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(71) Applicant and
(72) Inventor *(for all designated States except US)*: **ZWERN, Arthur, Louis** [US/US]; 2226 Coastland Avenue, San Jose, CA 95125 (US).

(74) Agents: **FORD, Stephen , S.** et al.; Stolowitz Ford Cowger LLP, 621 Sw Morrison Street, Suite 600, Portland, OR 97205 (US).

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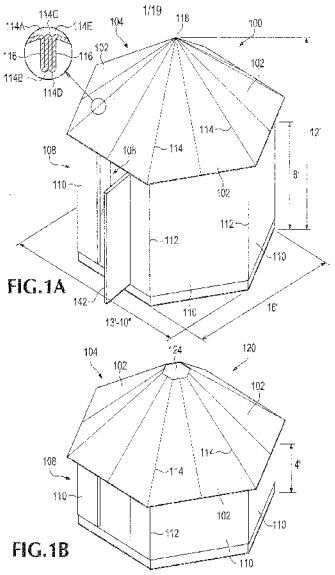
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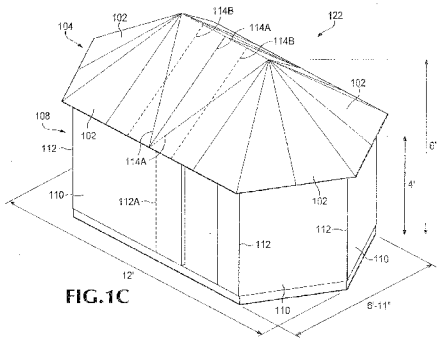
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(54) Title: FOLDABLE BUILDING STRUCTURES





(57) Abstract: A foldable building structure includes a wall assembly made from a semi-rigid continuous sheet material configured with creases that enable the sheet material to be bent or folded to form multiple integrally formed together walls. A roof assembly can be formed from a second semi-rigid continuous sheet material that is configured with creases that enable the sheet material to be bent or folded to form multiple integrally formed roof panels. A floor assembly can be made out a third semi-rigid continuous sheet of material that also can be folded to form foundation members and floor panels.

FOLDABLE BUILDING STRUCTURES

Field of Invention

The application pertains to foldable structures used for rapidly deploying low-cost housing, relief shelters, trade show booths, festival shelters/booths, backyard sheds, camping outposts, military checkpoints, and many other purposes.

Background

Structural panels, such as building insulation, have been used along with tape to assemble hexagonal structures in the manner of ancient yurts. The panels are cut along a diagonal to make roof panels. Tape is used to assemble the panels, seal the edges from weather, spread loads, and provide a tension ring around the base of a roof panel to transmit roof loads directly downwards onto wall panels as is a common feature of yurts. Holes are cut in the panels for windows and doors, often with one edge taped as a hinge.

In one example, the panels used for assembling the structure are pre-cut and packed flat for shipping as a 4'x 8' stack. Various seams between the panels may be pre-taped during fabrication, folded up for transport, and unfolded in the field, reducing the number of seams that require taping during deployment. The exterior wall and roof panels are typically made out of a layer of aluminum-coated polyisocyuranate, or other types of rigid foam core thermal insulation panels with a foil facer on each side, although other materials such as cardboard or plywood may be used.

Summary

Structures are assembled from foldable panels that do not require cutting or taping. An entire wall, roof, or floor assembly, and other optional features, are produced as single continuous sheets of a substantially rigid multilayer material. The sheets can be folded accordion-style into a 4'x 8', or other sized stack for transport, and then unfolded in the field to rapidly form different self standing structures.

These continuous foldable structures are more weather resistant and easier to assemble since there are fewer seams that have to be physically bonded together, and the fold creases do not suffer from problems of tape degradation that impact lifetime. The continuous sheet material has a width that corresponds with an intended wall height or roof shape. Creases are stamped into the rigid sheet that corresponds with particular structural shapes, such as a wall assembly or roof assembly. Additional creases enable a wide variety of optional integrated structures, including structural stiffening members, shelf and seating supports, room dividers, utility closets, and many others. During manufacturing, holes and slots can be cut into the sheets at pre-determined locations for window openings, holes, and other assembly features. The only other cuts that need to be made during manufacturing are between the sheets that form different wall or roof assemblies of different building structures.

The foregoing and other objects, features and advantages of the invention will become more readily apparent from the following detailed description of preferred embodiments which proceeds with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A-1C are perspective views of foldable housing structures.

FIG. 2 shows a continuous sheet used for forming a wall assembly.

FIG. 3 is a perspective view showing how ends of the wall assembly in FIG. 2 are joined to a door assembly.

FIG. 4A-4C are side sectional views of flashing used in the housing structures of FIGS. 1A-1C.

FIGS. 5A-5C shows how creases are formed in the continuous sheets of material to form housing structures.

FIG. 6 is a top plan sectional view for a wall assembly formed from a continuous sheet of material similar to that shown in FIG. 2.

FIG. 7 is a close up view for a portion of a door way for the wall assembly shown in FIG. 6.

FIG. 8 shows cutouts and creases in a wall panel that when folded together form a desk.

FIG. 9 shows the desk formed by the cutouts and creases of FIG. 8.

FIGS. 10A and 10B show how the continuous sheet for any wall configuration can be folded up into a single stack of equally sized sections.

FIGS. 11A-11C show how a sheet of material can be folded into a roof panel.

FIG. 12A and 12B shows sectional views inside of a foldable housing structure.

FIGS. 13-15 show how continuous sheets of material are creased and folded into roof assemblies.

FIG. 16 is a sectional view of another embodiment of a foldable housing structure seated on a floor assembly.

FIG. 17 is a perspective view of foundation members used for forming the floor assembly of FIG. 16.

FIG. 18 shows an alternative embodiment of foundation members used for forming the floor assembly in FIG. 16.

FIGS. 19A and 19B show other components of the floor assembly.

FIG. 20 shows another alternative embodiment of foundation members used for forming the floor assembly in FIG. 16.

FIG. 21 is a side view of a housing structure configured for sitting on an inclined ground surface.

DETAILED DESCRIPTION

FIGS. 1A-1C show examples of housing or storage structures that are made from continuous sheets of creased and/or folded material. Only a few examples are shown below for illustrative purposes. However, it should be understood that an almost limitless number of different structure shapes and sizes can be created from the creasing and folding schemes described below.

FIG. 1A shows a six sided hexagon housing structure 100 that can be erected from two continuous sheets of substantially rigid material. A first sheet of material is used to form the entire six sided wall assembly 108 and a second sheet of substantially rigid material can be used to form the entire roof assembly 104. The wall assembly 108 and roof assembly 104 each comprise multiple subsections referred to generally as wall

panels 110 and roof panels 102, respectively. The assembled hexagon structure 100 has an overall height of 12', an overall length of 13' 10", and an overall width of 16', although a wide variety of shapes and sizes are possible.

The wall panels 110 and roof panels 102 are formed from continuous sheets of relatively rigid material (see FIG. 2), but are separately delineated by horizontal or angled creases. For example, the different wall panels 110 are separately folded and oriented along horizontal creases 112 and the different roof panels 102 are separately folded and oriented along radially angled creases 114. One example process for forming the creases 112 and 114 is described in more detail below in FIGS. 5A and 5B.

In one embodiment, the wall panels 110 and roof panels 102 are each 8' (feet) high and 4' (feet) wide. Of course, this is only one example of the almost limitless combination of sizes that can be used for panels 102 and 110. The height of the wall panels 110 and roof panels 102 correspond to the width of the sheets used for making the wall assembly 108 and roof assembly 104, respectively. The width of the wall panels 110 and roof panels 102 correspond with the location of creases 112 and 114, respectively, formed on the continuous sheets.

The only seams that need to exist in the wall assembly 108 or roof assembly 104 are between the opposite ends of their associated continuous sheets of material. In one embodiment, the opposite ends of the continuous sheet forming wall assembly 108 form doorway 106, which prevents the seam from creating an extra potential leak path since a doorway is needed in any embodiment. A door 142 can be attached with hinges to one side of the wall assembly 108 for closing into doorway 106.

The continuous sheets of material (FIG. 2) used for forming the wall assembly 108 and roof assembly 104 are substantially rigid and therefore can be used for assembling free standing structures. However, such rigid materials are typically not naturally bendable or foldable to any significant degree without damaging the material. Thus, these types of rigid materials are typically cut into panels and then taped back together to form the angled corners of the hexagon structure 100 shown in FIG. 1. In addition, such rigid materials are often not structurally robust, and in cases where thin or relatively weak material is to be used, framing or other structural members are required to support forces such as snow loads, wind, and routine impacts.

However, the creases 112 and 114 enable this substantially rigid and relatively structurally weak sheet material to be easily folded and unfolded by a person without machine aid or additional material processing. Thus, the rigid material sheet no longer has to be cut into separate panels and then taped back together to form different housing and support structures. As mentioned above, these vertical wall creases 112 allow a first single continuous substantially rigid sheet of material to be folded into an entire wall assembly 108 that only has one seam. The roof creases 114 allow a second single continuous substantially rigid sheet of material to be folded into an entire roof assembly 104 that only has one seam. As will be shown, additional creases enable formation of integral stiffening struts and other features that in turn enable relatively weak material to form very robust structural systems.

This results in the housing structure 100 to be more resistant to external environmental conditions, such as rain, wind, cold, etc. Since little or no taping or panel attachment is necessary, the housing structure 100 also is easier and less expensive to

manufacture and more easily assembled or disassembled for moving, as well as more resistant to degradation over time from UV rays, freeze/thaw cycles, and other challenges.

The creases 114 in roof assembly 104 are shown in exploded detail in FIG. 1A, and additional detail will be shown later. In the example in FIG. 1A, portions 116 of the roof assembly 104 are folded together along creases 114A-114E to form the triangular shaped roof panels 102. An inner fold is formed with creases 114B, 114C, and 114D. The roof panels 102 are integrally formed together and slope radially downward from the center 118 to the ends of roof assembly 104.

FIG. 1B shows another hexagon shaped housing structure 120 that uses 4' x 8' wall panels 110 and 8' x 8' roof panels 102. The vertical creases 112 in the wall assembly 108 and the radially angled creases 114 in the roof assembly 104 can be similar to the creases described above in FIG. 1A. The hexagon structure 120 has a height of 8', length of 13' 10", and width of 16 feet. The creases 114 in the roof assembly 104 are arranged to form trapezoid shaped roof panels 102 that form an opening 124 in the top of housing structure 120. Such an opening may be used for ventilation and lighting purposes, and in use would include a rain cover as well as a rigid frame to constrain the roof, as will be later described.

FIG. 1C shows another embodiment of a stretched hexagon housing structure 122. The wall panels 110 and roof panels 102 are 4'x 4' and in this embodiment the crease 112A separating the two front wall panels 110 and the crease separating the two back wall panels are not folded or bent. Thus, the housing structure 122 has a length of 12' and a width of 6' 11".

The size and shape of the roof assembly 104 can be varied by folding together different combinations of radially angled creases 114A and/or parallel creases 114B. For example, folding the roof assembly 104 together at radial angled creases 114A forms another angled corner of the roof assembly 104. Folding together parallel creases 114B shorten the length of the roof assembly 104. Any variety of different structure shapes can be formed simply by changing the arrangement of creases and the size of the continuous sheet material.

Foldable Wall Assembly

FIG. 2 shows a continuous sheet 126 of substantially rigid sheet material used for forming the wall assemblies 108 of FIGS. 1A-1C. The sheet 126 can be manufactured from a high-volume production process. Creases 112 are stamped into the continuous sheet of material 126 forming the 8' x 8' wall panels 110. In some embodiments, there may be additional creases 128 stamped in-between the creases 108. This allows the same stamping operation to also form 4'x 8' panels and allows the wall panels 110 to be stacked into a single 4' wide stack for transport.

The sheet 126 is cut at locations 130 to form wall assembly 108. A stamper or cutter may stamp or cut out other sections 132 of sheet 126 for using as windows. By only creasing sections 132, the housing assembler has the option of manually cutting out the window or door along the crease line. In another embodiment, a stamper may crease the top horizontal edge of sections 132. A cutter may then cut out the two vertical edges and the bottom horizontal edge of sections 132. This creates a foldable flap or shutter that can then be bent along the upper horizontal crease.

Another door section 134 can optionally be cut into one of the sheets 126 to form a second doorway. The second doorway section 134 might be an emergency exit door, produced in the same manner as a foldable shutter, and semi-permanently sealed shut with caulk, tape, or other means until needed for rapid egress. It may also be produced via perforations intermittent with creasing, to yield a punch out panel that will preferentially yield to force versus the rest of the structure.

By producing both wall assemblies 108 and roof assemblies 104 as continuous sheets, a production line can alternate between wall and roof production sequentially, and automatically stack finished wall/roof combinations together.

Referring to FIGS. 2 and 3, several parallel creases 136 can be stamped relatively close together at each end of each wall assembly 108. The creases 136 allow the ends of the wall assembly 108 to be rolled up into posts 140. The rolled up posts 140 that both form the doorway106 and operate as a door frame for supporting the door 142 shown in FIG. 1A.

A separately manufactured transom 144 can be attached at a bottom of doorway 106 and can include pins 143 that insert into holes extending down from the bottom of the two posts 140. The bottom of the wall assembly 108 and posts 140 may have cut-outs 145 on opposite sides of the doorway 106 to enable the transom 144 to seat flush with the bottom side of wall assembly 108. In other embodiments, where there are no cutouts 145, the transom 144 may seat into a cutout in a floor assembly or may be partially seated into a hole in the ground.

The transom 144 in one embodiment is a cut piece of 4"x 4" wood or a molded piece of plastic that determines the entryway point. The transom 144 is anchored to the

ground or to a floor assembly and used for positioning the remainder of the building structure (FIGS. 1A-1C). The pins 143, or clamps, are used for locating the bottom corners of the wall assembly 108 at the correct positions with respect to each other so that the door 142 (FIG. 1A) fits properly.

A separately manufactured header 146 can be inserted in the top of the doorway 106 and inserted onto the two posts 140 that stick up from the top of posts 140. The top of posts 140 are cut down from the top of wall assembly 108 and pins 141 inserted into the top ends. The bottom side of header 146 includes holes (not shown) that receive the pins 141 so that the top side of header 146 sits substantially flush with the top of wall assembly 108. The header 146 can be a wood or molded plastic panel and can include an awning 147 to protect the top of the doorway 106 from rain and may also include an opening 149 for ventilation. Alternatively, the header 146 may contain an adjustable air vent, window, or other type of rain diverter.

The door 142 (FIG. 1A) can be installed with hinges inside of the doorway 106 formed by the two posts 140, transom 144, and header 146. Alternatively, the door 142, transom 144, and header 146 can all be part of one integral pre-manufactured unit that is installed together between the two posts 140 at the same time, and together close the only seam in the finished wall assembly 108.

Flashing

Referring back to FIG. 2, layers may be removed from a top and/or bottom surface of the multilayer sheet 126 to form flashing 148. For example, one opposite facing and a center corrugated layer may be removed from the sheet 126. This is

explained in more detail below in FIG. 5. A remaining single facing of the sheet 126, and possibly an external aluminum or other weather resistant layer, forms the flashing 148 which is integrally formed with the rest of sheet 126.

FIGS. 4A-4C show how the flashing is used for preventing water from entering the housing structure 100 between the roof assembly 104 and the wall assembly 108. In FIG. 4A, a roof flashing 150 extends down from the roof panel 102 and forms an eave. The roof flashing 150 is formed in the same manner as flashing 148 in FIG. 2, except that the sheet of material 126 (FIG. 2) is configured with creases for folding into roof panels 102, instead of wall panels 110.

The wall flashing 148 extends up from the inside surface of wall panel 110 and can be bent up and inward to overlap with a bottom end of the roof panel 102. The two flashings 148 and 150 provide two layers of overlapping material across the seam between the wall assembly 108 and roof assembly 104.

FIGS. 4A and 4B also show how the flashing 148 and/or 150 may include an adhesive layer 152. The adhesive layers 152 allow the flashing 150 to be adhered to an outside surface of the wall panel 110 and allow the flashing 148 to be adhered to the inside surface of the roof panel 102. The flashings 148 and 150, and adhesive layer 152, removes the need for separate taping along the interface between roof assembly 104 and wall assembly 108.

FIG. 4C shows an alternative embodiment where the flashing 150 is bent upward to form a gutter. Gutter clips 154 can be attached to the outside surface of wall panels 110 with tape or can be clipped onto the top side of the wall panels 110 to hold the flashing 150 in the upward gutter position.

The flashing 150 can be pre-manufactured or bent during assembly to include a slight horizontal incline toward one particular lateral side of the roof panel 102. The gutters formed on all of the roof panels 102 by the flashing 150 can each have coordinated horizontal inclines so that all rain water captured off of the roof panels 102 drains to a same location on the outside of the building structure 100.

FIGS. 5A-5C show examples of how a substantially rigid sheet 126 may be creased for folding into housing structures. Creasing some types of multilayer materials, such as cardboard, is known to those skilled in the art. However, these techniques have never been used for creasing a substantially rigid sheet of building material 126. In one embodiment, the sheet 126 is a multilayer material that includes a center corrugated layer 164 that is sandwiched between facing layers 160 and 162. The multilayer sheet 126 can have different thicknesses that provide different degrees of rigidity, but in one embodiment the sheet is about 1/4" thick.

The layers 160, 162, and 164 can be made out of any material but in one embodiment are made out of a polypropylene or other resin based water resistant material. In another embodiment, any combination of layers 160, 162, and 164 may be made out of cardboard or some other fiber material. Instead of using a corrugated material, the center layer 164 may alternatively be compressible foam or other compressible material. An additional weather and/or heat resistant layer 166, such as aluminum, paper, or plastic, can be applied on one or both of the outside and inside facings 160 and 162.

Aluminum is a particularly good surface material for applying to either facing 160 or 162 as it is waterproof, durable, reflects damaging UV radiation, and provides an

excellent radiant barrier. An exterior layer 166 of aluminum reflects infrared radiation keeping the interior of the housing structure cool by day. An interior layer of aluminum reflects occupants' radiated body heat and other interior thermal radiators to keep the interior of the structure warm at night.

Since radiated heat is the primary heat flow impacting occupied structures, integrating aluminum layer 166 around a thermally insulating core 164, such as polyiso foam or other suitable material, provides far greater thermal comfort than their R values would suggest. To minimize cost, an extremely thin aluminum layer 166 can be used, such as aluminum foil or "space blanket" material.

As explained above, the sheet material 126 is substantially rigid and typically cannot be bent or folded at relatively sharp angles. In the case of corrugated materials, this is especially true for bends or folds in directions that do not follow a wave crest in the corrugation. FIG. 5A shows how, during manufacturing, a stamp 156 is applied to the sheet 126 at particular locations that can be associated with the sides of wall panels 110, roof panels 102 (FIG. 1A), or other foldable features as will be described in more detail below. The stamp 156 crushes the corrugated or foam layer 164 compressing the multiple layers 160, 162, 164, and 166 together into a crease 112 or 114. The crease 112 or 114 now has a substantially smaller cross-sectional thickness than the remainder of sheet 126. This allows the rigid sheet 126 to easily be bent of folded along the crease 112 or 114.

Referring to FIG. 5C, in some processes, the stamp 156 may not compress both sides 160 and 162 together, but may only press down against one side of sheet material 126 while the other side of material 126 lies against a flat plate 167. This causes the

crease 112 or 114 to preferentially fold away toward the side where the crease 112 or 114 was formed. In some cases, heat or a vacuum may be used to assist the creasing process.

The flashings 148 and 150 described above in FIGS. 2 and 4 can be formed by a cutter 158 that removes the facing 162 and corrugated center layer 164 from one side of sheet 126. The remaining facing 160 and layer 166 form the flashing 148 or 150. An adhesive layer 152, as described in FIG. 4A, can optionally be applied to the flashing 148 or 150 and the flashing bent into particular configurations during assembly, as also shown above in FIG. 4.

The extended end of the flashing 148 or 150 may be folded over the edge of the corrugation 164 and glued or thermally/acoustically bonded to the outside surface of the opposite facing. Doing this effectively seals the edge of the panel and strengthens it, and is useful in many places where panel edges are exposed to moisture, pests, UV, or other challenges.

Alternative Wall Configurations

FIG. 6 shows how continuous production methods may also be used to fold the wall assembly 108 into more complex configurations beyond the six-plane structure shown above in FIGS 1A-1C. Additional creases can be used for creating vertical planar folds 168 that can extend inside or outside of the hexagon housing structure 100 and strengthen the rigidity of the wall panels 110 by acting as "T" wall struts. The folds 168 can also be used for interior room dividers/walls, exterior utility enclosures, vertical structural supports for interior or exterior furniture, and supports for lofts or shelves.

The folds 168 are shown in more detail in FIG. 7 and are alternatively referred to as vertical supports or wall struts. The wall strut 168 is formed along creases 170A, 170B, and 170C by folding each of the creases so that the two sections 172 of the wall panel 110A fold together.

Horizontal elements for slotted sheet interior furnishings may be inserted into slots cut into the vertical wall supports 168. For example, a first set of folds 168A extend into the interior of wall assembly 108 and are used for supporting shelves 171 that extend horizontally out from the wall panel 110. Windows may be included above and below the shelves 171. Folds 168B extend externally out from the wall panel 110B and form an outdoor utility space for an off-grid infrastructure such as for water collection/purification, livestock shelter, or tools.

A set of folds 168C with a partially creased cutout as described earlier can be used for supporting a second door 176 and folds 168D can be used in conjunction with the folds 168C to hold more shelves. Folds 168E are used for supporting a desk top 178 and a shelf 180 that are shown in more detail below in FIGS. 8 and 9.

Folds 168F are located further apart and may be longer than some of the other folds 168 for use as a closet. A closet rod 182 may be inserted through holes cut in the folds 168F for holding hanging clothes. A curtain rod or door 181 may also be attached in-between folds 168F for closing the closet.

Regularly spaced apart folds 168G may extend along all or any portion of the interior surface of wall assembly 108 and retain rigid insulation panels 184. In one embodiment, the insulation panels 184 are made from a relatively rigid polyisocyanurate (polyiso) or

polystyrene foam, or other suitable material thermal insulation material, that are held by friction in-between the folds 168G.

This results in a high R-value and a triple radiant barrier; one on the exterior wall surface, one facing the occupants, and one between the insulation and the exterior wall structure 108. The insulation panels 184 provide excellent thermal insulation as well as a robust interior wall surface, while also providing additional shear strength to the wall assembly 108.

For practical reasons such as standardizing the sizes of insulation inserts, the folds 168 may be located on a grid using rule-based designs such as only placing creases in a design every 1', if a crease is needed. This would make all insulation inserts either 1, 2, or 4 feet wide rather than random widths, provide modularity benefits to users, and simplify packing into 4' x 8' stacks for transport. Alternatively, the entire housing structure 100 could be based on a 16" grid for the struts or vertical supports, to match standard United States home wall construction products such as insulation, so long as there is a transport fold every 4 feet. The creases could also be based on a metric system.

Folds 168H extend outside in front of doorway 106 and provide a sheltered door entryway. The folds 168H can be extended an entire 8' width and support a roof to provide a sheltered porch. Folds 168 might also be used to support a bed platform for supporting a mattress. Lofts or shelves can be placed on top of interior vertical supports 168 to store items or create a sleeping loft in the "attic" formed by the cone of the roof assembly which is shown in more detail below in FIG. 12A. These are all just examples of the different uses for the different internal and external folds 168 that operate as vertical wall supports or struts.

Other folds 173 can be formed at the corners of the wall assembly 108 and connected to each other by pins 175, clamps, ropes, or other fasteners, to enforce a triangular cross section column structure at the wall corners. This provides great strength and if done at all six corners, constrains the entire wall assembly into a hexagonal shape. It also provides more surface area at the bottom edge for contacting either the ground or a floor assembly.

FIG 6 also shows how creases may be added to extend the interior space outward for purposes of a utility closet 110A or other need.

FIG. 8 shows in more detail how a flat wall panel 110 of the wall assembly 108 is creased and cut to form part of a desk and shelf. The wall panel 110 is creased into five different sections 110A-110E by creases 194. A portion of the upper halves of wall panel sections 110B and 110D are cut out to include slots 188, 190, and 191. Creases 196A and 196B bisect the lower halves of wall panel sections 110B and 110D, respectively.

FIG. 9 shows how vertical wall supports 168E are formed by folding each of the wall sections 110B and 110D together along the creases 196A and 196B, respectively. The vertically elongated supports 168E extend perpendicularly out from the wall panel 110 and include upper slots 188 and lower slots 190 that receive and interlock with a shelf 180 and desk top 178, respectively. The slots 191 receive a cross-member 179 that adds further lateral support to the vertical folds 168E and also provides additional support underneath the desk top 178.

The vertical wall supports 168 described in FIGS. 6-9 can be used to integrate a complete set of interior furnishings made from slotted furniture pieces. The double-

walled vertical supports 168 can also include holes for installing tension rings, tie-down anchors, hammocks, privacy drapes, or other interior/exterior components.

The vertical supports 168E structurally improve the wall panel 110, and the insertion of shelves 180 greatly stiffens the wall. This structural robustness improvement occurs in many dimensions, and provides the equivalent of studs, cross-members, and shear stiffener walls in stick-built construction.

Shipping

FIGS. 10A and 10B shows how a sheet of building material 126 may be configured with equally spaced apart creases 119 that enable the entire sheet 126 to be folded together accordion style for shipping in a single stack of panels that are all the same size. For example, the creases 119 enable the entire sheet 126 to be folded together for shipping into 4' x 4' or 4'x 8' stack.

Some of the shipping creases 119 can also perform "double duty" also operating as a crease for a wall edge or also operating as a vertical wall support 168 as shown in FIG. 6. For example, shipping crease 119A is only used for folding the sheet 126 into an equal sized stack for shipping. However, shipping crease 119B also functions as a center crease for a vertical strut 168K and shipping crease 119C operates as one of the side creases for a vertical strut 168L. Shipping crease 119D also serves double duty as an edge crease 112A between two wall panels.

Shipping creases 119 that are not used for other wall edges or vertical struts would then simply appear as an unfolded or unbent crease in the final wall structure. For example, shipping creases 119E and 119F simply form part of a straight wall panel 110

after the sheet 126 is unfolded and then refolded into a wall assembly 108. The shipping creases 119 that are not used in the final assembled wall assembly do not disturb the weather resistant integrity of the wall assembly 108 since there is no separation or seam formed at the creases.

A weakened line in the vertical direction may result from unused creases. However, wall assembly 108 still remains stiff and can withstand wind loads because of the vertical supports 168 (FIG. 6) also formed in the wall assembly 108 for furniture and other accessories. The vertical supports 168 create vertical "T" beams all around the wall assembly 108 that are analogous to corrugated metal. In addition, when using corrugated materials, the corrugations would generally be aligned in the vertical axis for a wall assembly 108, to provide greatest stiffness in the direction of gravity.

The different wall panels 110 in FIG. 10A are delineated by corner creases 112. The wall panels 110 will have different lengths in the unfolded sheet 126 in FIG. 10 based on what other wall features are included in that particular wall panel. For example, wall panel 110 defined between wall creases 112A and 112B has a longer unfolded length than wall panel 110B defined between wall creases 112B and 112C. This is because wall panel 110A includes additional material for vertical struts 168L, 168L, and 168M. Wall panel 110B has no vertical supports and therefore has a shorter unfolded length in sheet 126.

In many applications where extreme limits on per family shelter cost preclude the use of costly and strong shelter materials, this tight integration of shelter skin, structural support, and optional occupant features provides an exceptional rigid and stable structure

that can withstand severe weather conditions and is ideal for providing shelter to disaster relief victims.

About half the cost of each extra housing structure feature is measured in linear inches or feet of additional material needed for the accordion folded sheet 126. The vast majority of disaster victims worldwide receive no more than an emergency tent from relief agencies that degrades in months. The housing structures described herein provide disaster and refugee shelters that perform like homes for long periods of time at prices similar to tents.

Roof Assembly

FIG. 11A shows one embodiment of the roof panels 102 previously shown in FIG. 1A. The roof panel 102 may be made out of the same material as the wall panels 110, such as the material previously described in FIG. 5. In one embodiment, multiple separate roof panels 102 are cut from sheets of material 126, shipped, and then taped or otherwise fastened together to form a roof assembly 104 as shown in FIGS. 1A-1C. The roof panels 102 may alternatively be taped together into a roof assembly 104 in a factory, folded, and then shipped. In another embodiment, a single sheet of material is used to form multiple roof panels 102 that are each formed into a triangular or trapezoid shape by folding the sheet along radially angled creases. This is explained in more detail below in FIGS. 13, 14, and 15.

To strengthen a single roof panel 102, or to strengthen an entire roof subsystem, such as half or all of a roof assembly 104, one or more folds 204 are formed that dissect

opposite halves 200A and 200B of the roof panel 102. The folds 204 operate as a stiffening truss that provides additional support and rigidity to the roof panel 102.

In FIG. 11A, the creases 202A are formed during manufacturing and enable a person to form the folds 204 during assembly of the housing structure. The creases 202A start from substantially a same pinnacle location 206 at a top side of the roof panel 102 and extend radially downward and outward from location 206, through the center, and to a bottom side of the roof panel 102.

FIG. 11B shows and alternative embodiment with parallel creases 202B formed during manufacturing that extend in parallel from a top side of the roof panel 102, through the middle, and to a bottom side of the roof panel 102. The creases 202B are used for forming folds 205.

When completely folded as shown in FIG. 11C, the folds/roof truss 204 or 205 extends downward into the interior of the housing structure. Folds 204 form an angled roof truss as shown by folds 204 in FIG. 12A. The folds 205 form an elongated rectangular roof truss similar to the ruff trusses 235 shown in FIG. 16 below. The creases 202A and/or 202B can also be folded in upward direction so that the fold/truss 204 or 205 extends upward above a top surface of the roof panel 102 similar to folds 234 in FIG. 16. If the sheet of material used for forming the roof panel 102 includes flashing as described above in FIG. 4, the extra flashing at the folds 204 or 205 can be folded up. Small panels can be located at the end of the roof edges to from gutters.

FIG. 12A shows the folds 204 extending into the interior side of housing structure 100. The fold/trusses 204 can each be located so that they rest, or are adjacent to, the tops 208 of the "T" girders/vertical wall struts formed by folds 168 in the wall assembly

108. Holes 210 may also be located at the tops of the vertical wall folds/supports 168 and are aligned with holes 210 located at the bottom ends of the fold/trusses 204. Rope 212, wire, cable, bolts, pins, tape, wire ties, or any other connecting piece, can be inserted through the aligned holes 210 to secure the roof assembly 104 to the tops of the "T" folds 168 in the wall assembly 108. This allows the roof assembly 104 to be rigidly attached to the wall assembly 108 without penetrating or otherwise impacting the watertight surfaces of the wall or roof assembly.

Instead of connecting individual aligned holes 210, a single rope 212, wire, or cable, etc. can be threaded through all the holes 210 at the bottom ends of all the roof folds/trusses 204 and tops of "T" folds 168 to form a tension ring that adds structural integrity to the overall housing structure 100, or a single rope 212, wire or cable can be threaded through just the holes 210 around the bottom of the roof prior to assembling the roof onto the wall assembly. As shown in FIG. 12B, for strength, each roof/wall connection or other attachment point for rope, wire, cable, bolt, or other fastener is held via double-thick folded portions of roof panels 102 and wall panels 110 for strength.

There are many ways to route tensioning elements such as rope 212 or cable and many ways to provide attachment locations. Each merely requires holes to be punched in appropriate places during the continuous production process, or punched/drilled in the field for later modifications. Such holes may be easily finished with grommets for additional strength. Also, furniture and other items such as hammocks may be suspended from the holes using ropes or other tensioning elements in addition to the slotted shelving approach previously shown for integrating furniture with compression elements.

In addition to rope 212 and holes 210, the top ends 208 of the wall supports 168 and the bottom ends of the roof trusses 204 can each be notched with a cutter during the manufacturing process to fit like a tongue and groove joint. This is shown in FIG. 14D below and can be used to interlock the roof assembly 104 with the wall assembly 108 instead of the side-by-side arrangement shown in FIG. 12A and B. The holes 210, and/or anchoring holes 214, may also be used with rope and/or suitable ground anchors 216 to anchor the housing structure 100 to the ground. As previously explained above, boards 226 can be laid on the top ends 208 of the vertical supports 168 to form a loft 228 that provides additional sleeping or storage space.

FIG 12A also shows how a pre-fabricated window 218 can be inserted into a hole 132 formed in the wall panel 110. In one embodiment, the hole 132 is pre-cut into the wall assembly 108 as previously described in FIG. 2. Slots are also cut into the vertical supports 168A just above and just below the pre-cut window hole 132. The pre-manufactured window 218 includes a frame 222 that contains a piece of glass or plastic 224 and may also include a screen, opening panel, and other common window components. The frame 222 includes slots that interlock with the horizontal slots in the vertical wall supports 168A above and below the window hole 132 and hold the window 218 into the window hole 132 formed in wall assembly 108. Alternatively, an ad hoc window frame may be made using a frame 222 consisting of two horizontal members slotted onto the vertical wall supports 168A on either side of the window opening.

In another embodiment, during manufacturing, a cutter cuts only the sides and bottom ends of the window hole 132 and then stamps a horizontal crease across the top end of the window hole 132. This forms a flap along the horizontal crease that can be

either bent inwards or outwards to provide a light and storm cover for the window. In this example, a portion of the middle vertical support 168A would extend vertically along the middle of the window flap providing additional rigidity to the flap. The vertical support extending along the window flap can be folded oppositely to the reset of the vertical supports 168A to extend out into the exterior of the housing structure 100.

FIG. 13A shows a continuous sheet 242 that includes creases 237 and 238 that enable the sheet 242 to be folded into a six sided hexagon shaped roof with only one seam. FIG. 13B shows a cross-sectional view of the sheet 242 in FIG. 13A after it is folded together. The two triangular portions 234 are folded together along the center crease 237B bring the two outside creases 237A and 237C together. This forms a single triangular fold 234 that is shown in FIG. 13B. The triangular fold 234 extends down into substantially an entire attic portion formed by the roof assembly 104. The parallel creases 238 when folded together form an elongated rectangular roof strut similar to roof strut 235 in FIG. 16.

Since there only one fold 234 between each set of diagonal creases 237A and 237C, the fold 234 is larger and extends further downward than other roof crease configuration that include more folds. Some of these examples are shown below. Holes 239 can be located at the corners of folds 234. A rope can be inserted through the holes 239 effectively creating a miniature tension ring that holds the roof assembly 104 together and directs the weight of roof assembly 102 vertically downward.

FIG. 14A shows another embodiment of a continuous sheet of roof material 230 used for forming the entire roof assembly 104. The exterior edge of the finished roof assembly 104 is shown at the bottom side of sheet 230 and what will become the peak of

the roof assembly is shown on the top side of sheet 230. The flashing 150 can also optionally be formed on the bottom end of sheet 230 as also previously explained in FIGS. 4 and 5. Additional notches 231 and slits 233 may be cut into the sheet 230 to remove the flashing 150 at folds 235. In one embodiment, the sheet 230 is 8' wide and made out of the same multi-layer corrugated material previously shown in FIGS. 5A and 5B. Of course other materials could also be used.

Creases 232 extend radially upward and outward from the bottom side of sheet 230. The portions 234 in-between the creases 232 are folded together in a manner analogous to a "Chinese Fan" or accordion. The folds 234 create a hexagon shaped roof perimeter. The folds 234 form the corners of the roof assembly 104 and provide roof-stiffening ribbing. The sizes of the roof panels 102 in this embodiment are 8' x 8' but could be any combination of dimensions including 4'x 8' or other metric sizes.

The parallel creases 238 are used to form roof trusses 235 that extend along the center of each 8-foot roof panel 102. The roof trusses 235 operate as roof-stiffening ribbing that helps prevent a snow load or human climber from collapsing the roof panels 102 at the center of each large plane, whereas the roof-to-roof folds 234 naturally stiffens against load at the roof apexes. The roof trusses 235 have an elongated rectangular shape, compared with the angled shape of the folds 234.

There are more radial angled creases 232 used in the sheet 230 in FIG. 14 than the number of angled creases 237 used in the sheet 242 in FIG. 13A. Therefore, more folds 234 can be formed between roof panels 102 in FIG. 14A that do not extend as far down into the attic space of the roof assembly as the folds 234 formed by the creases 237 in FIG. 13B. Thus, the thickness and height of the folds 234 between roof panels 102 can

be varied according to the number of creases 232. The number of folds 234 can be varied according to the particular building structure application.

Parallel creases may also exist every 4' so that the sheet 230 can be folded during shipping as explained above in FIG. 10. For the roof material sheet this is straightforward by also using each center crease 232A of each accordion set of creases 232 and using each center crease 238A in the parallel creases 238 as a shipping crease. Alternatively, for shipping the entire roof truss 235 may extend outboard from the edge of a 4' wide accordion stack of roof 104, and all the roof trusses 235 may be folded against the edge of the accordion and strapped down to protect the accordion. The top edge of the continuous roof material sheet 230 may be fabricated with notches 240 to provide a more flush fit at the roof apex of the roof assembly 104.

FIG. 14B shows a flat top edge of notch 231 that may be used for attaching the ends of roof struts 235 against the sides of vertical wall supports 168 as described above in FIG. 12A. The holes 210 are located in the bottom ends of roof struts 235 between the creases 238 for retaining a tension ring and interlocking with the top end of the vertical wall supports 168 as also described above in FIG. 12A.

FIG 14C shows an alternative notch configuration 231B that has an angled top edge that when folded together in the final roof assembly enables the ends of roof struts 235 to sit squarely on the tops 210 of the vertical wall supports 168 shown in FIG. 12A. The notch configuration 231C in FIG. 14D when folded together forms a tongue at the bottom of roof strut 235 that can insert into a groove formed in-between the vertical wall supports 168 shown in FIG. 12A.

FIG. 15 shows another arrangement of creases on a continuous sheet material 244 that when folded together forms the entire roof assembly 104. The top ends of the adjacent sets of radially extending creases 239 are spaced apart a distance 246 that form hexagon shaped roof panels 102 similar to those shown in FIG. 1B. In one embodiment, the roof panels 102 have an 8' lower edge and form a 2' upper edge of a hexagonal opening 124 at the peak of the roof assembly 102 as shown in FIG. 1B. The rectangular roof trusses formed by creases 238 extend along the center of trapezoid shaped roof panels 102.

This particular embodiment has several advantages. The folded roof assembly 104 formed from continuous sheet 244 is steeper to better shed snow and provides more interior space. The roof assembly 104 also uses less material to achieve the desired shape. The opening at the roof peak also provides a convenient and functional location for a skylight, vent, or complete roof utility accessory (see FIG. 16). Roof assembly 104 in FIG. 15 also contains creases 238 that form rectangular roof trusses 235 along the center of the roof panels 102 and accordion folds 234 that form the corners of the roof assembly 104.

Accessories

FIG. 16 shows a cross section of the housing structure 120 similar to that previously shown in FIG. 1B, except that the folds 234 are folded upward, instead of downwards. The folds formed between the parallel creases 238 in FIG. 15 function as rectangular roof trusses 235 that extend below the roof assembly 104. The accordion folds 234 formed between the creases 239 in FIG. 15 form the corners of the roof

assembly 104 and also function as angled trusses. The folds 234 are folded upwards in FIG. 16 to support a roof utility accessory 156 but can alternatively be folded downward as shown in FIG. 1B.

As explained above, the roof assembly 104 can be formed from a single continuous sheet of material that has only one seam. This seam is an ideal place to insert a roof utility accessory 256 that performs one or more functions in an integrated manner for low cost. The accessory 256 can operate as exhaust ventilation for a living space, exhaust chimney for cooking stove/fire, cap the roof apex 260 for water/weather protection, and include a tube 268 that accepts a pole at the bottom of the roof apex 260 for supporting snow loads and/or a loft structure. The accessory 156 can be fitted with equipment to receive solar power, charge batteries, project lighting, provide utility power outlets, detect smoke/fire/carbon monoxide, and other off-grid human conveniences. A lightning rod 201 can extend upward from the top of accessory 256 to protect occupants within an aluminum coated shelter.

The roof utility accessory 256 can be installed via flanges surrounding a cutout in one or more roof panels 102 as the panels come together for the last seam to close, or by implementing the roof with trapezoidal panels 102 and a central hole 124. The roof utility accessory 256 can also clamp between the top and bottom of the hole 124. For example, serrations or notches in the roof accessory 256 can clamp a particular shape of the roof's accordion folds 234 at the peak area 260. The shape of the peak area 260 in this embodiment provides a geometrically complex yet multidimensional-constrained set of surfaces for integrating the roof accessory 256. The roof accessory 256 allows air 262 to ventilate out of the structure 250 while preventing rain from entering, since even a

loose or irregular fit between the roof accessory 256 and the top surface of roof assembly 104 will allow air to flow but no rain to enter. A simple butterfly or other closure inside the roof accessory 256 can adjust air flow from the interior.

Floor Assembly

FIG. 16 also shows a floor assembly 270 that can be used to support the wall assembly 108. Different components of the floor assembly 270 can be manufactured and formed from a single continuous sheet of material. For example, floor panels 274 can all be folded from the same continuous piece of material, similarly to the roof assembly 104 as shown in FIGS. 13, 14, and 15. However, the creased floor sheet is folded flat to form the floor panels 274, where the roof panels 102 are angled upwards to form the angled roof assembly 104. Accordingly, the floor panels 274 may be shorter than the roof panels 102 to form more acute triangles. For example, in one embodiment, the roof panels 102 are 8 feet wide where the floor panels 274 for the same building structure may only need to be around 6' 11" wide.

The folds 280 extend down and out from the bottom side of floor panels 274 and include notches that interlock with notches formed in lower foundation members 276. Other upper foundation members 282 extend radially outward from the center of the floor assembly 270 and provide additional longitudinal support and rigidity underneath the floor panels 274.

FIG. 17 shows how the foundation members 276 and 282 can each be formed from a same continuous roll 273 of material that in one embodiment uses a multilayer sheet of material similar to that described in FIGS. 5A and 5B. For a center corrugated

layer 164 is sandwiched between facing layers 160 and 162. The layers 160, 162, and 164 can be made from polypropylene or a weather resistant cardboard material.

In this embodiment, the center layer 164 provides a substantial amount of relatively stiff vertically aligned corrugations that, when constrained with multiple other foundation members 276 and 282 in a grid-like matrix foundation 277, provide an extremely rigid vertical support structure. Similar slots in folds 280 of floor 274 can also insert in slots 300 in foundation member 276.

The material in roll 273 can have prefabricated perforations 275 that enable the different foundation members 276 and 282 to be physically separated from each other during assembly. In one such embodiment, multiple upper foundation members 282 can be separated from the roll 273 before the beginning of the continuous roll that is used to form lower members 276. In another embodiment, the upper foundation members 282 and lower foundation members 276 are formed from an upper or lower half, respectively, of a double wide roll 273 that is perforated along the longitudinal center. The upper half of roll 273 is separated from the lower half and the two separate halves used for detaching or forming the upper foundation members 282 and lower foundation members 276, respectively. Creases 292 can also be prefabricated into the roll 273 to enable folding and bending as previously described in FIG. 5. The roll 273 may be unrolled in the factory and folded up as one or more 4' long or 8' long accordion strips for transport.

Referring back to FIG. 16, in one embodiment, the upper foundation members 282 are rolled up on the ends to form wall supports 272. In this novel arrangement, an offset 284 exists between the top side of upper foundation member 282 and the top surface of wall support 272. This offset 284 allows the wall assembly 108, when seated

on the wall supports 272, to extend down below the floor panels 272. This overlap 284 prevents water from leaking between the interface of floor assembly 270 and wall assembly 108 into the interior 258 of housing structure 120. Thus, the floor panels 274 will remain dry even during wet external conditions, while alternative structures that place the wall onto a flat platform can allow moisture intrusion.

FIGS. 18 and 19 show an alternative embodiment of the foundation 277. The end of the roll of material 273 shown in FIG. 17 is unrolled from a center location 286 into a continuous rounded spiral shape 288. At grid location 290, the roll 273 is unwound into straight hexagonal lower foundation members 276 that are each delineated by prefabricated creases 292. The roll continues to be unwound and bent as creases 292 into a substantially hexagon shaped spiral that has a slightly smaller perimeter dimension than the wall assembly 108 (FIG. 16). An end 296 from the roll is interlocked back with another lower foundation member 27A6 using a double-width slot 302A in an upper member 282A. The upper foundation members 282 extend radially out from the center 286 toward the perimeter of the foundation 277.

Any floor shape can be formed using the upper and lower foundation members 282 and 276, respectively. For example, the foundation 277 can be formed into any of the cross-sectional building structure shapes shown in FIGS. 1A-1C. In another alternative embodiment to FIG 18, the spiral shape of the lower foundation members 276 can be replaced with discrete concentric hexagonal rings. The ends of each ring goes through a double wide slot in one upper radial member 282 to constrain the closed ring.

As mentioned above, the upper foundation members 282 can also be rolled out from either the same material roll 273 as the lower foundation members 276 or can

formed from a separate roll. In either case, the roll 273 containing the upper members 282 may have perforations 275 as shown in FIG. 17 that allow the upper members 282 to be detached from each other during building foundation 277.

As shown in FIG. 19A, the bottom sides of the upper foundation members 282 include notches 302 that interlock with notches 300 that extend up from the top sides of the lower foundation members 276. Additional creases may be prefabricated at each radial end of each upper foundation member 282 so that the end can be rolled up into a wall support 272 as previously explained in FIG. 16.

The floor panels 274 are laid down over the interlocked foundation members 276 and 282. In FIG. 19A, each floor panel 274 may be formed from one or two separate pieces of material. For example, sections 274A and 274B of floor panel 274 may be two separate pieces of material that each fold down on opposing sides 304A and 304B, respectively.

Notches 306 are prefabricated into the folded down sides 304A and 304B and interlocked with some of the notches 300 prefabricated and extending up from the lower foundation members 276. An additional strip of material 307 is shown extending out from the end of side 304A of floor panel section 274A that can be rolled up to form one of the wall supports 272.

In another embodiment, the two portions 274A and 274B of the floor panel 274 are part of the same continuous sheet of material. In this embodiment, the bottom of sides 304A and 304B are integrally formed together from the same sheet of material. A crease extends between the bottom ends of the two folded sides 304A and 304B so that

the two sides 304A and 304B can be folded together. The notches 306 are pre-cut during manufacturing to into both side 304A and 304B.

FIG. 19B shows another embodiment where multiple floor panels 274 are all integrally attached and formed together in the same continuous sheet of material 281. The folds 280 as previously shown in FIG. 16 can operate similar to upper foundation members 282 by extending radially out from the center to the perimeter of the floor assembly 270. Additional folds 304, similar to what was described above in FIG. 19A, may intersect each floor panel 274. The sheet of material 281 includes pre-manufactured holes in folds 280 and 304 that form slots, similar to the slots 306 in FIG. 19A, when the folds 280 and 304 are folded together. The slots interlock with some of the slots 300 in lower foundation members 276.

In some embodiments, slots 303 may be formed into the floor panels 274 to receive the vertical wall supports 168 formed in the wall panels 110. The wall assembly 108 is lowered down over the floor assembly 270. The bottom end of vertical wall strut 168 inserts down through slot 303 in floor panel 274 and interlocks with the slot 300A that extends up from the lower foundation member 276. At the same time, a bottom end of a rolled up corner 285 of the wall assembly 108 sit down onto the top of wall support 272. Pins may be inserted into the tops of wall supports 272 that insert up into mating holes formed in the rolled up corners 285 of the wall assembly 108. Other types of attachment apparatus, such as tabs and slots could also be used.

Alternatively, bottom ends of the vertical wall supports 168 may be cut out so that a bottom end of wall support sits flush on the top side of floor panel 174. In yet another embodiment, extensions 285 may be folded on the sides of wall assembly 108. These

extensions 285 are configured to sit on wall supports 272 when the wall assembly 108 is seated down on top of the floor assembly 270. The extensions 285 provide additional surface area for the wall assembly 108 to contact the wall supports 272.

Regardless of whether the floor assembly 270 is composed of a single piece or many, there will be edges of one or more panels 274 that rest on radial foundation members 282. To prevent the edges of such floor panels from sagging, the radial upper foundation members 282 may include extra edge support creases 267 in some areas that are folded into a radial zig-zag pattern.

FIG. 20 shows an alternative embodiment of the floor assembly 270 where the lower and upper foundation members 276 and 282, respectively, are arranged in a rectangular grid with a hexagon perimeter. The foundation members are removed at the perforations 275 as previously shown in FIG. 17, and some of the members turned upside down to be used as upper foundation members 282. As also explained above in FIG 17, a double wide roll may have perforations along that center that allow a top roll to be separated from a bottom roll.

The foundation grid in FIG. 20 can use any arrangement of lower and upper foundation members 272, and 282. For example, the lower and upper foundation members may be alternated in either side-to-side and/or front-to-back directions across the floor assembly 270. Alternatively, some of the foundation members may also extend radially out from the center of the floor assembly 270 as previously shown in FIG. 18.

The floor panels 274 are then laid out over the top of the foundation members 276 and 282. Again, the floor panels 274 can be formed from separate material pieces or

folded from a same continuous sheet of material that has crease patterns similar to the crease patterns for any of the roof assemblies 274 shown in FIGS. 13, 14, or 15.

A set of members 276 or 272 may be rolled at the ends to form larger rolls 305 that can be used as a foundation for suspending boards or additional multilayer material that function as a front door step or front porch.

If needed for extreme terrain, continuously produced, ship-flat material can be rolled into tubular cross sections such as squares or triangles or circles as shown for door posts 140 and wall support 272. Such cross sections may then be used as risers under the foundation or additional wall support 272.

FIG. 21 shows other ways that the floor assembly 270 can be used on sloped ground surface. When formed from a continuous sheet of material, the floor panels 274 as described above in FIG. 16 may have folds 280A and 280B that extend downward. If the housing structure 250 is located on a sloped ground surface 310, partial and separated hexagon foundation rings 312 of different heights or with slots having different depths can be located under the housing structure 250 at different corresponding elevations. The floor struts formed by folds 280A and 280B are then inserted into slots extending up from the variable sized foundation rings 312. Some of the floor struts formed by folds 280A underneath the uphill side of the housing structure 250 might sit directly onto the ground surface 310 and/or on additional shorter foundation ring 312 parts.

The distance that the folds 280A extend downward depend on the number of folds between adjacent floor panels 274. For example, one fold 280 between two adjacent floor panels 274 will extend further down below the floor panel 274 than two folds. The number of folds 280 used to form the floor struts can be varied according to the slope of

ground surface 310. For example, on a slight incline, more folds 280 may be used between adjacent floor panels 274 to form a smaller less angled floor strut. Alternatively, on a ground surface 310 with a larger incline, fewer folds 280 may be used to form a larger more angled floor strut. This provides some flexibility, even in the field during deployment.

In another application, the folds 234 between adjacent roof panels 102 are folded in an upward direction to support a rain fly 314. The upwardly directed folds 234 hold the rain fly 314 up above the roof panels 102 to provide an additional layer of rain protection and ventilation. The rain fly 314 can be made of any nylon or water resistant material and may include a radiant barrier reflective coating, or alternatively the fly may be made from a porous sun-rejecting material such as Aluminet. The rain fly 314 may be secured to the ground surface 310 with conventional tent anchors 316, may be secured to struts at the wall top, or may be secured to the floor assembly 270. Such attachments may be made using holes, slot & tab, or other means as described for attachment previously.

In a same manner as explained above with respect to floor struts, the number of folds 234 used between adjacent roof panels 102 determine how high the roof struts extend above the roof panels 102. For example, fewer folds 234 are used to increase the height and angle that the roof struts extend above the roof panels 102, and more folds 234 are used to decrease the height and angle of the roof struts.

Installation

The housing structures described above can be installed as follows, with some steps scenario-dependent. The use of a platform and floor versus none might be budget dependent, while the exact choice of platform embodiment might be dependent on slope, ground softness, and expected routine flooding levels. Similarly, the choices of material strengths/stiffening features and internal or external convenience features and furnishings will depend on cultural, financial, and climate parameters. The discussion will therefore remain general, while the foregoing descriptions present the detailed embodiments that enable the broad range of customization options in the present invention.

If a raised floor assembly is not used, the ground is smoothed out to the extent possible around an intended location. If needed, sloped ground is dug into to embed an uphill corner of the housing structure to ensure that a flat wall does not point directly uphill. Referring to FIG 3, one or more ground anchors are installed through holes 151 in transom 144 at the desired doorway location to secure the transom 144 in the ground. Then the wall assembly 108, roof assembly 104, and finishing proceeds generally as will be described for use with a raised floor, with the walls anchored directly to the ground as shown in FIG 12A. To protect the interior from flooding, a plinth can be formed inside the structure after assembly to raise the height of the floor level above the surrounding terrain and above the bottom of the walls using rubble base, gravel, and straw/mud, covered with a layer of cardboard, plastic, tarp, or other available flooring material. This also hides the anchors.

If a raised floor assembly 270 is used, the lower foundation member 276 as shown in FIG 18,19 (spiral), FIG 20 (rings or grid), or FIG 21 (partial rings on a slope) are unrolled or unfolded and secured to the ground, with the specific choice dependent on terrain and

the availability of suitable materials and factories. A transom or front step as shown in FIG. 3 or FIG. 20 is installed, and any upper foundation members foundation members 282 not integral to a continuous floor panel 274 are then interlocked with the lower foundation members 276. Separate or continuously integrally formed together floor panels 274 are then installed as shown in FIG 19, and any remaining foundation anchoring is completed.

The wall assembly 108 is unfolded, and if desired for convenience of assembly, it may be laid on the ground while individual wall features such as wall struts and furniture supports 168 are folded out of the wall panels 110 and fastened to themselves to yield the final six wall panel lengths. The wall assembly 108 is then secured to the open ends of the transom 144 via pins 143. This ensures that wall assembly 108 is instantly secured against wind when stood up. To constrain the top of the wall assembly 108, the doorway header 146 with integrated rain diverter 147 (FIG. 4) is attached between top open ends of the wall assembly 108. The door 142 (FIG. 1A) is inserted in the doorway at this or a later time.

The remainder of the wall assembly 108 is then secured around its base, which may include any combination of inserting the wall supports 168 through slots 303 and into slots 300A, and inserting pins 281 that protrude from wall supports 272 into the extensions 285 and/or rolled up corners 287 formed on the outside of wall assembly 108 as shown in FIG 19. Rope or other tensioners as shown in FIG 12A, or otherwise can also be attached to the roof assembly 104 and/or wall assembly 198. In addition, as shown in FIG 6, wall struts or other features 175 adjacent to each wall to wall corner may be secured to matching struts on the next wall panel, which forces each wall to wall

corner to contain a triangular cross section strut that constrains the proper wall to wall angle.

If expandable wall technology is used or if trusses 168G are spaced for insertion of panel insulation 184 as shown in FIG. 6, the wall panels 184 may be filled with insulation. Flashings 148 and 150 as described in FIG 4A, 4B, and 4C may also be used to seal and cosmetically finish the floor/wall interface.

The roof assembly 104 is unfolded and the roof utility accessory 256 inserted into a notch between the last two roof panels 102 and a last seam of the roof assembly 104 is sealed. In many cases, this seal will be done using a part that serves as a wire race, stove vent pipe, and means for otherwise moving utility resources and wastes between the living area and the roof accessory. Also, for maximizing packing density, the roof assembly 104 may sometimes be shipped as two halves, requiring two final seals in the field. Also, if discrete roof panels 102 are used, such as shown in FIG 11A or 11B, they may be pre-hinged at a factory or warehouse and unfolded similarly to a roof assembly 104 in the field, or secured to each other in the field. Additionally, a tension ring may be formed in the roof assembly 104 in the manner shown in FIG 13B.

Once the roof is assembled, one roof truss hole is roped to the transom 144 for safety in windy conditions. Then the completed roof assembly 104 is placed on top of the wall assembly 108, locating positioning aids such as roof trusses directly over the wall trusses they interface with, and securing at least two or more roof trusses to wall trusses using the mating holes 210 shown in FIG 14A, 14B, and 14C to temporarily constrain the roof assembly 104.

A tension ring 212 is formed on the roof assembly 104 as shown in FIG. 12A and the roof assembly 104 is more securely attached to the wall assembly 108 by running the rope 212 through holes 210 or rings on struts at roof/wall interfaces around the entire perimeter of the housing structure, and securing with a tensioner such as manual tensioning of a rope, knotting, or a turnbuckle. The roof assembly 104 can be additionally secured to the ground by running rope between the roof assembly 104 mounting holes and other mounting holes in the walls, floor, or platform or even directly to ground anchors, such as via zigzag between an anchor hole at a center bottom of each wall panel 110, through adjacent strut holes at the roof corners, and down to a next anchor hole at a center bottom of a next wall panel 110, etc. The ground anchor at the doorway is skipped and the rope routed through the doorway header and secured with the tensioner.

Tape backing is peeled off of tape that extends along the top the wall assembly flashing 148, and the flashing pressed against an inside surface of the roof assembly 104 to seal the inside of the wall/roof interface. Tape backing is peeled off tape that extends along a bottom of roof assembly flashing 150 and pressed against the top of the wall assembly 110 to seal the outside of the wall/roof interface, or gutters are integrated.

Radiant barrier insulating panels can be inserted between vertical support struts 168G inside the wall assembly 108 as shown in FIG. 6. Seats, shelves, counters, and other interior furnishings are inserted into the slots in other vertical support struts 168 located inside the wall assembly 108. If desired, additional protection for the roof and occupants may be added via the rain fly 314 as described in FIG. 21.

Having described and illustrated the principles of the invention in a preferred embodiment thereof, it should be apparent that the invention may be modified in arrangement and detail without departing from such principles. Claim is made to all modifications and variation coming within the spirit and scope of the following claims.

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Claims

1. A building structure, comprising:

a continuous sheet of substantially rigid building material having creases configured to enable folding into multiple integrally formed together and separately alignable walls for a portable self supporting wall assembly that that is all formed from the same sheet of continuous substantially rigid building material.

2. The building structure of claim 1 wherein the multiple walls form an entire enclosed wall assembly for a housing structure that has only one seam formed at opposite ends of the continuous sheet.

3. The building structure of claim 2 wherein the multiple walls are configured to fold into a hexagon shaped wall assembly.

4. The building structure of claim 1 wherein at least some of the creases enable portions of the sheet to be folded away from the walls to form vertically elongated supports.

5. The building structure of claim 4 wherein the vertically elongated supports are combined with horizontal members to frame an opening for a window having a thickness substantially greater than a thickness of the walls formed from the sheet of material.

6. The building structure of claim 4 further comprising holes located in the continuous sheet that form horizontally aligned slots in the supports when the portions of the sheet are folded together, wherein the slots are configured to receive and interlock with horizontal platforms.

7. The building structure of claim 4 wherein the vertical supports form sides of shelves, desks, utility sheds, or closets that are integrally formed into the same continuous sheet that forms the walls of the structure.

8. The building structure of claim 4 wherein the vertical supports extend out from both an inside surface and an outside surface of the walls.

9. The building structure of claim 4 wherein the vertically elongated supports are regularly spaced to constrain rigid thermal insulation panels.

10. The building structure of claim 4 wherein at least one of the vertically elongated supports extends out from the wall to partition an interior portion of a building structure formed by the wall assembly.

11. The building structure of claim 1 wherein at least some of the creases are configured to fold into an extended room that extends an interior portion of a building structure out away from a perimeter of the wall assembly.

12. The building structure of claim 2 wherein the opposite ends of the continuous sheet are spaced apart to form a doorway for the housing structure.

13. The building structure of claim 12 further comprising multiple closely spaced apart parallel creases located on opposite ends of the continuous sheet that are configured to enable the opposite ends of the continuous sheet to be rolled up into door posts that extend vertically up on opposite sides of the doorway.

14. The building structure of claim 1 wherein the continuous sheet comprises a corrugated cardboard or polypropylene middle section sandwiched between first and second facings.

15. The building structure of claim 14 wherein the middle section and first facing are removed along a top edge of the continuous sheet to form a flashing, and wherein the flashing is configured to overlap an interface between the wall assembly and a roof assembly.

16. A building structure comprising:

a wall assembly; and

a continuous sheet of substantially rigid building material having creases configured to enable folding of the continuous sheet into one or more separately alignable roof panels that form at least a portion of a roof assembly.

17. The building structure of claim 16 wherein at least some of the creases in the continuous sheet extend radially outward from a same apex across a width of the continuous sheet, and are configured to fold the continuous sheet into multiple integrally formed together triangular or trapezoidal shaped roof panels.

18. The building structure of claim 17 wherein the multiple roof panels enclose the entire wall assembly and have only one seam formed at opposite ends of the continuous sheet.

19. The building structure of claim 17 wherein the multiple roof panels form a hexagon shaped roof assembly.

20. The building structure of claim 17 wherein at least some of the creases in the continuous sheet enable portions of the continuous sheet to be folded together to form elongated roof struts that extend out from the roof panels.

21. The building structure of claim 20 wherein at least some of the roof struts extend up above the roof panels and some of the roof struts extend down below the roof panels.

22. The building structure of claim 16 wherein a middle layer and a first side facing are removed from a bottom edge of the continuous sheet, and wherein a remaining second side facing along the bottom edge is configured to extend down over the wall assembly and operate as a flashing between the roof assembly and the wall assembly.

23. The building structure of claim 16 wherein a middle layer and a first side facing are removed from a bottom edge of the continuous sheet, and wherein a remaining second side facing is configured to be bent upward above the wall assembly and operate as a rain gutter that extends around the wall and roof assemblies.

24. The building structure of claim 16 wherein at least some of the creases are configured to extend folds upwards above an upper roof assembly surface, the folds configured to support a protective layer above the upper roof assembly surface.

25. A building structure comprising:

a wall assembly;

a roof assembly; and

one or more sheets of substantially rigid building material having creases configured to enable folding of the sheets into a floor assembly having floor panels configured to reside inside of the wall assembly higher than a bottom end of the wall assembly.

26. The building structure of claim 25 wherein the floor assembly includes:

lower foundation members that extend across the floor assembly; and

upper foundation members configured to interlock with the lower foundation members.

27. The building structure of claim 26 wherein at least some ends of the upper foundation members are configured to be rolled up to form wall supports that support the bottom end of the wall assembly.

28. The building structure of claim 26 wherein the lower or upper foundation members are integrally formed together from a same continuous roll of substantially rigid material.

29. The building structure of claim 28 wherein the lower foundation members are rolled out into a spiral that starts from a center of the floor assembly and extends out into a hexagon at an outside perimeter of the floor assembly.

30. The building structure of claim 26 wherein the floor panels have a triangular or trapezoidal shape and include sides that fold down to interlock with the bottom foundation members.

31. The building structure of claim 30 wherein multiple floor panels are formed from a same continuous sheet of substantially rigid material and portions of the continuous sheet between the floor panels form floor struts that interlock with the lower foundation members.

32. An integrated building assembly, comprising:

at least a portion of a wall for forming at least part of a building structure; and

one or more wall extensions that are integrally formed with the wall and that extend out of the wall, wherein the wall extensions are configured to both stiffen the wall and also provide at least one additional building feature comprising at least one of a piece of furniture, a room partition, a door frame, a window frame, a insulation holder, or a utility closet.

33. The integrated building assembly of claim 32 wherein the portion of the wall and wall extensions are formed out of a same continuous sheet of building material having creases configured to:

enable folding of a first portion of the sheet into the portion of the wall for the building structure, and

enable folding of a second portion of the sheet into the wall extensions that extend out of the wall.

34. The integrated building assembly of claim 32 further comprising

one or more furnishing members configured to interlock with the extensions to form home furnishings that are integrally formed with the wall.

35. The integrated building assembly of claim 32 wherein at least one of the furnishing members comprises a shelf that interlocks across adjacent extensions in horizontal alignment to form shelving that extends out from the wall.

36. The integrated building assembly of claim 32 wherein at least one of the furnishing members comprises a desk top that interlocks across adjacent extensions in horizontal alignment that together with the adjacent extensions form a desk that is integrally formed with the wall.

37. A foldable structure, comprising:

an elongated sheet of continuous building material that is generally too rigid to be bent or folded together; and

creases in the building material configured to enable bending or folding of the sheet of building material into multiple different substantially rigid building panels that are all integrally formed together from the same sheet of continuous building material.

38. The foldable structure of claim 37 wherein a first set of parallel creases extend equal distances apart across a width and length of the sheet, the first set of creases configured to enable folding of the sheet into a single stack of building panels of equal width and height.

39. The foldable structure of claim 38 further comprising a second set of parallel creases located closely together across at least a first end of the sheet, the second set of creases configured to enable the first end of the sheet to be rolled up into a support post.

40. The foldable structure of claim 38 further comprising a second set of multiple parallel creases located in-between the first set of creases, the second set of creases

configured to enable portions of the building material to be folded together to form vertical supports that extend out from the building panels.

41. The foldable structure of claim 40 further comprising slots in the vertical supports configured to suspend platforms out from the building panels.

42. The foldable structure of claim 37 further comprising a bendable flashing integrally formed with, and extending from. at least one side of the sheet.

43. The foldable structure of claim 37 wherein different groups of angled creases that extend radially out from an apex on a first edge of the sheet to different locations on a second edge of the sheet, the different groups of angled creases configured to enable folding of the building material into multiple adjacently triangular or trapezoidal shaped roof or floor panels that each extend radially outward from a central location.

44. The foldable structure of claim 43 further comprising multiple parallel creases located in-between the groups of angled creases, the parallel creases configured for folding portions of the elongated sheet together to form struts that extend out from the roof or floor panels.

45. The foldable structure of claim 37 further comprising:

interlocking foundation members;

wall supports extending around a perimeter of the foundation members and configured to support the building panels; and

floor panels configured for placing on top of the foundation members.

46. The foldable structure of claim 45 wherein:

most or all of a lower set of foundation members are integrally formed together from a same continuous roll of material and

an upper set of foundation members interlock over the lower foundation members.

47. The foldable structure of claim 46 wherein ends of at least some of the foundation members are configured to be rolled up to form the wall supports.

48. The foldable structure of claim 45 wherein the wall supports are located lower than the floor panels so that a bottom end of the wall panels extend over and below the floor panels.

49. The foldable structure of claim 45 wherein the floor panels comprise one or more sheets of substantially rigid material that includes creases that enable a side portion of the rigid material to be folded downward for interlocking with the foundation members.

50. The foldable structure of claim 49 further comprising an elongated sheet of substantially rigid floor material that includes creases that enable the sheet to be folded into multiple different integrally formed together floor panels that each have a triangular

or trapezoidal shape and folds in-between the floor panels sheet are configured to interlock with the foundation members.

51. A portable building structure, comprising:

a floor assembly including floor panels, interlocking foundation members configured to support the floor panel, and wall supports integrally formed from at least some of the interlocking members; and

a wall assembly made from a semi-rigid continuous sheet material configured with creases that enable the sheet material to be bent or folded to form multiple integrally formed together walls, wherein a bottom end of the wall overlaps the floor assembly and sits on the wall supports.

52. The portable building structure of claim 51 further comprising a roof assembly formed from a second semi-rigid continuous sheet material configured with creases that enable the sheet material to be bent or folded to form multiple integrally formed together triangular or trapezoidal shaped roof panels.

53. The portable building structure of clam 52 wherein the wall floor assembly, wall assembly, and roof assembly all have a hexagon shape.

54. The portable building structure of claim 52 further comprising vertical supports formed by folding portions of the continuous sheet together, the vertical supports configured to hold horizontal platforms out from sides of the wall assembly.

55. The portable building structure of claim 52 wherein the floor panels are folded from a semi-rigid continuous sheet material configured with creases that enable the sheet material to be bent or folded to form multiple integrally formed together triangular or trapezoidal shaped floor panels and wherein folds in-between the floor panels are configured to sit on the foundation members.

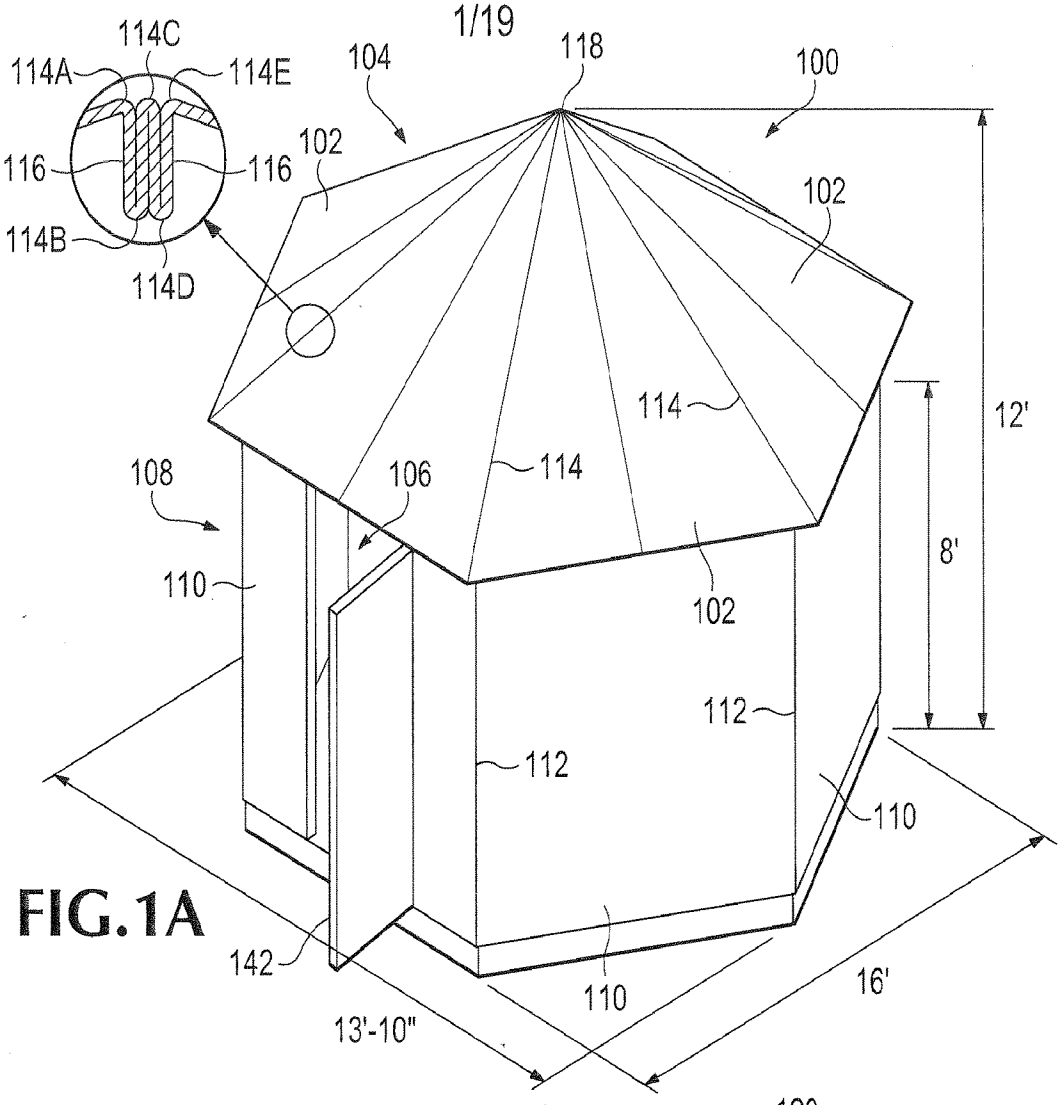

114C
114A
114E
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116
114B
114D
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118
100
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114
114
12'
8'
108
106
110
102
112
112
110
142
110
16'
13'-10"

FIG.1A

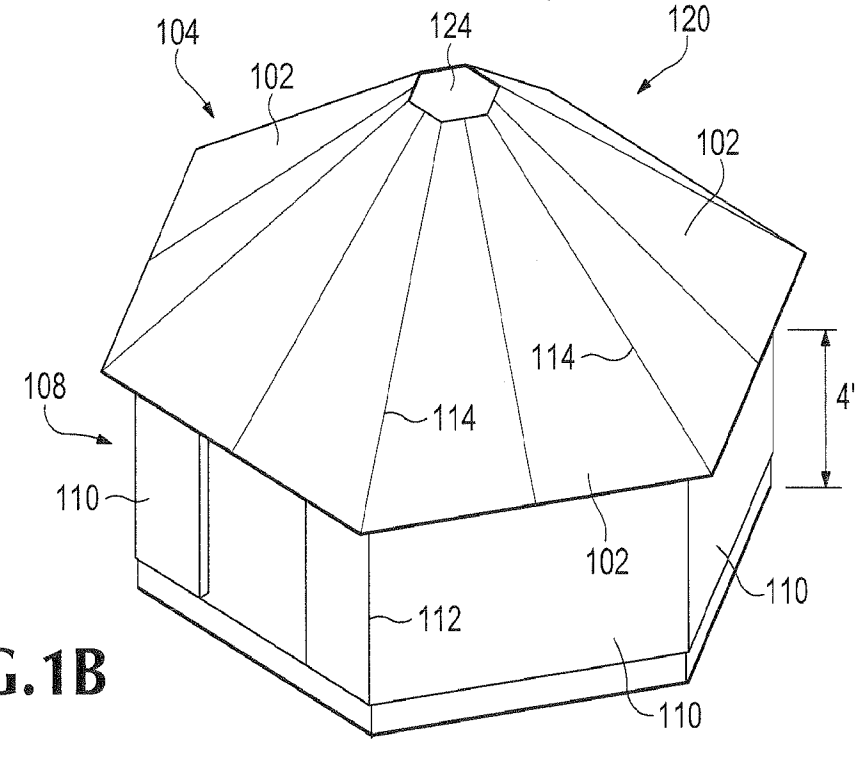

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124
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102
102
114
114
4'
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110
102
110
112
110

FIG.1B

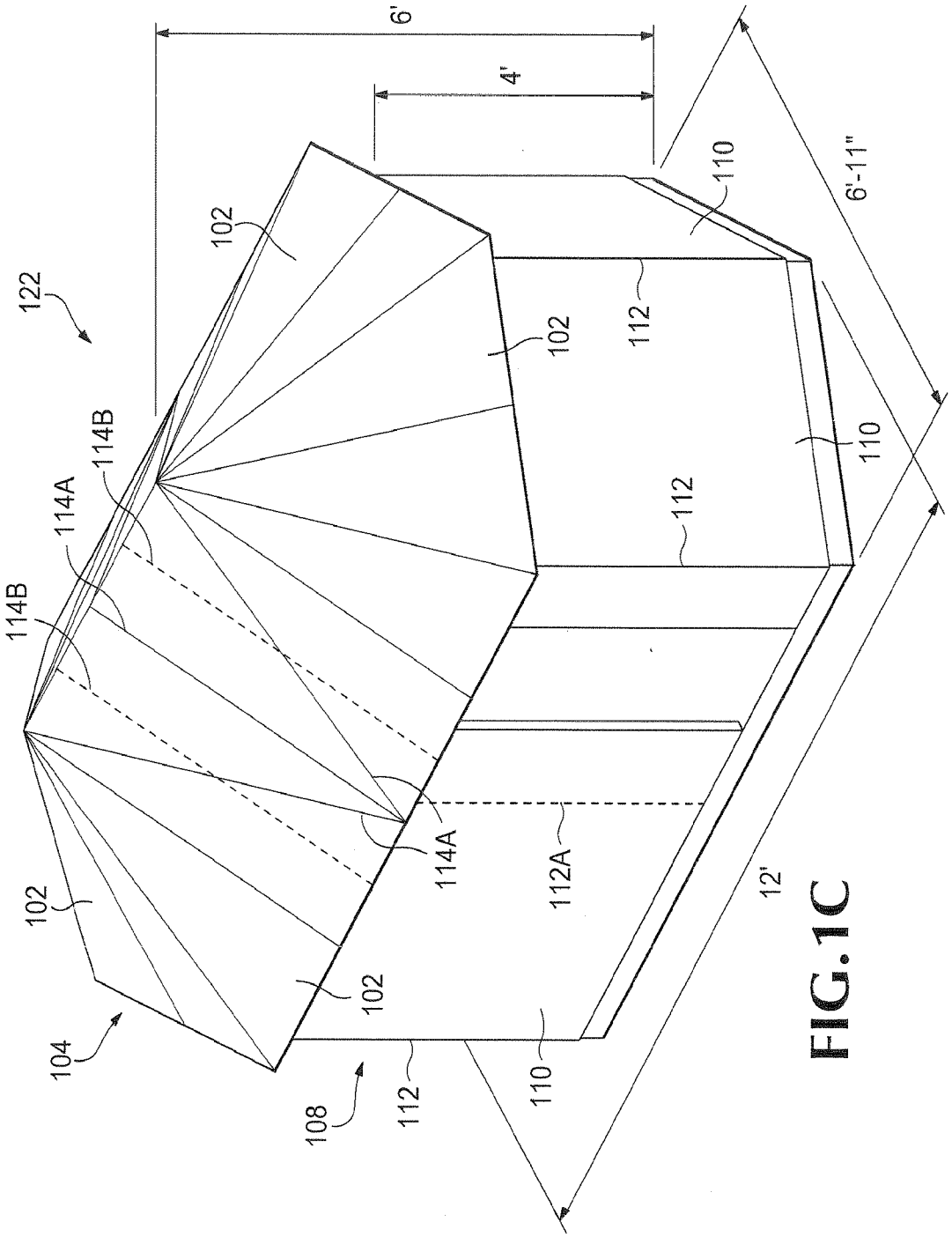


FIG. 1C

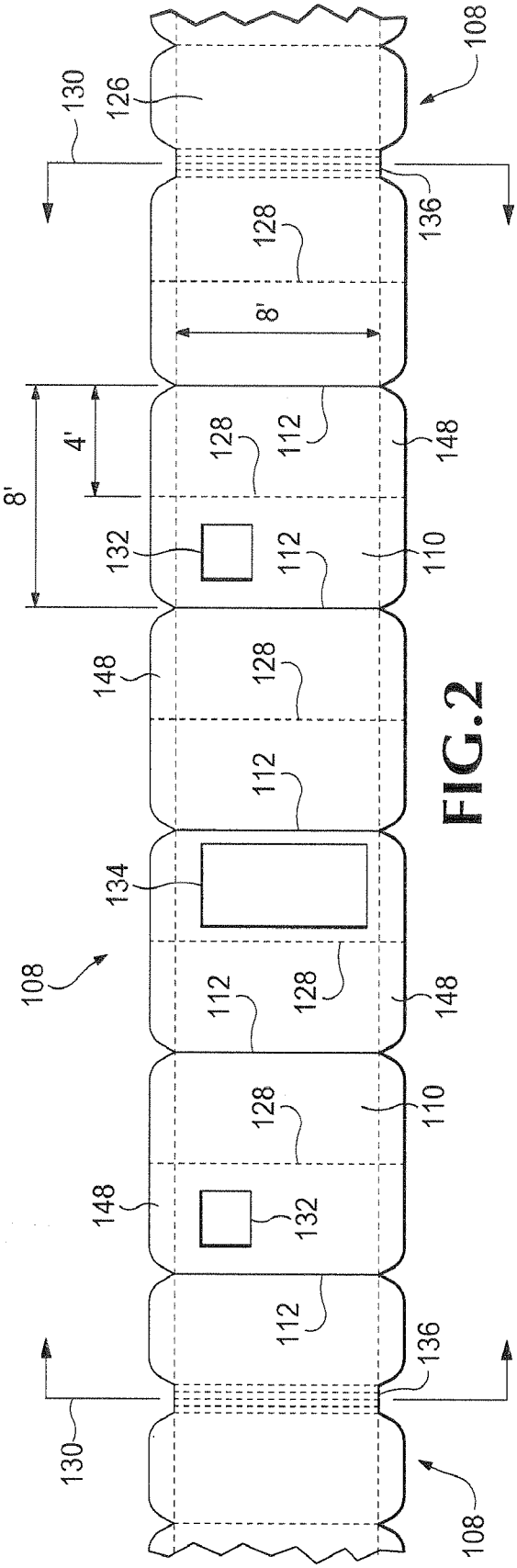

108
130
126
136
128
8'
4'
8'
128
112
148
132
112
110
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128
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112
128
148
128
110
148
132
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136
130
108

FIG. 2

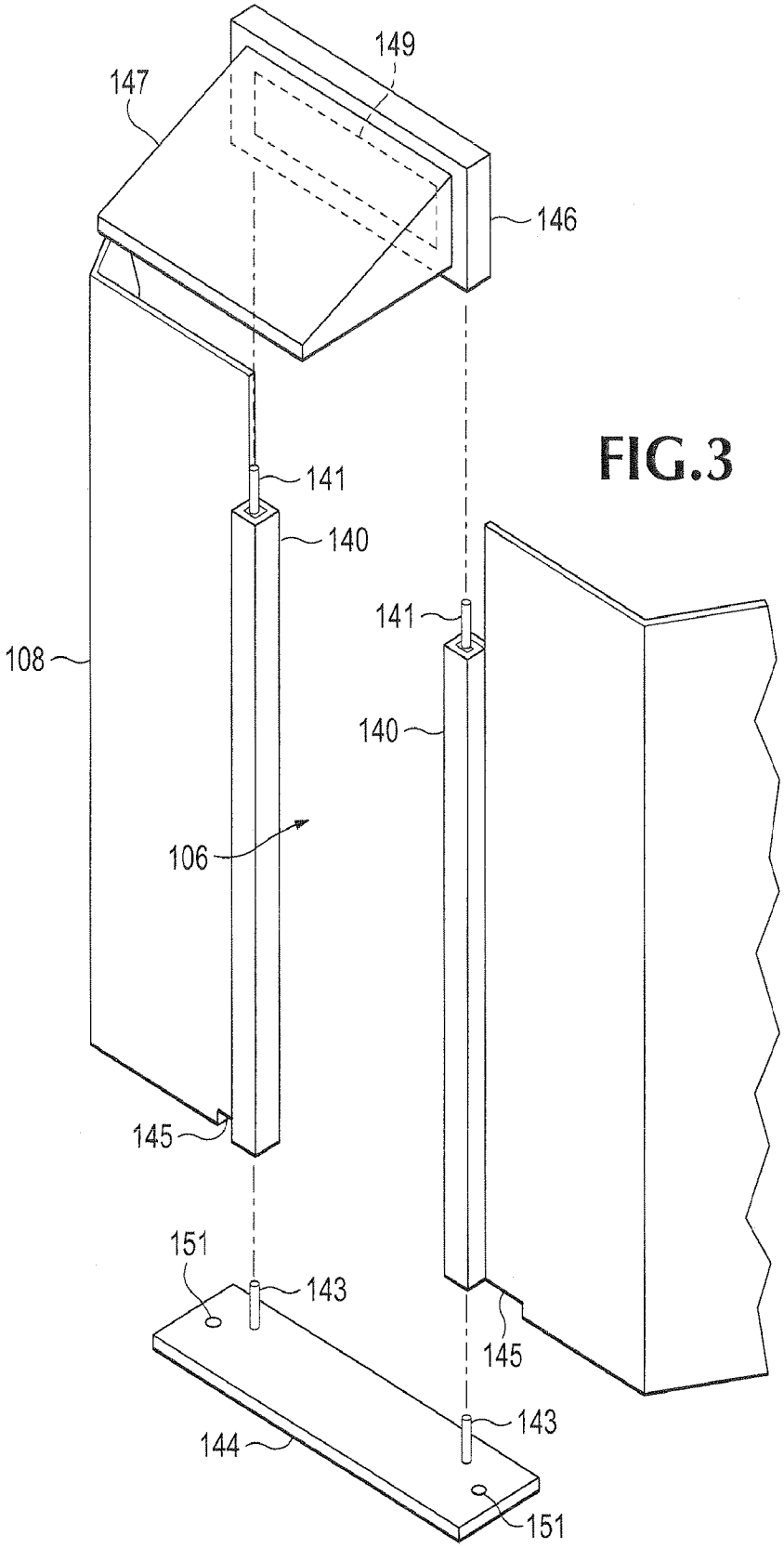


FIG.3

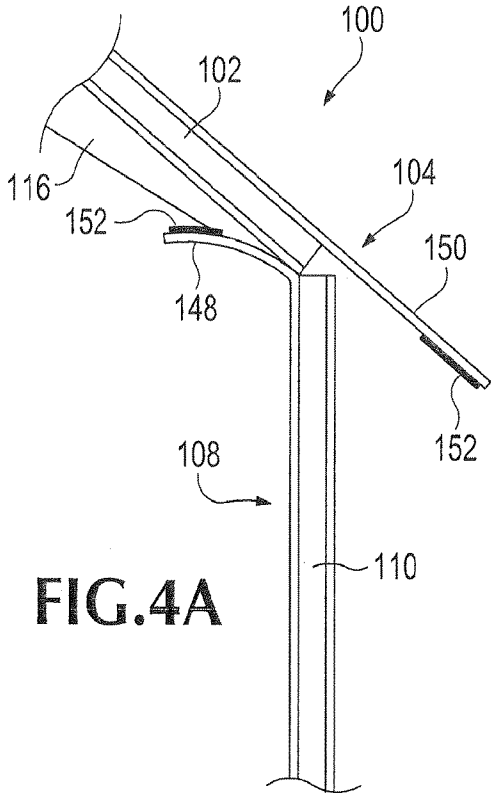


FIG.4A

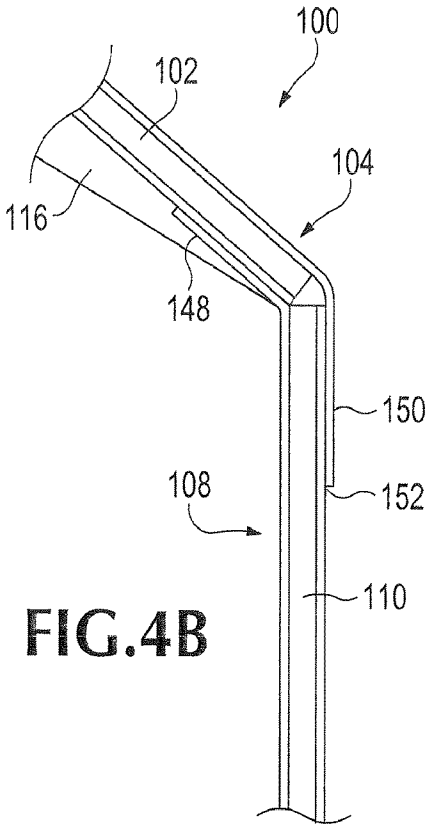


FIG.4B

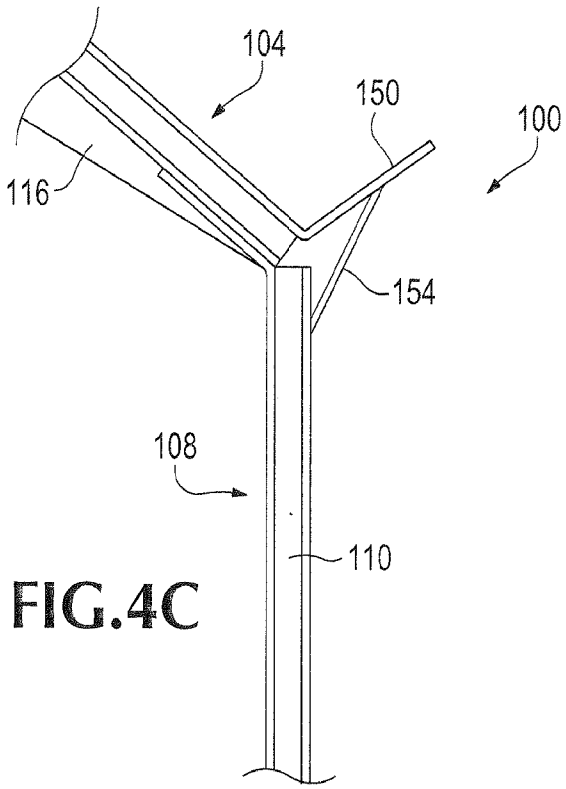
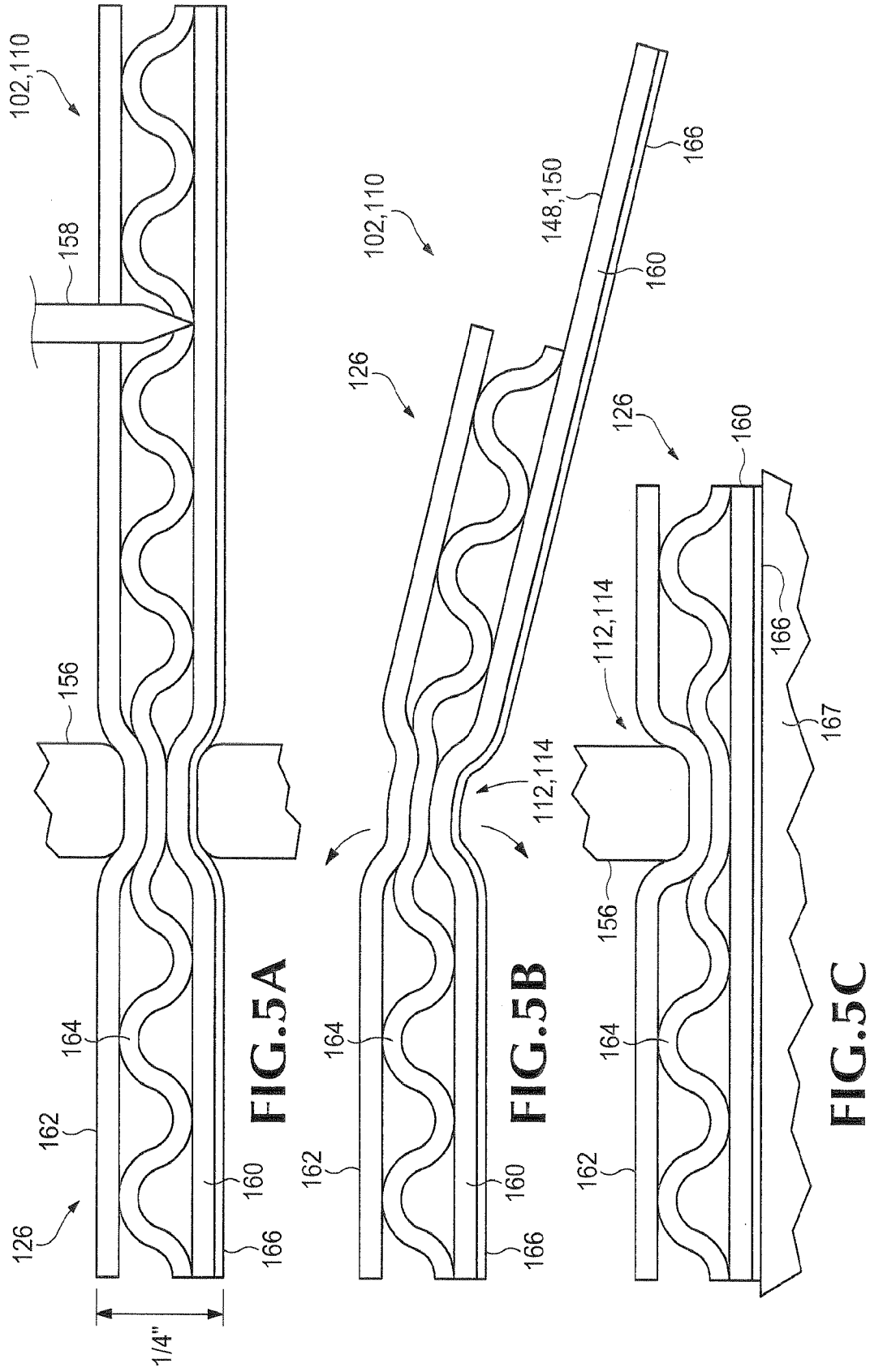


FIG.4C


102,110
158
156
164
162
160
166
126
1/4"
FIG.5A
102,110
148,150
166
160
126
112,114
164
162
160
166
FIG.5B
126
160
112,114
166
167
156
164
162
FIG.5C

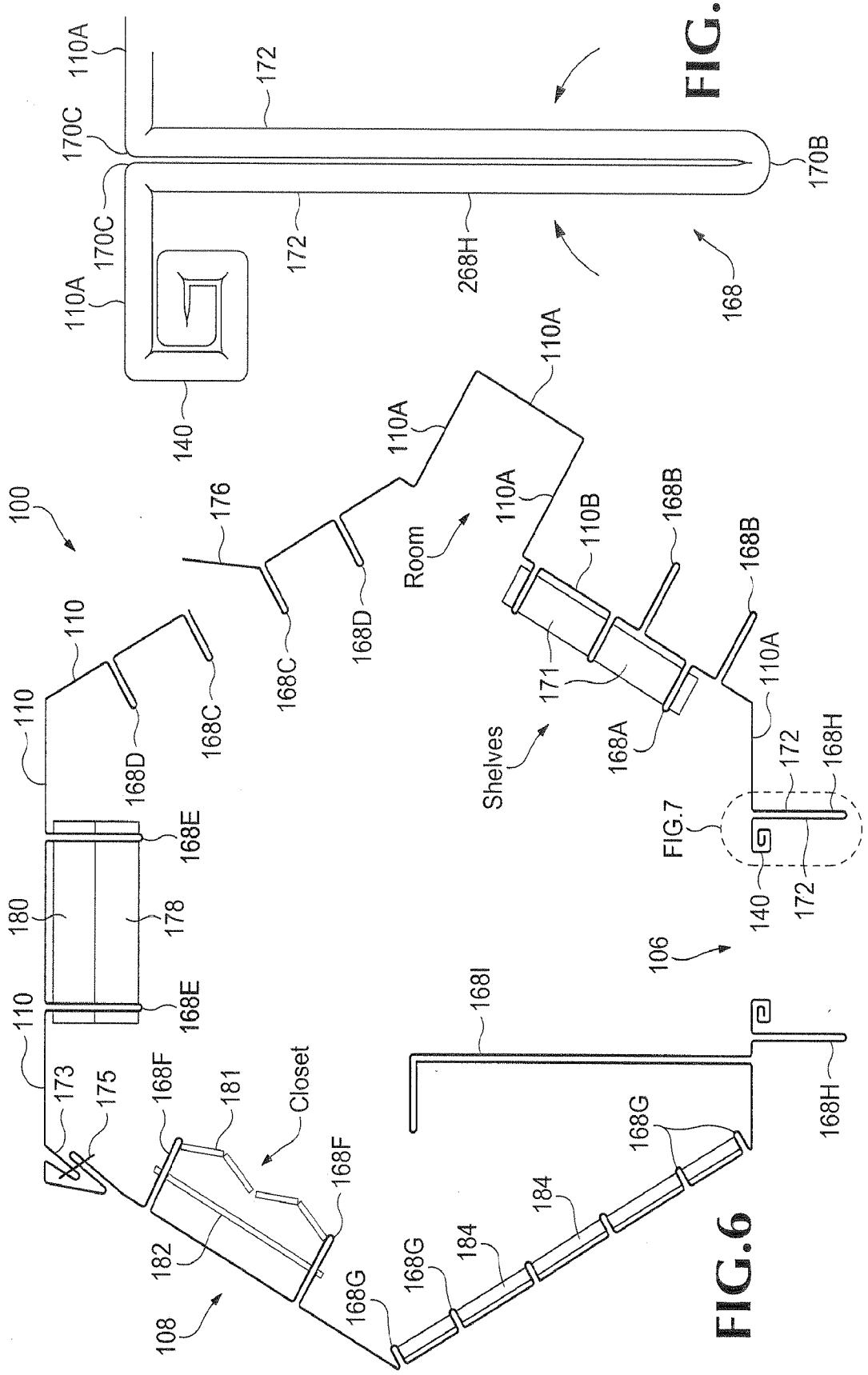

100
110
110
110
173
175
168F
181
Closet
168F
182
108
168G
168G
184
184
168G
168I
168H
106
180
178
168E
168E
168D
168C
168C
176
110A
110A
110A
110A
Room
110A
110B
168B
168B
110A
171
168A
Shelves
172
168H
FIG.7
140
172
140
110A
170C
170C
110A
172
170B
268H
168
FIG.7

FIG.6

FIG.7

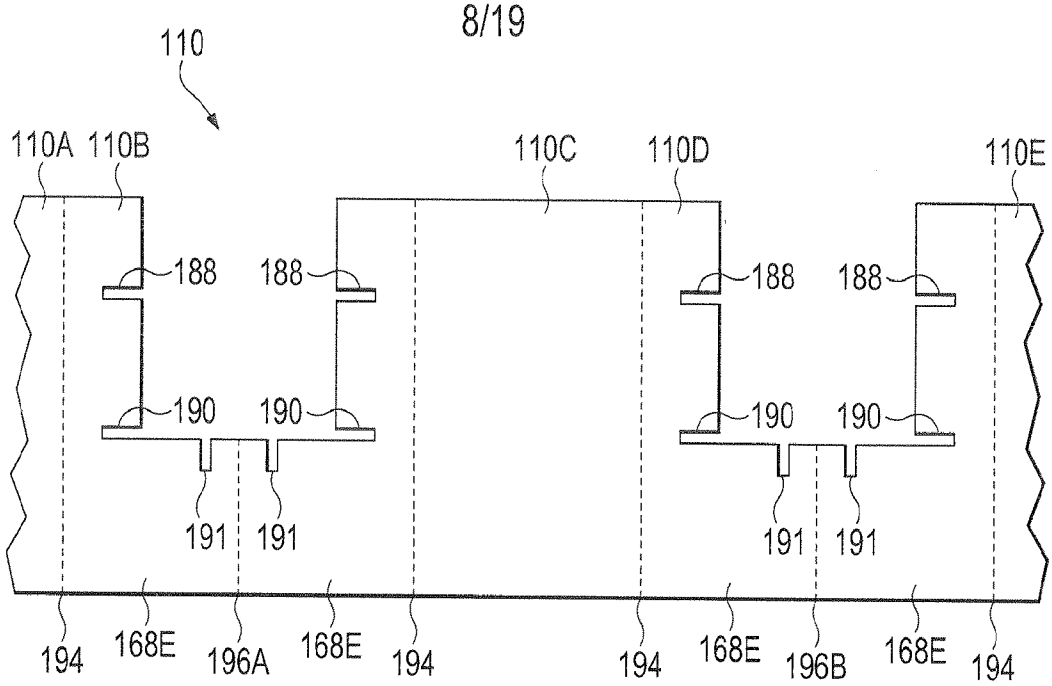

110
110A
110B
110C
110D
110E
188
188
188
188
190
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194
168E
196A
168E
194
194
168E
196B
168E
194

FIG.8

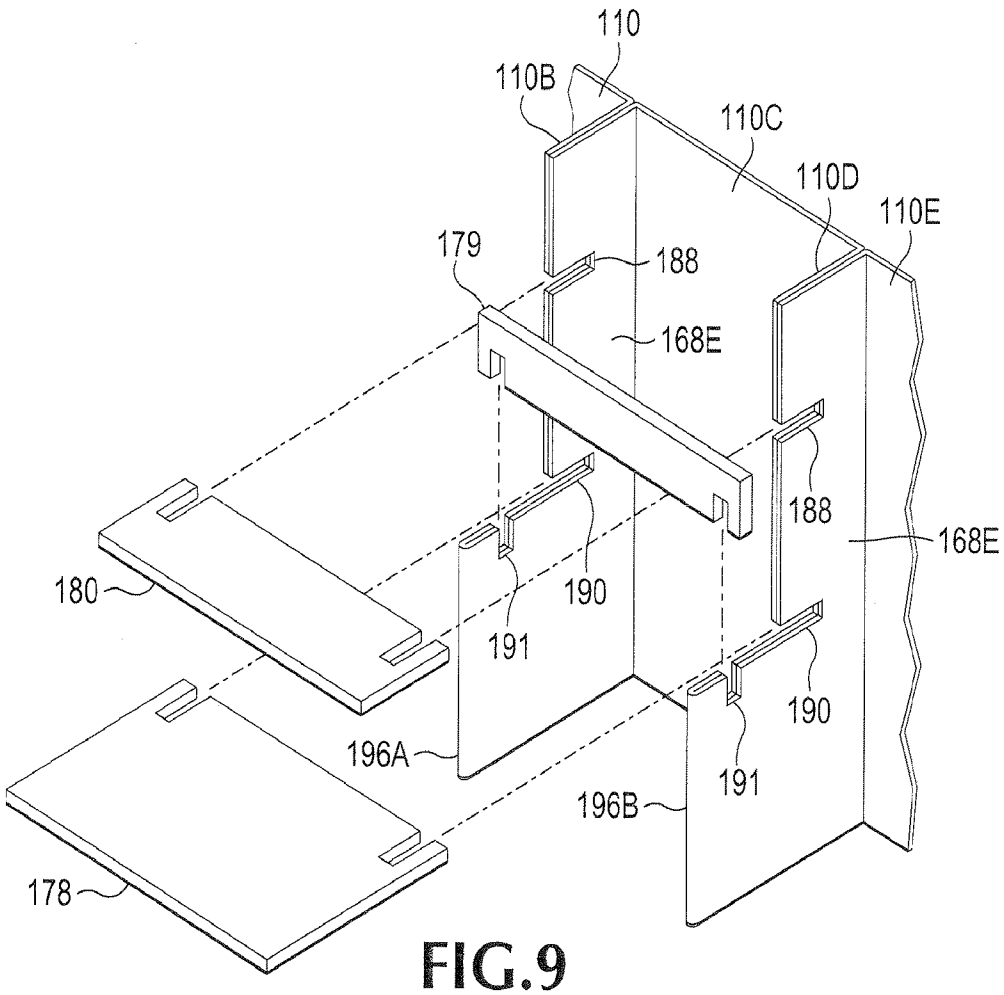

110
110B
110C
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110E
179
188
168E
188
168E
180
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191
190
196A
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196B
178

FIG.9

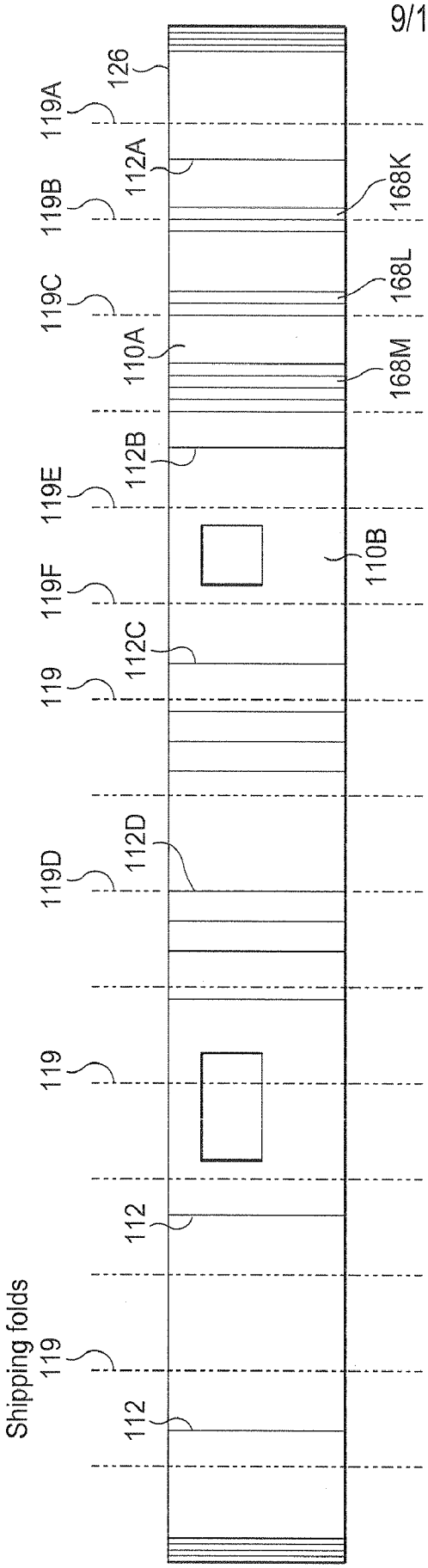


FIG.10A

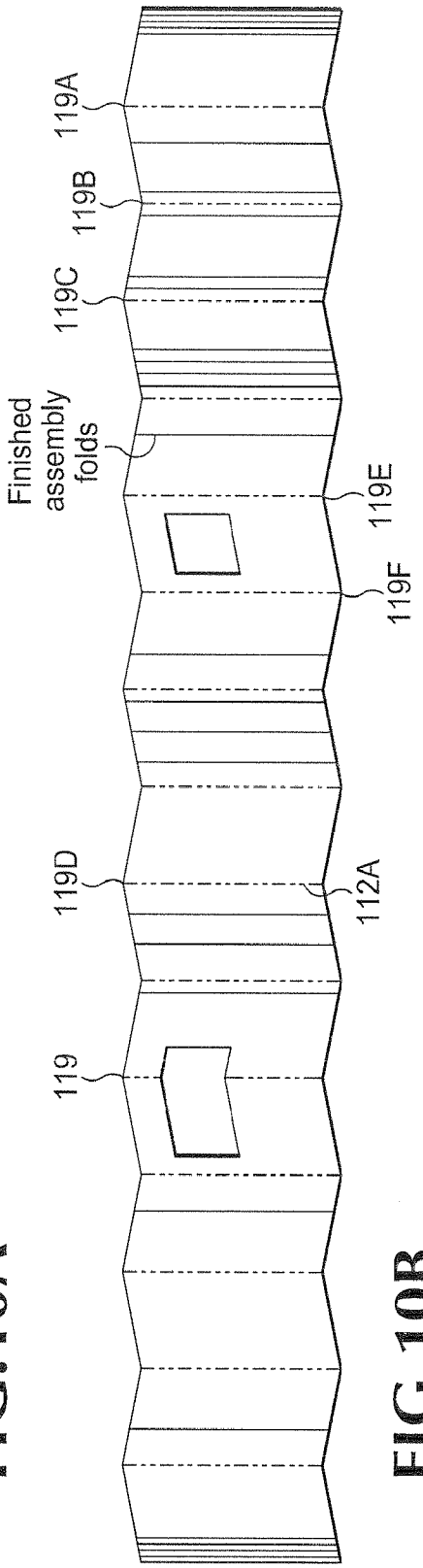


FIG.10B

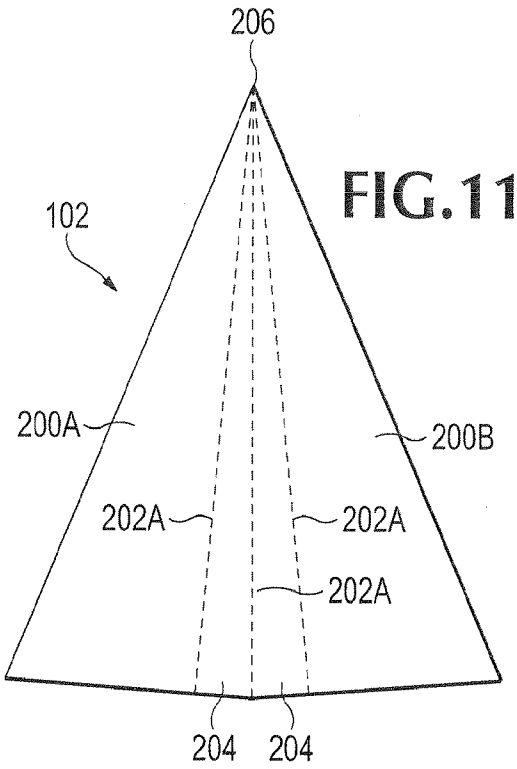


FIG.11A

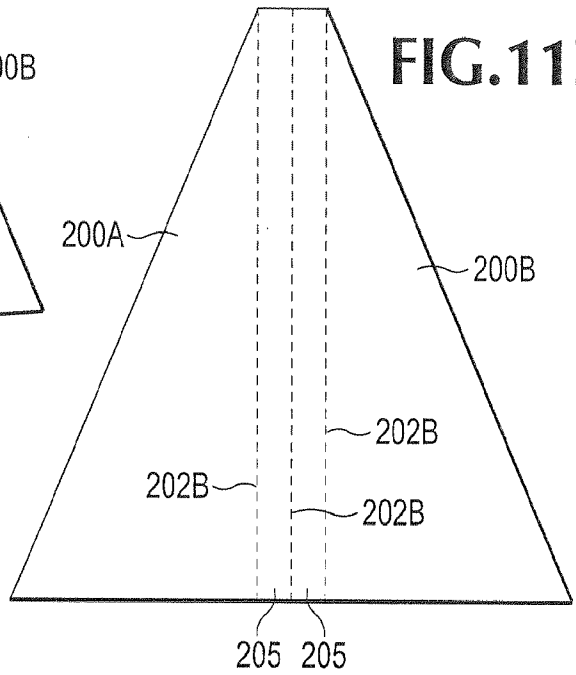


FIG.11B

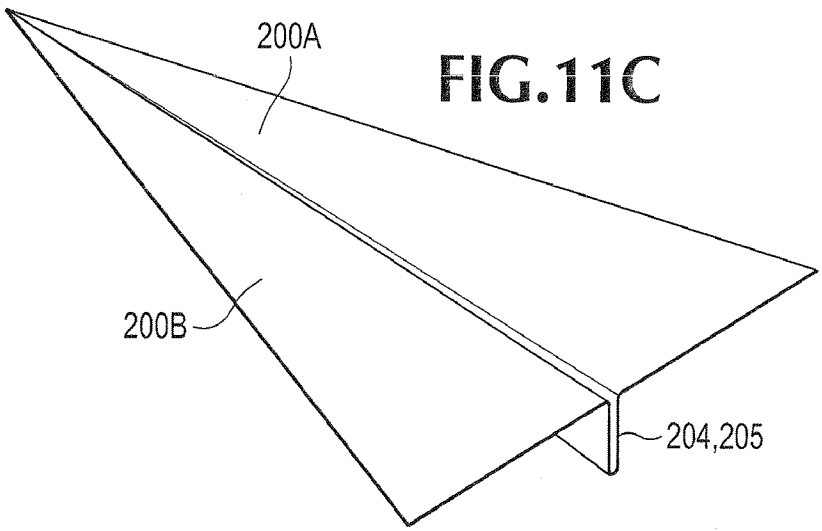


FIG.11C

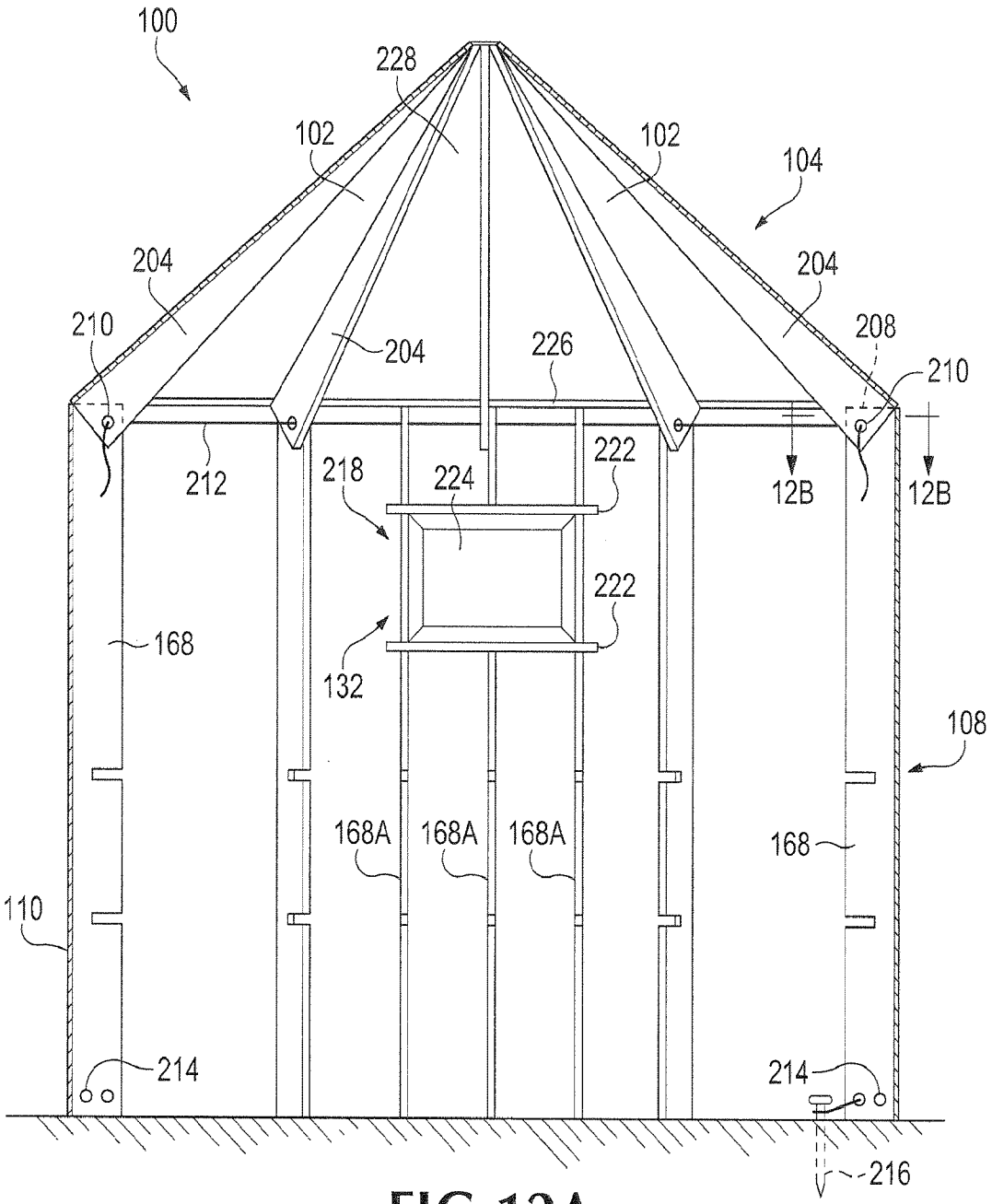


FIG.12A

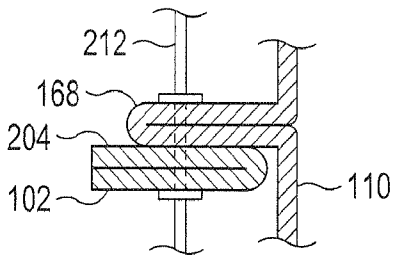


FIG.12B

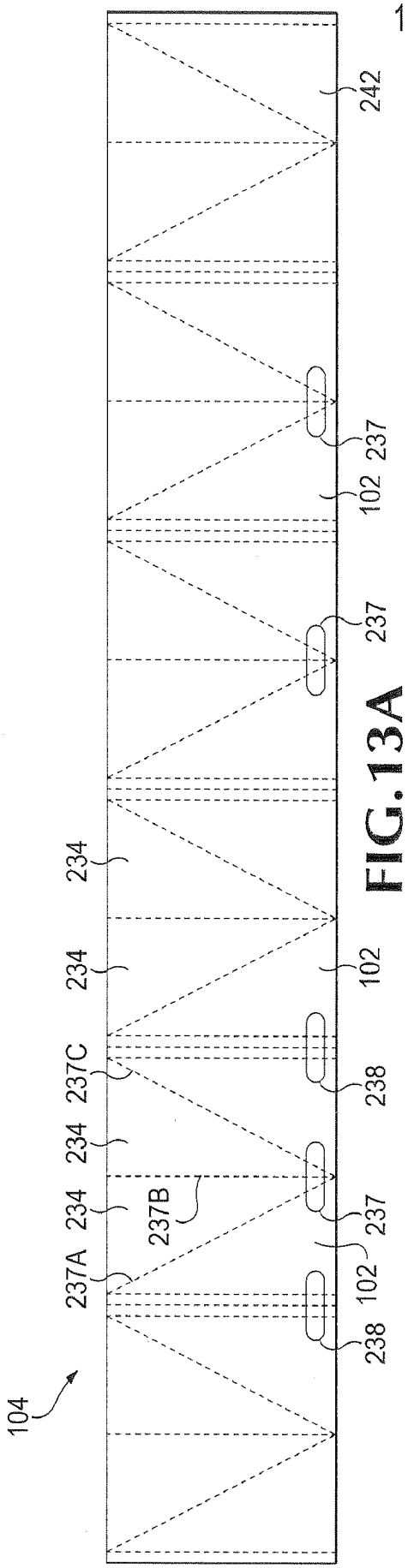


FIG. 13A

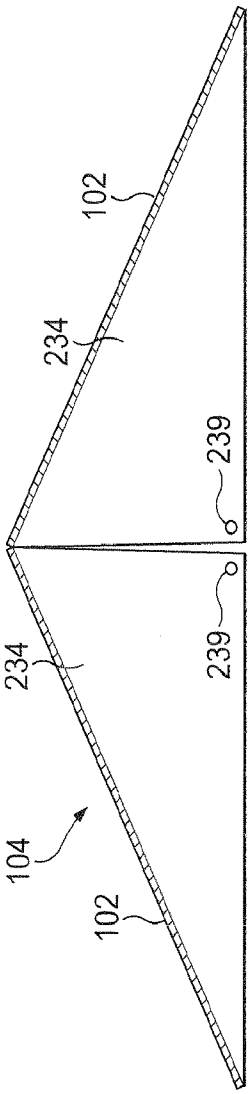


FIG. 13B

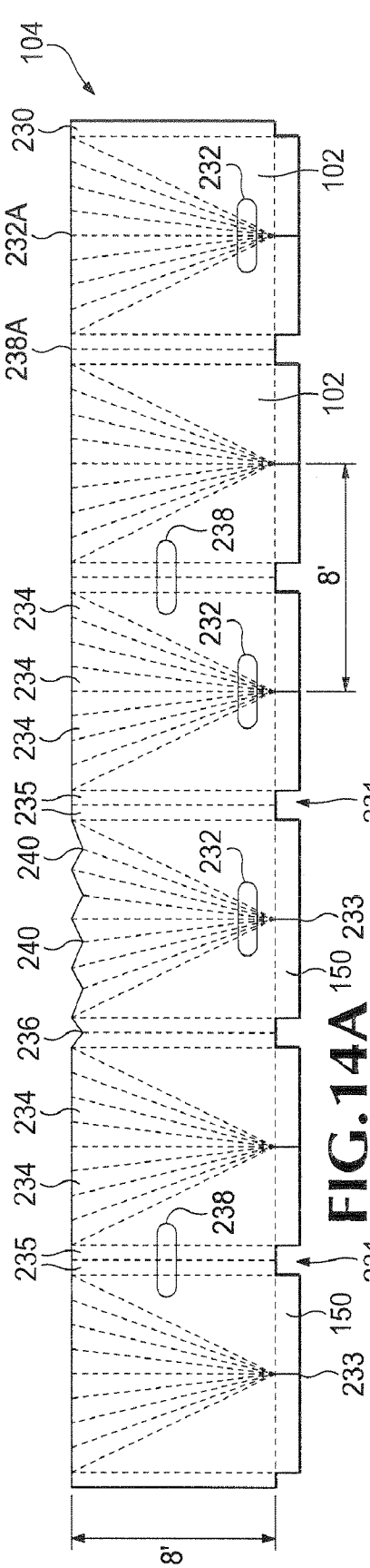


FIG.14A



FIG.14B

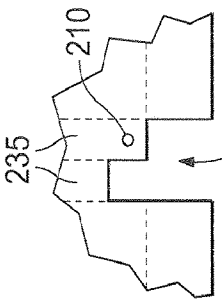


FIG.14C

FIG.14D

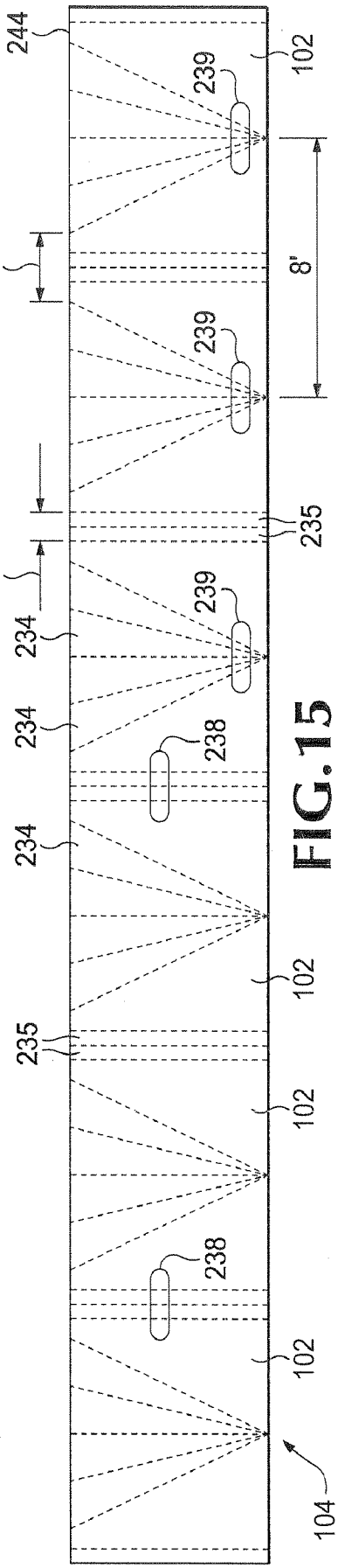


FIG.15

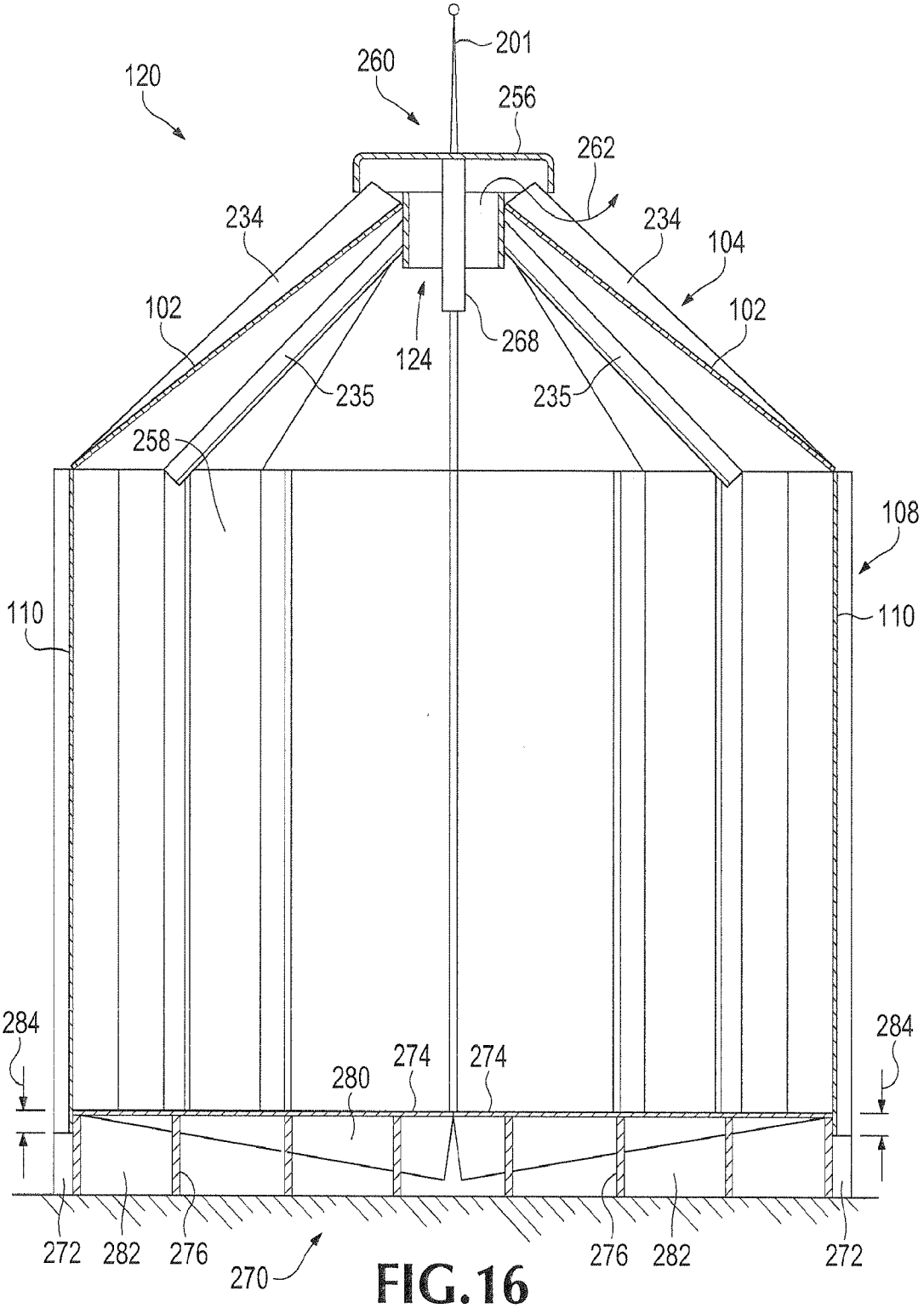

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272

FIG.16

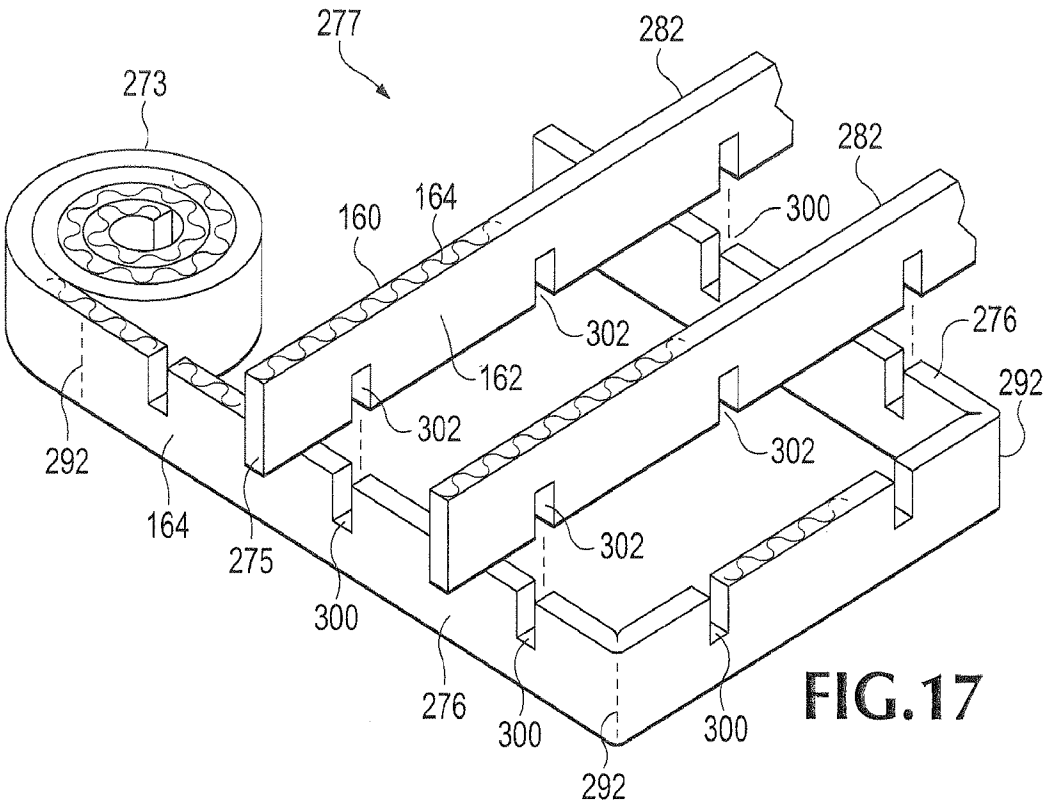

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292

FIG.17

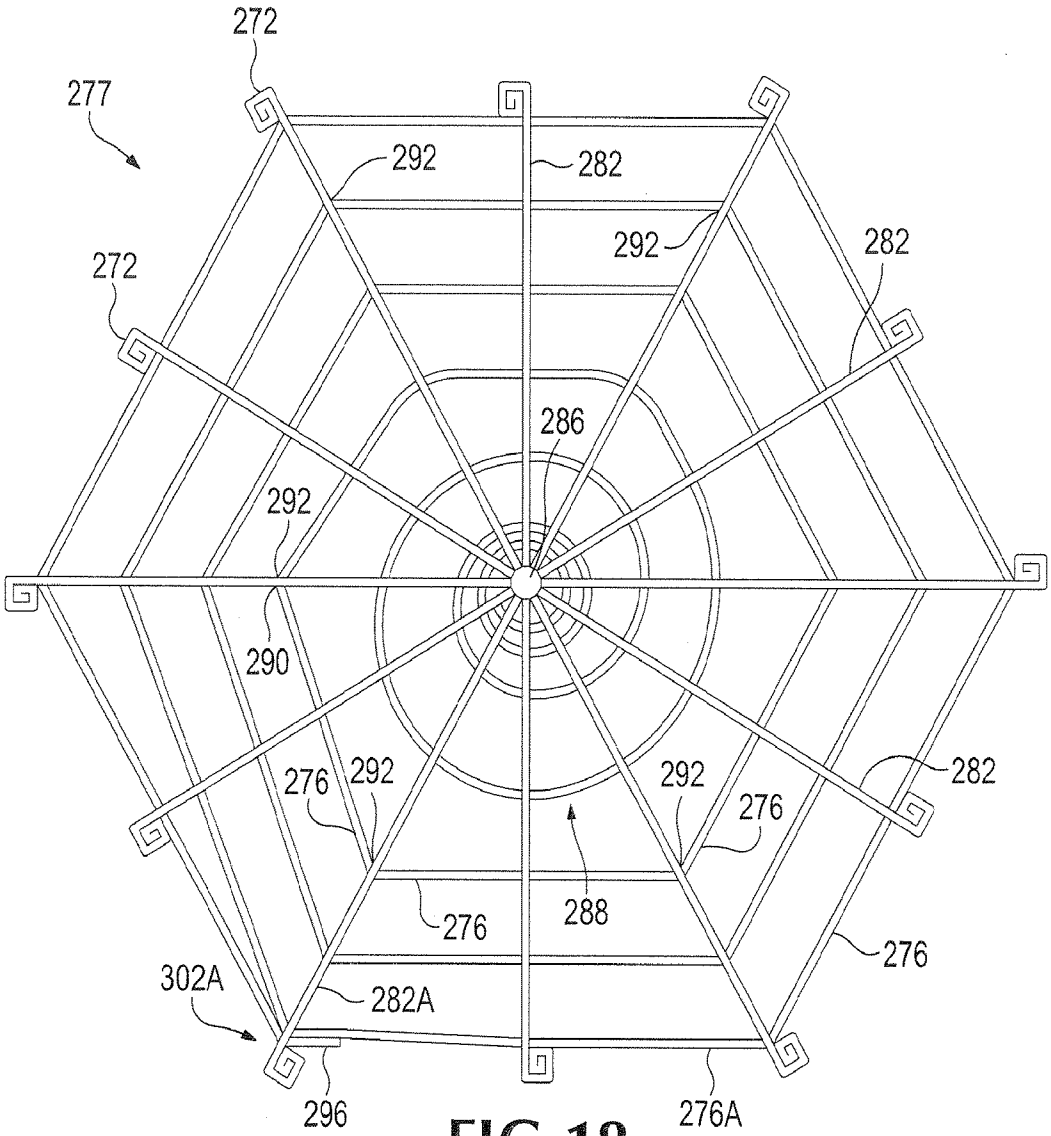

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276
288
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282A
296
276A

FIG.18

FIG.19B

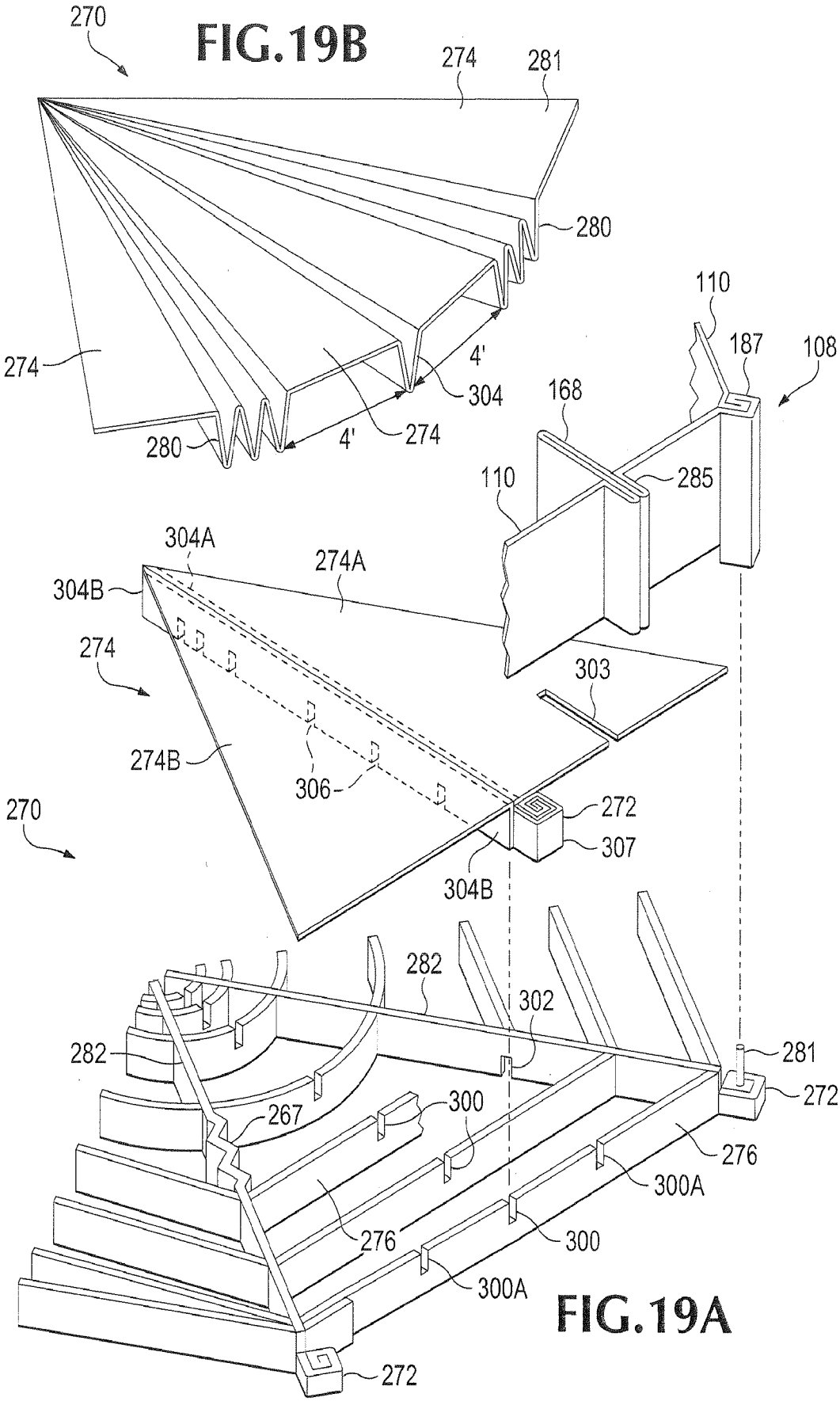


FIG.19A

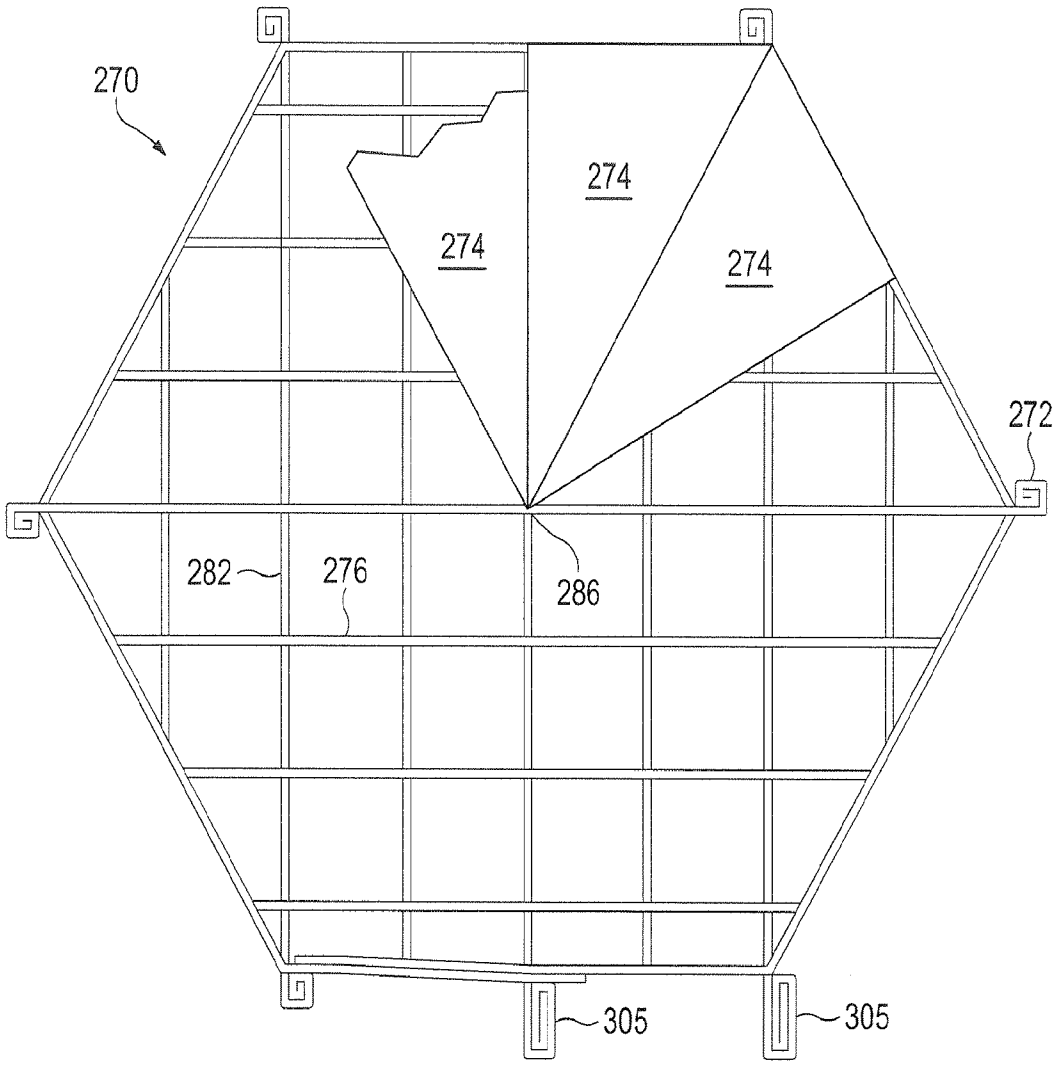


FIG.20

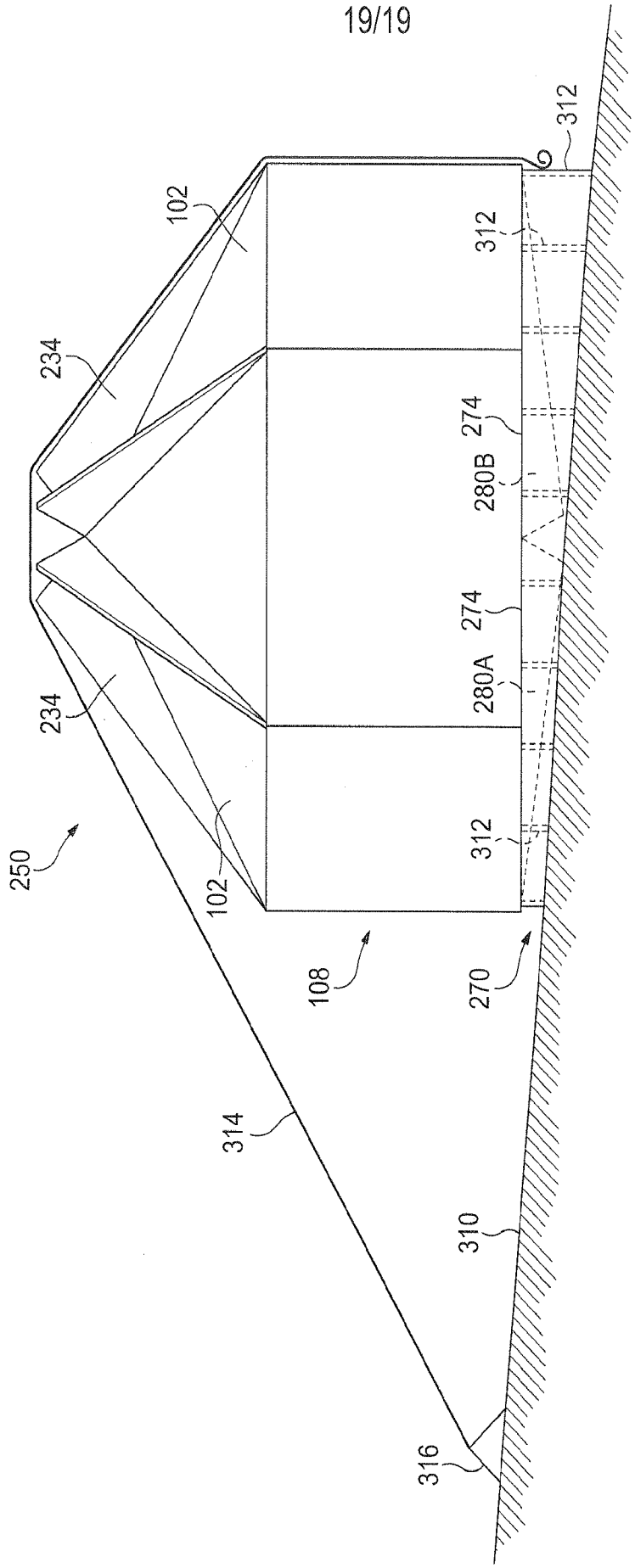

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280B
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280A
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102
108
270
314
310
316

FIG.21