - E04B 1/2403; E04B 1/3445 (2023.08)

ADD. - E02D 2300/0029; E02D 2600/20; E04B 1/3483; E04B 1/58 (2023.08)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History document

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

Electronic database consulted during the international search (name of database and, where practicable, search terms used)
See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2021/0340752 A1 (FOLDING HOLDINGS LLC) 04 November 2021 (04.11.2021) entire document	1-4, 6-9, 19, 21, 23-27, 29, 31
Y	US 6,571,527 B1 (RATTINI) 03 June 2003 (03.06.2003) entire document	1-4, 6-9, 19, 21, 23-27, 29, 31
A	US 2014/0123587 A1 (LEE) 08 May 2014 (08.05.2014) entire document	1-14, 19-31
A	US 2008/0178551 A1 (PORTER) 31 July 2008 (31.07.2008) entire document	1-14, 19-31
A	US 2021/0017765 A1 (STRICKLAND) 21 January 2021 (21.01.2021) entire document	1-14, 19-31

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 August 2023	SEP 29 2023
Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300	Authorized officer Taina Matos Telephone No. PCT Helpdesk: 571-272-4300

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2023/023830

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See extra sheet(s).

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-14, 19-31

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2023/023830

Continued from Box No. III Observations where unity of invention is lacking

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, claims 1-14 and 19-31, is drawn to a method of fabricating a built-up structural element, comprising: obtaining a pair of steel hollow structural sections.

Group II, claims 15-18 and 32-38, is drawn to a method of fabricating a building, comprising: coupling the first and second steel hollow structural sections to one another via one or more spanning members to form a first structural assembly.

The inventions listed as Groups I-II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: the special technical feature of the Group I invention: obtaining a pair of steel hollow structural sections, each steel hollow structural section having a uniform cross-sectional profile over an entirety of a longitudinal length thereof; for each of the pair of steel hollow structural sections, cutting a plurality of openings in the steel hollow structural section to vary the cross-sectional profile of the steel hollow structural section over the longitudinal length thereof; for each of the pair of steel hollow structural sections, cutting a plurality of bolt holes distinct from the plurality of openings in the steel hollow structural section along the longitudinal length thereof; stacking the pair of steel hollow structural sections together to form a stacked configuration in which the plurality of bolt holes of each steel hollow structural section align with each other; and bolting the pair of steel hollow structural sections together via the plurality of bolt holes to secure the pair of steel hollow structural sections together in the stacked configuration as claimed therein is not present in the invention of Group II. The special technical feature of the Group II invention: coupling the first and second steel hollow structural sections to one another via one or more spanning members to form a first structural assembly; shipping the first structural assembly to an installation location in a first package; fabricating a third steel hollow structural section; fabricating a fourth steel hollow structural section; shipping the third and fourth steel hollow structural sections to the installation location in a second package distinct from the first package; stacking the first and third steel hollow structural sections together at the installation location; bolting the first and third steel hollow structural sections together at the installation location; stacking the second and fourth steel hollow structural sections together at the installation location; and bolting the second and fourth steel hollow structural sections together at the installation location as claimed therein is not present in the invention of Group I.

Groups I and II lack unity of invention because even though the inventions of these groups require the technical feature of fabricating a pair of steel hollow structural sections, this technical feature is not a special technical feature as it does not make a contribution over the prior art.

Specifically, US 2020/0354950 to Z-MODULAR HOLDING, INC. teaches fabricating a pair of steel hollow structural sections (the upper corner connector 102 and lower corner connector 8 can be made from hollow castings of steel, para. 0145. The connector bodies (108, 10) are 4″ square to accept a 4″ ×4″ Hollow Structural Section (HSS). In another embodiment, the connector bodies (108, 10) are 6″ square to accept a 6″ ×6″ HSS. Connectors 102 and 8 have adequate thickness for the intended function and details such as draft angles and uniformity of sections which facilitate casting, para. 0147).

Since none of the special technical features of the Group I or II inventions are found in more than one of the inventions, unity of invention is lacking.