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61/388,673 1 October 2010 (01.10.2010) US(71) Applicant (for all designated States except US): **BLU HOMES** [US/US]; 760 Main Street, 2nd Floor, Waltham, Massachusetts 02451 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **ROTHWELL, Elizabeth** [US/US]; 354 Somerville Avenue, Apt. 2, Somerville, Massachusetts 02143 (US). **DENG, Kevin** [US/US]; 223 Highland Avenue, Apt. 1, Somerville, Massachusetts 02143 (US). **MICHAUD, Dennis** [US/US]; 83 Lexington Avenue, Somerville, Massachusetts 02144 (US).(74) Agents: **BROOK, David, E.** et al.; Hamilton, Brook, Smith & Reynolds, P.C., 530 Virginia Rd. P.O. Box 9133, Concord, Massachusetts 01742-9133 (US).

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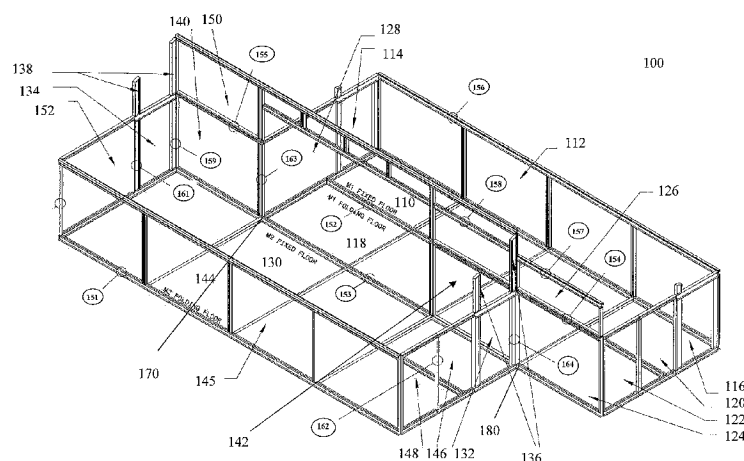


FIG. 1

(57) Abstract: Buildings are described that incorporate at least a folding building module and a complementary building module that also can be a folding building module. The building modules can be shipped to the building site separately and can be unfolded and connected quickly. The described foldable houses and buildings exhibit more design flexibility, are formed from easily transported building modules, and/or allow folded building modules that are substantially in finished condition. Additionally, methods for forming the buildings and houses are described.



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BUILDINGS FORMED FROM COMPLEMENTARY BUILDING MODULES, AND METHODS FOR BUILDING SAME

RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. 61/388,673, filed
5 October 1, 2010. The entire teachings of the above application are incorporated herein by
reference.

BACKGROUND OF THE INVENTION

Foldable houses have been described in the literature; however, very few have been built.
10 Reasons that have hindered commercialization of foldable houses include the large extent of
work that needs to be performed at the building site, the presumed limited design capabilities and
difficulty of designing houses that have sufficiently large and interesting floor plans while
having corresponding compact and easily transportable folded configurations.

There is, therefore, a need for foldable houses and buildings that exhibit more design
15 flexibility, are formed from easily transported folding building modules, and allow buildings that
are substantially in finished condition.

SUMMARY OF THE INVENTION

A first embodiment of the present invention is a building formed at least in part from a
first unfolded building module connected to a complementary building module.

20 A second embodiment of the present invention is a house. The house is formed at least in
part from a first unfolded building module and a connected complementary second unfolded
building module, wherein the first unfolded building module and the second unfolded building
module, each independently, have a core part and an unfolded part attached to the respective core
part; i) the unfolded part of the first unfolded building module is connected to a complementary
25 core part of the second unfolded building module, ii) the unfolded part of the first unfolded
building module is connected to the complementary unfolded part of the second unfolded
building module, or iii) the core part of the first unfolded building module is connected to a

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complementary core part of the second unfolded building module; and the first unfolded building module and/or the second unfolded building module contain kitchen elements and/or bathroom elements in one or both of the respective core structures that were present in the respective folded building modules.

5 A third embodiment of the present invention is a method of forming a building. The method includes (a) setting a first folded building module on a foundation, the folded building module having a core structure and an unfoldable structure attached to the core structure, the unfoldable structure including a plurality of foldably connected panels, (b) unfolding part or all of the unfoldable structure of the first folded building module to form an unfolded structure, (c)
10 setting a complementary building module on the foundation and positioned such that panels of the complementary building module complement respective panels of the unfolded structure, (d) connecting the panels of the complementary building module and respective panels of the unfolded structure, and (e) connecting one or more roof elements to the building modules.

BRIEF DESCRIPTION OF THE DRAWINGS

15 The foregoing will be apparent from the following more particular description of example embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating embodiments of the present invention.

20 FIG. 1 is a schematic axonometric view of the structural frame of a house according to an exemplary embodiment of the present invention, substantially provided by two connected complementary structural frames of two respective unfolded building modules.

 FIG. 2 is a perspective view of an exemplary unfolding sequence according to an embodiment of the present invention starting from two separate folded structural frames of
25 respective two separate folded building modules to the structural frame described in FIG. 1.

 FIG. 3 is a schematic floor plan of a completed house according to an exemplary embodiment of the present invention, based on the structural frame of FIG. 1.

 FIG. 4 provides schematic views from four sides of a completed house according to an exemplary embodiment of the present invention, based on the structural frame of FIG. 1.

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FIG. 5 is a schematic view of a frame element according to an exemplary embodiment of the present invention.

FIG. 6 is a schematic view of a frame element according to an exemplary embodiment of the present invention.

5 FIG. 7 is a schematic view of a frame element according to an exemplary embodiment of the present invention.

FIG. 8 is a schematic view of a frame element according to an exemplary embodiment of the present invention.

10 FIG. 9 is a schematic view of a frame element according to an exemplary embodiment of the present invention.

FIG. 10 is a schematic cross-sectional view illustrating an exemplary connection assembly connecting a fixed floor panel of one building module with a folding floor panel in unfolded configuration of another complementary unfolded building module.

15 FIG. 11 is a schematic cross-sectional view illustrating an exemplary connection assembly connecting a fixed back wall panel of one building module with a removable side wall panel of another complementary unfolded building module.

20 FIG. 12 provides a schematic perspective and plan view illustrating an exemplary connection assembly connecting a fixed back wall frame element and a fixed floor frame element of one building module with a folding floor frame element and side wall frame element of a complementary unfolded building module.

FIG. 13 is a schematic cross-sectional view illustrating an exemplary connection assembly connecting a fixed interior wall panel and a fixed interior side panel of one building module with an exterior flip (i.e., folding) wall panel of another complementary unfolded building module.

25 FIG. 14 provides a schematic perspective view illustrating an exemplary connection assembly of a folding floor frame element and exterior flip wall frame element of one building module with a fixed floor frame element, fixed interior wall frame element, and fixed side wall frame element of a complementary unfolded building module.

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FIG. 15 is a schematic axonometric view of the structural frame of a house according to an exemplary embodiment of the present invention, substantially provided by three connected complementary structural frames of three respective unfolded building modules.

FIG. 16 is a schematic axonometric view of the structural frame of a house according to an exemplary embodiment of the present invention, substantially provided by two connected complementary structural frames of two respective unfolded building modules.

FIG. 17 provides schematic views of a house that can be built with a structural frame such as the one shown in FIG. 15.

FIG. 18 provides schematic views of a house that can be built with a structural frame such as the one shown in FIG. 16.

DETAILED DESCRIPTION OF THE INVENTION

The buildings and, particularly, houses of the present invention are formed at least in part from an unfolded building module connected to a complementary building module. The combination of foldable building technology in conjunction with complementary design as described herein allows fabrication of substantially finished houses and buildings that exhibit more design flexibility, are formed from easily transported building modules, and require little finishing at the building site. It further allows to reduce the weight of the structural frame, allows large spaces with high ceilings extending from one complementary building module to another, allows single and therefore thin panels between complementary building modules, and allows overall reduction of material, labor and transport costs.

A description of example embodiments of the invention follows.

Several houses using the building technology described herein have been built and are described in the following FIGS. 1 to 16.

FIG. 1 is a schematic axonometric view of the structural frame 100 of a house according to an exemplary embodiment of the present invention. In this embodiment, the structural frame is a structural steel frame, and is substantially provided by two connected complementary structural frames of two respective unfolded building modules. The first unfolded structural frame is made from a number of frame elements, specifically, a fixed floor frame element 110 in

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fixed connection with a fixed back wall frame element 112, a fixed side wall frame element 114, and a further fixed side wall frame element 116. Frame element 112 is also in fixed connection with frame elements 114 and 116. In combination, the frame elements 110, 112, 114 and 116 form a core structure of the first unfolded building module. Fixed floor frame element 110 is

5 foldably connected to a folding floor frame element 118, and fixed side wall frame element 116 is foldably connected to a folding side wall frame element 120 which itself is foldably connected to a further folding side wall frame element 122. The folding floor frame element is further foldably connected to an exterior flip (i.e., folding) wall frame element 124, which itself is further foldably connected to another exterior flip (i.e., folding) wall frame element 126.

10 Analogously to fixed side wall frame element 116, fixed side wall frame element 114 can be connected to foldable side wall frame elements (similar to frame elements 120 and 122).

Alternatively, as is the case here, a removable side wall frame element 128 can be installed. The foldably connected frame elements provide the unfolded structure of the first building module, and any removable frame element can be installed (i.e. connected) separately to respective

15 adjacent frame elements. In fully folded configuration the foldably connected frame elements arrange compactly as shown in step (1) of FIG. 2 and leave substantially all of the core structure volume available for other parts to be prefabricated and finished in the core volume. It is noted that the fully folded structural frame 210 of the first building module includes two foldable side wall frame elements (similar to frame elements 120 and 122) connected to fixed side wall frame

20 element 114. However, except for this difference, the folded and unfolded configurations associated with the first structural frame are the same. With respect to FIG. 1, additionally, in

fully folded configuration, the foldable floor frame element 118 provides a wall of the folded module, which increases structural stability of the building module in folded configuration, protects prefabricated and finished parts in the core volume, and thereby facilitates transportation
25 of the respective building module.

The second unfolded structural frame is also made from a number of frame elements, specifically, a fixed floor frame element 130 in fixed connection with a fixed side wall frame element 132, a further fixed side wall frame element 134, a fixed back wall frame element 140, and a further fixed back wall frame element 142. Frame element 140 is also in fixed connection
30 with frame element 134, and frame element 142 is also in fixed connection with frame element

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132. In combination, the frame elements 130, 132, 134, 140 and 142 form a core structure of the second unfolded building module. Fixed floor frame element 130 is foldably connected to a folding floor frame element 144, which in turn is foldable connected to a flip wall 145. Fixed side wall frame element 132 is foldably connected to a folding side wall frame element 146 which itself is foldably connected to a further folding side wall frame element 148. The fixed back wall frame element 140 and 142 are further foldably connected with a folding clerestory frame element 150. Side frame elements 136 and 138 are in fixed connection with respective fixed side wall frame elements 132 and 134, and are not part of the structural frame in folded configuration. Analogously to fixed side wall frame element 132, fixed side wall frame element 134 can be connected to foldable side wall frame elements (similar to frame elements 146 and 148). Alternatively, as is the case here, a removable side wall frame element 152 can be installed. The foldably connected frame elements provide the unfolded structure of the second building module, and any removable frame element can be installed (i.e. connected) separately to respective adjacent frame elements. In fully folded configuration the foldably connected frame elements arrange compactly as shown in step (7) of FIG. 2 and leave substantially all of the core structure volume available for other parts to be prefabricated and finished in the core volume. It is noted that the fully folded structural frame 220 of the second building module includes two foldable side wall frame elements (similar to frame elements 146 and 148) connected to fixed side wall frame element 134; however, except for this difference, the folded and unfolded configurations associated with the second structural frame are the same. With respect to FIG. 1, additionally, in fully folded configuration, the foldable floor frame element 144 provides an exterior wall of the folded building module and the foldable clerestory frame element 150 provides a further exterior wall of the folded building module, which increases structural stability of the building module in folded configuration, protects prefabricated and finished parts in the core volume, and thereby facilitates transportation of the respective building module.

As described above, FIG. 1 shows the structural frame of a house made from two complementary structural frames, a first unfolded structural frame and a second unfolded structural frame. Although only frame elements and respective structural load carrying members are shown it is to be understood that typically the house is not only formed from two complementary folded structural frames, but from two folded building modules that when

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unfolded complement each other and form a substantially finished house including even kitchen elements including but not limited to cabinets, appliances, and sink(s), and/or bathroom elements including but not limited to cabinets, shower, bathtub, toilet, and sink.

As described above, the structural frame shown in FIG. 1 is made from a number of frame elements. Exemplary connection assemblies are also indicated in 151-164, 170 and 180.

FIG. 2 is a perspective view of an exemplary unfolding sequence according to an embodiment of the present invention starting from two separate folded structural frames of respective two separate folded building modules to the structural frame described in FIG. 1. For ease of visualization, only the structural frames are shown and not the complete building modules, however, the respective building modules include the structural frames and, thus, the unfolding sequence is the same for the structural frame and the respective building module. A first folded structural frame of 210 of a first folded building module is unfolded to form an unfolded structural frame 215 of the unfolded building module. Firstly, as shown in (1), the first folded structural frame 210 is set on a foundation (not shown). Then, the folding floor frame element 118 folds down to the configuration shown in (2). In the next step, the exterior flip wall frame element 124 folds up to the configuration shown in (3). In a further step, a further exterior flip wall 126 folds up to the configuration shown in (4). Then, the accordion walls 218 and 219 fold out as shown in (5) to yield the unfolded structural frame 215. The unfolded structural frame 215 and corresponding unfolded building module exhibit an opening 216, here on the front side of the unfolded structure of the unfolded structural frame 215. Accordion wall 218 is made from two folding side walls, as described above as alternative for the removable side wall 128 in FIG. 1. Accordion wall 219 is made from folding side walls 120 and 122 (shown in FIG. 1). Subsequently, a second complementary folded structural frame 220 is set on the foundation and connected to the first unfolded structural frame 215 and corresponding building module. The second building module and structural frame 220 are adapted to complement the first building module and structural frame 215. Specifically, in this embodiment, the interior wall frame element 142 and part of the folding clerestory frame element 150 of the second structural frame 220 complement the front side of the first unfolded structural frame 215 by providing interior wall frame elements for the first unfolded structural frame 215. Here, the opening 216 is reduced in area by fixed interior wall frame element 142. In the context of the unfolding of

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folded building modules, the second building module having the second structural frame, typically, includes substantially finished panels corresponding to the frame elements, and panels corresponding to frame elements such as 142 can have interior finishing material on both sides. After the second complementary folded building module is set (only structural frame 220 is shown), the folding floor frame element 144 folds down to the configuration shown in (8). Then, the flip wall frame element 145 folds up to the configuration shown in (9). Then, the accordion walls 225 and 230 fold out as shown in (10) to the configuration shown in (11). Accordion wall 225 is made from two folding side walls, as described above as alternative for the removable side wall 152 in FIG. 1. Accordion wall 219 is made from folding side walls 146 and 148 (shown in FIG. 1). Finally, the folding clerestory frame element 150 is folded up to yield the structural frame 200 of a house according to an exemplary embodiment of the present invention. Likewise, the unfolding of the corresponding building modules that include the first and second structural frames, results in part of a house, and, at this stage, further elements such as some interior walls and/or roof elements are connected to the structural frame to form the completed house.

Typically, kitchen and bathroom elements are already included in the folded building modules.

FIG. 3 is a schematic floor plan 300 of a completed house according to an exemplary embodiment of the present invention, based on the structural frame 100 of FIG. 1. The house is formed in part from two complementary unfolded building modules that are the basis for the completed respective parts 210 and 220 of the house. Substantial parts of the plumbing, heating, cooling and electrical system (not shown) can be installed in the core structure of the building modules. This includes kitchen elements such as 322 and bath elements such as 324. Interior walls such as 326 can be foldably attached to the structural frames of the building modules, or they are separate and are connected to the structural frame at the building site. Typically, the structural frame can be adapted for attachment of these interior walls. The house includes several rooms, including a kitchen area 330, a first bathroom 335, a first bedroom 340, a second bathroom 345, a second bedroom 350, an office room 355 and a living room 357. The house features a plurality of windows 360, which typically are included in the folded building modules.

FIG. 4 provides schematic views from four sides (a), (b), (c) and (d) of a completed house according to an exemplary embodiment of the present invention. The house is based on the structural frame of FIG. 1, and can have the floor plan shown in FIG. 3. The house has two

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parts 310 and 320. Part 210 is substantially provided by an unfolded building module having the unfolded structural frame 215 (see FIG. 2) and part 210 is substantially provided by an unfolded building module having the unfolded structural frame 235 (see FIG. 2). The views further show the roof elements 410 and 420.

- 5 FIG. 5 is a schematic view of an exemplary fixed back wall frame element 140 in FIG. 1 with exemplary dimensions. It can, for example, be made from four structural steel load carrying members that have the following exemplary dimensional characteristics:

Member	Tag	Length
510	C 6 x 13	12'
520	W 4.125 x 13	12' 2"
530	W 6.25 x 16	8' 9" 7/8
540	HSS 4 x 2 x 0.25	8' 9" 7/8

- 10 In the "Tag" column of the Table above and the ones below, W stands for "W-Section" or a "Wide Flange" member, C for a "C-Channel", and HSS for "Hollow Structural Steel Member". For Cs and Ws, the first number is the depth of the member and the second number is the weight per lineal foot. So, in the case of "C 6 x 13", it is a C-channel member with a depth of 6" and a weight of 13 pounds/ft.

- 15 FIG. 6 is a schematic view of an exemplary interior wall frame element 142 in FIG. 1 with exemplary dimensions. It can, for example, be made from four structural steel load carrying members that have the following exemplary dimensional characteristics

Member	Tag	Length
610	PLATE 4 x 0.25	12' 2"
620	W 4.125 x 13	12' 2"
630	HSS 4 x 2 x 0.25	8' 9" 5/8
640	W 6.25 x 16	8' 9" 5/8

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FIG. 7 is a schematic view of an exemplary clerestory frame element 150 in FIG. 1 with exemplary dimensions. It can, for example, be made from twelve structural steel load carrying members that have the following exemplary dimensional characteristics:

Member	Tag	Length
701	C 6 x 10.5	23' 10'
702	W 6.25 x 16	48'
703	HSS 2 x 4 x 0.25	12' 2"
704	W 4 x 13	11' 5" 3/4
705	HSS 2 x 4 x 0.25	12' 2"
706	HSS 4 x 2 x 0.25	6' 2" 1/4
707	W 6 x 16	6' 2" 1/4
708	W 6 x 16	6' 2" 1/4
709	HSS 4 x 2 x 0.25	6' 2" 1/4
710	W 4 x 13	2' 2" 3/4
711	W 4 x 13	2' 2" 3/4
712	W 4 x 13	2' 2" 3/4

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FIG. 8 is a schematic view of an exemplary exterior flip (i.e., folding) wall frame element 124 in FIG. 1 with exemplary dimensions. It can, for example, be made from four structural steel load carrying members that have the following exemplary dimensional characteristics:

Member	Tag	Length
810	C 6 x 13	12'
820	W 4.125 x 13	12'
830	HSS 4 x 2 x 0.25	8' 9" 7/8
840	HSS 4 x 2 x 0.25	8' 9" 7/8

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FIG. 9 is a schematic view of an exemplary exterior flip (i.e., folding) wall frame element 126 in FIG. 1 with exemplary dimensions. It can, for example, be made from four structural steel load carrying members that have the following exemplary dimensional characteristics:

Member	Tag	Length
910	HSS 2 x 4 x 0.25	12'
920	W 6.25 x 16	12'
930	HSS 4 x 2 x 0.25	3' 5" 1/4
940	HSS 4 x 2 x 0.25	3' 5" 1/4

5

FIG. 10 is a schematic cross-sectional view illustrating an exemplary connection assembly 1000 connecting a fixed floor panel 1010 (based on the fixed floor frame element 130 of FIG. 1) of one building module with a folding floor panel (in unfolded configuration and based on the folding floor frame element 118 of FIG. 1) of another complementary unfolded building module. Cross-sectional view (a) of FIG. 10 shows the panels 1010 and 1020 in connected and finished configuration. Cross-sectional view (b) of FIG. 10 shows the cross-sectional outlines 1011 and 1012 of respective panels 1010 and 1020. Cross-sectional view (c) of FIG. 10 shows how the two panels are connected with suitable fasteners 1070 (e.g., HILTI Kwik-Flex screws) by fastening the steel plate 1042 of panel 1020 with the C-channel 1035 of panel 1010, and by fastening the steel plate 1040 of panel 1010 with the C-channel 1037 of panel 1020. Panels 1010 and 1020 are substantially in finished condition, however, to allow fastening the C-channels, a section 1031 above the C-channels is unfinished (or the part 1031 can be included in the folded building module, and disassembled before the respective panel is moved into unfolded configuration) to allow access to the channels for fastening purposes (as shown in view (b) of FIG. 10). After, the panels 1010 and 1020 are connected, the unfinished area 1031 can be finished with finishing material (e.g., flooring) 1030 (or, the part 1031 can be returned into position). Each panel includes blocking members 1055 connected to the interior surface areas of the respective C-channels, and further blocking members 1050 connected to the respective blocking members 1055. The blocking members are adapted to facilitate connection

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of subflooring 1060 (e.g., plywood, oriented strand board, or other pre-finish surfacing) and finish floor 1065 to the frame element. As illustrated in FIG. 10 the structural load carrying members, C-channels 1035 and 1037, of the two panels complement each other to form a combined structural load carrying member of approximately I-beam shape indicated in FIG. 1 as element 153. Additionally, the panels 1010 and 1020 complement each other to form a continuous floor area from one unfolded building module to the connected unfolded building module.

FIG. 11 is a schematic cross-sectional view illustrating an exemplary connection assembly 1100 connecting a fixed back wall panel 1120 (based on the fixed back wall frame element 140 of FIG. 1) of one building module with a removable side wall panel 1110 (based on the removable side wall frame element 128 of FIG. 1) of another complementary unfolded building module. FIG. 11 shows the panel 1110 and 1120 in connected and finished configuration. Panel 1110 includes a hollow structural steel member 1114, a blocking member 1112 fastened to the member 1114, and interior wall board (e.g., gypsum board) 1116 and sheathing 1118 (e.g., plywood, oriented strand board, etc.). Panel 1120 includes a steel I-beam member 1124, a blocking member 1122 fastened to the member 1124, and interior wall board 1126 and sheathing 1128 fastened to the blocking member. After the panels 1120 and 1124 are fastened to each other, a further blocking member 1122 and interior wall board 1123 are used to finish the connection assembly. As illustrated in FIG. 11 the structural load carrying members, I-beam 1124 and 1114, of the two panels complement each other to form a combined structural load carrying member indicated in FIG. 1 as element 163. Additionally, the panels 1110 and 1120 complement each other to form a continuously finished wall through the connection corner 1150.

FIG. 12 provides a schematic perspective (a) and plan view (b) illustrating an exemplary connection assembly 1200 similar to 170 in FIG. 1 of structural load carrying members 1210 of a fixed back wall frame element (only shown in part) and structural load carrying members 1220 of a fixed floor frame element (only shown in part) of one complementary building module with structural load carrying members 1230 of a side wall frame element (only shown in part) and structural load carrying members 1240 of a folding floor frame element (only shown in part) of

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another complementary unfolded building module. The bolt holes 1250 can be drilled on site to ensure alignment and the structural load carrying members bolted with bolts (not shown).

FIG. 13 is a schematic cross-sectional view illustrating an exemplary connection assembly 1300 connecting a fixed interior wall panel 1301 (based on the fixed interior wall frame element 142 of FIG. 1) and a fixed interior side panel 1302 (based on the fixed side wall frame element 132 of FIG. 1) of one building module with an exterior flip (i.e., folding) wall panel 1303 (based on the exterior flip (i.e., folding) wall frame element 124 of FIG. 1) of another complementary unfolded building module. FIG. 13 shows the panels 1301, 1302 and 1303 in connected and finished configuration except for one area which is adapted to receive a non-structural interior wall panel 1304 which includes blocking members 1385 and interior wall board 1380. Panel 1303 includes a hollow structural steel member 1305, a blocking member 1310 fastened to the member 1305, and sheathing 1315 and interior wall board 1320 fastened to the blocking member 1310. Panel 1302 includes a steel I-beam member 1325, a blocking member 1330 fastened to the member 1325, a blocking member 1335 fastened to the member 1325, and sheathing 1340 and interior wall board 1345 fastened to the blocking members. Panel 1301 includes a hollow structural steel member 1350, a blocking member 1355 fastened to the member 1350, two blocking members 1360 and 1365 fastened to the blocking member 1355, and interior wall board 1370 and interior wall board 1375 fastened to the blocking members. The folded up exterior flip wall panel 1303 of the first building module is complementary to the fixed panels 1301 and 1302 of the second building module. The structural load carrying members, I-beam 1325, hollow structural steel sections 1360 and 1305 of the three panels complement each other to form a combined structural load carrying member (also, indicated in FIG. 1 as element 164), and the three panels upon connection provide continuous finishing through the connection corners 1390.

FIG. 14 provides a schematic perspective view illustrating an exemplary connection assembly 1300 similar to 180 in FIG. 1 of structural load carrying members 1310 of a folding floor frame element and structural load carrying members 1320 of an exterior flip wall frame element of one building module with structural load carrying members 1330 of a fixed floor frame element, fixed interior wall frame element (not shown), and structural load carrying members 1340 of a fixed side wall frame element of a complementary unfolded building module.

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FIG. 15 is a schematic axonometric view of the structural frame 1500 of a house according to an exemplary embodiment of the present invention, substantially provided by three connected complementary structural frames 1510, 1520 and 1530 of three respective unfolded building.

5 FIG. 16 is a schematic axonometric view of the structural frame of a house 1600 according to an exemplary embodiment of the present invention, substantially provided by two connected complementary structural frames 1610 and 1620 of two respective unfolded building modules.

10 FIG. 17 provides schematic views of a house that can be built with a structural frame such as the one shown in FIG. 15. FIG. 17 provides a front view (a) showing three connected complementary building modules 1710, 1720 and 1730, a back view (b), a view on the outside of an unfolded building module 1710 (c), a back view on the outside unfolded building module 1730 (d), a view from inbetween module 1710 and 1730 on module 1710 (e), and a view from inbetween module 1710 and 1730 on module 1730 (e).

15 FIG. 18 provides schematic views of a house that can be built with a structural frame such as the one shown in FIG. 16. FIG. 18 provides a back view (a) showing two connected complementary building modules 1810 and 1820, a front view (b), a first side view (c) and a second side view (c).

20 Building modules of the present invention can be formed from fixed panels and folding panels that are foldably connected to other folding panels or fixed panels. Accordingly, building modules can include folding panels or are entirely formed from fixed panels. Typically, the building modules include folding panels in an arrangement that allows the building modules to be folded into a folded configuration (typically, of box shape) that takes up a smaller volume, primarily, for transport purposes. Such a folding building module can be unfolded to result in an
25 unfolded building module.

30 The panels that can form an unfolded building module have frame elements (see, e.g. FIGS. 5-9) which typically are made from a number of structural load carrying members in fixed connection. The structural load carrying members of different panels can be connected to provide a fixed connection of the panels in both folded and unfolded configuration of the folding building module, or can be foldably connected to provide a foldable connection of the panels and

thereby allow folding and unfolding of the folding building module. After unfolding and affixing of the frame elements of the panels through connection of respective structural load carrying members, the frame elements form at least part of the structural frame of building or house.

5 The buildings (typically, houses) of the present invention are formed at least in part from a first unfolded building module connected to a complementary building module. The complementary building module can be a folding building module, but can also be a fixed building module, that is, a building module that does not have a structure that can be unfolded. Typically, buildings, and particularly, houses are formed at least in part from a first unfolded
10 building module connected to a complementary second unfolded building module.

 The complementary building modules of the present invention are not merely building modules that can be placed structurally independently side by side, stacked, or otherwise positioned next to the each other, but are adapted to complement each other. Typically, this is achieved without substantial structural redundancy. In comparison, when conventional building
15 modules are connected, substantial structural redundancy results, for example, a marriage wall for building modules placed side by side, or a ceiling of a first building module connected to the floor of a second building module stacked on top of the first building module. As a contrasting example, the complementary building module of the present invention can include a panel having a first side and an opposing second side, and the first side provides an interior surface in
20 the complementary building module and the second side provides and interior surface in the connected first unfolded building module.

 The unfolded building module and the complementary building module typically are connected through structural load carrying members. Typically, these members are dimensioned and shaped to form a combined structural load carrying member, which has a load carrying
25 capacity suitable for the part of the structural frame of the building that it provides. Connecting structural load carrying members in connection assemblies such as illustrated in FIGS. 10-14 minimizes structural redundancy. Further, typically, the structural load carrying members considered separately (unconnected) do not have a load carrying capacity suitable for the part of the structural frame of the building that it provides. More generally, typically, the
30 complementary building modules are structurally interdependent.

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The complementary folding building modules of the present invention can further be dimensioned and shaped to fold compactly and/or arrange compactly with other folded building modules.

The buildings of the present invention can be formed, in part or substantially completely, from a plurality of complementary unfolding building modules. The number of complementary unfolding building modules that can be connected to form the buildings of the present invention is not limited in principal; however, typically, the buildings include up to one hundred complementary unfolding building modules, more typically, up to ten, even more typically, two or three complementary unfolding building modules.

The folding building modules of the present invention can have a core part and an unfolded part connected to the core part. Typically, (i) the unfolded part (or structure) of a first unfolded building module is connected to a complementary core part (or structure) of a second unfolded building module or to a fixed building module, or (ii) the core part (or structure) of a first unfolded building module is connected to a complementary core part (or structure) of the second unfolded building module or a fixed building module.

Buildings of the present invention can further include non-complementary building modules and parts (such as non-structural removable walls, non-structural interior walls, etc.) that can be affixed to the parts of the buildings that are formed from connected complementary building modules (particularly, complementary unfolded building modules).

The complementary building modules of the present invention can be prefabricated such that the buildings, after unfolding on the building site and connecting of removable sections (such as roof elements and non-structural interior walls), are substantially in finished condition. That is, they do not typically require or at least significantly reduce the addition of interior and exterior finish materials with the exception of minor, non-structural finishing in areas required for folding movement. Further, typically, the houses of the present invention include roof sections that are panelized but can be easily installed at the building site. The prefabrication process can be reduced substantially, even to the extent that merely complementary folding structural frames of the present invention are prefabricated and unfolded and connected at the building site.

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Further, all necessary mechanical and electrical systems for the residential or commercial foldable building, for example, all the required appliances and plumbing fixtures, can be installed in a core part (or structure) (i.e., a part of the structural frame of the foldable building that is made of frame elements that are not unfolded at the building site). Flexible piping and wiring can also be chased throughout both fixed and foldably connected panels of the foldable building units of the present invention.

Use of structural steel in the form of appropriately dimensioned I-beams, c-channels, wide-flange beams, and hollow structural sections allows for large frame geometries as part of the structural frame of the foldable building unit, for example, rectangular frame elements spanning the entire side of a foldable building, reducing prefabrication cost and/or simplifying unfolding at the building site.

Further, foldable structural frames substantially made of metal frame elements (e.g., made from hot-formed steel such as I-beams, c-channels, wide-flange beams, and hollow structural sections) can be prefabricated to superior tolerances such that a respective folding building module in substantially finished condition upon unfolding exhibits reduced or no gaps in the seam areas between foldably connected frame elements thereby reducing the work associated with on-site finishing of these seam areas.

The buildings of the present invention, for example, the building corresponding to the structural frame shown in FIG. 1 can further include a number of prefabricated interior walls (e.g., as shown in FIG. 3) that can be fixed, foldably connected, or panelized and form one or more rooms in the unfolded building.

The buildings of the present invention can be several stories high.

Steel frame elements of the present invention are typically combined with wooden or light-gauge metal intermediate elements to form lightweight steel and wood/light-gauge metal hybrid structures in which the frame elements provide structural stability and the wooden or light-gauge metal intermediate elements provide substantial lateral structural resistance and/or are used to attach interior and exterior finishing material using standard construction approaches, reducing labor training and associated costs.

In certain embodiments of the present invention, structural load carrying members connecting different frame elements of the structural frame allow blocking material (e.g. wood or

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light-gauge metal studs) to be connected to inside areas of the structural load carrying members, and the structural load carrying members are positioned such that the blocking members face the outside of the foldable building unit. This allows structural frames that have a continuous conventional structural grid (e.g., 16 inch wood lumber grid) through the edges/corners of the folding building module, thereby allowing attachment of exterior finishing material through the edges/corners using standard construction approaches, reducing labor training and associated costs, and work at the building site.

Use of these strong and lightweight structures can also substantially reduce the amount of required building material and the weight of the frame elements, which in turn facilitates the transport of larger folded building modules for a given maximal allowed weight according to given road regulations.

Indirect connections of interior and/or exterior finishing materials to metal frame elements (particularly, frame elements made of structural steel sections) are one aspect of a “multi-tolerance” building approach that disaggregates and cushions brittle or otherwise fragile finish materials from the vibrational, kinetic and settling forces applied to the structural frame during shipping, setting, unfolding and settling of the prefabricated foldable building units. A second aspect of a multi-tolerance building approach is provided by using offset hinges (in particular, L-shaped offset hinges) which are specifically engineered to safely nest hingedly (i.e., foldably connected with one or more hinges) connected frame elements at a designed distance away from its neighboring frame element, allowing, for example, for thicker wall depths and thus the prefabricated inclusion of finish materials. This is associated with a significant reduction in the scope of work to be completed on-site, where costs and scheduling are far less manageable. Thus, foldable building units of the present invention can include final interior finishing, such as trim, gypsum board, paint or wallpaper.

Structural load carrying members of the present invention can be foldably connected with hinges to foldably connect frame elements and respective panels. More typically, structural load carrying members of the present invention can be foldably connected with offset hinges, and preferably, L-shaped offset hinges adapted and positioned to remain within the building envelope. In completely folded configuration of foldably connected panels, L-shaped offset hinges provide an offset, which allows sufficient clearance for finish and other materials.

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Further, the interior finish materials attached to the frame elements can be sufficiently offset from each other to avoid direct and potentially damaging contact, for example, during transport.

A folding building module in “unfolded configuration” is a foldable building unit in which the foldably connected frame elements have been unfolded into positions that can be maintained in the finished condition of the resulting building. A folding building module in “folded configuration” is a folding building module in which foldably connected frame elements are folded into positions suitable for uploading, transport, and/or unloading of the building unit.

A “structural frame” as used herein, refers to the totality of structural load carrying members of a building module or building that are primarily responsible for providing structural stability of the building module or building by transmitting loads (e.g., static, dynamic, and/or vibrational loads) to the ground. Structural frames can include members that are made of a plurality of materials in various forms and dimensions. Suitable materials that can be used include but are not limited to metal (e.g., aluminum or steel), wood and polymers. Typically, steel is used.

Suitable structural load carrying members include but are not limited to hollow structural sections, C-channels (with or without return), I-beams (including S and W type), T-beams, angle beams, and wide-flange beams. For example, the structural load carrying members can be commercially available American standard structural load carrying members. The selection of a material, form and dimension for a given structural part or member of a structural frame is interdependent and depends on factors such as the position of the structural part or member in the structural frame, and whether the member is part of a frame element that is foldably connected.

In the context of the shape of structural load carrying member, “inside”, “inside area”, “interior area”, “inside surface” or “interior surface” refers to the areas of the structural load carrying member that are inside of a box enveloping the structural load carrying member. That is, if a cross-sectional view of the structural load carrying member is considered any part of the perimeter of the structural load carrying member that is inside of a rectangle enveloping (i.e., with minimum perimeter length of the rectangle) the structural load carrying member corresponds to the “inside”, an “inside area”, an “interior area”, an “inside surface” or an “interior surface.”

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Interior and exterior finish materials can be attached to the structural frame, typically, by attachment with intermediate elements affixed to frame elements of the structural frame. Interior and exterior finishing materials are typically attached (e.g., glued, nailed, screwed, welded and/or bolted, or otherwise affixed) to intermediate elements. Interior finish materials include but are not limited to wall finishing (for example, gypsum board), ceiling finishing and floor finishing (for example, sheathing with Bamboo flooring on top). Exterior finishing elements include but are not limited to siding and roofing.

For finish materials, and, in particular, interior finish materials, it has been found that “indirect connection” to the frame elements to reduce contact, partially or entirely, of the interior finish materials with the frame elements is advantageous for one or more of the following reasons. Reduced contact can (a) reduce the transfer of structural stresses from one or more frame elements of the structural frame to the often fragile and brittle interior finish materials thereby reducing or eliminating significant damage (such as dry wall cracking) of the interior finish materials, in particular, during folding, uploading, transporting, unloading and/or unfolding of the foldable building unit, and settling, (b) reduce or eliminate the exposure of the interior finish materials to water, for example, water that can condensate on metal parts of the frame elements, and (c) reduce heat transfer between the inside of the finished building unit to the outside of the finished building unit.

Thus, generally, it is preferred to use indirect rather than direct connections of finish materials, particularly, interior finish materials with respective frame elements. However, even though indirect connections are typically preferred, not all connections between interior finish material and a respective frame element have to be indirect.

Typically, intermediate elements are made, at least in part, of materials that have a force cushioning effect, that is, force cushioning elements such as, for example, wood, sprayed foam, and light-gauge metal studs. Typically, an intermediate element is positioned and dimensioned such that it can connect or can be connected (e.g., using powder-actuated fasteners or self-tapping screws) to the frame element through one area of the intermediate element (e.g., through one side of the intermediate element) and that it can be connected to the finish material, particularly, the interior finish material (for example, using nails or screws) through another area

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of the intermediate element (e.g., through another side of the intermediate element). Even more preferably, intermediate elements are entirely made of force cushioning materials such as wood.

Folding building modules of the present invention typically include wall panels and floor sections that are in substantially finished condition, that is, with the exception of unfinished areas dimensioned to accommodate folding of the frame elements, and unfinished areas due to wall connection seams (i.e., seams between walls that are not connected but upon unfolding jointly form a wall), these wall panels, roof and floor panels are finished.

A building or house or part of a building or house that is substantially in finished condition after connection of two or more complementary modules of this invention is a building, house or part thereof in which more than 75%, preferably 85%, and more preferably 90% of the construction of the building, house or part thereof is completed upon connection of the complementary modules. Thus, the complementary building modules (unfolded and/or fixed) can connect to form part of a building or house which is in substantially finished condition upon connection of the modules. If substantially all of the building is made from complementary building modules, the entire building can be in substantially finished condition once the complementary building modules are connected. Examples of when a part of a building or an entire building is "substantially finished", is when the interior surfaces of the part are substantially finished with finish material, such as a finish floor (e.g., tiles, hardwood floor, laminate, etc.), finish wall (e.g., wall board, wall paper, etc.), electrical elements (e.g., switches, lamps, electrical wiring, electrical panel, etc.), and heating and cooling elements (e.g., heating system, cooling system, duct work, etc.); typically, this even includes kitchen elements including but not limited to cabinets, appliances and sink(s), and/or bathroom elements including but not limited to cabinets, shower, bathtub, toilet and sink. However, the substantially finished building, house or part thereof typically includes some unfinished elements upon connection of the complementary building modules, for example, wall connection seams (i.e., seams between walls that are not connected but upon unfolding jointly form a wall), areas in connection assemblies intended for connection of removable substantially finished panels (e.g., the area in FIG. 13 to which panel 1304 will be connected).

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“Finished panels” as referred to herein, are panels that include frame elements and interior finish materials connected (typically, indirectly) to them, and can also include elements such as doors and windows.

5 The folded building modules of the present invention are typically dimensioned such that transport with a transport vehicle is possible, preferably, with a semitrailer and without requiring a special transport permit. Regulations pertaining to the operation of trucks and trailers vary from country to country, and, in some instances from state to state.

10 Further, the folded building modules of the present invention can include a folding floor panel which provides a wall of the folded building module, which increases stability of the building module in folded configuration, protects prefabricated and finished parts in the core volume, and thereby facilitates transportation of the building module.

15 A fourth embodiment of the present invention is a building built in a process including the following steps: (a) setting a first folded building module on a foundation, the folded building module having a core structure and an unfoldable structure attached to the core structure, the unfoldable structure including a plurality of foldably connected panels; (b) unfolding part or all of the unfoldable structure of the first folded building module to form an unfolded structure; (c) setting a complementary building module on the foundation and positioned such that panels of the complementary building module complement respective panels of the unfolded structure; (d) connecting the panels of the complementary building module and
20 respective panels of the unfolded structure; and (e) connecting one or more roof elements to the building modules.

A fifth embodiment of the present invention is a building comprising a first unfolded building module connected to a complementary building module.

25 A sixth embodiment of the present invention is a house comprising a first unfolded building module connected to a complementary second unfolded building module, wherein the first unfolded building module and the second unfolded building module, each independently, have a core part and an unfolded part attached to the respective core part; i) the core part of the first unfolded building module is connected to a complementary unfolded part of the second unfolded building module, or ii) the core part of the first unfolded building module is connected
30 to a complementary core part of the second unfolded building module; and the first unfolded

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building module and/or the second unfolded building module contained kitchen elements and/or bathroom elements in one or both of the respective core structures that were present in the respective folded building module.

5 A first specific embodiment is a building or house as described in the first, second, fourth, fifth or sixth embodiment of the present invention, wherein the first unfolded building module includes a structural load carrying member through which the unfolded building module is connected to a structural load carrying member of the complementary building module without substantial structural redundancy.

10 More particularly, the structural load carrying member of the first unfolded building module can form part of a first panel and the structural load carrying member of the first unfolded building module can form part of a second panel, and the first panel and second panel upon fastening of the structural load carrying members in a connection area provide substantially finished exterior and/or interior surfaces continuously throughout the connection area with the exception of an area for the fastening of the structural load carrying members.

15 A second specific embodiment is a building or house as described in the first, second, fourth, fifth or sixth embodiment, wherein the complementary building module is a second unfolded building module.

20 A third specific embodiment is a building or house as described in the first, second, fourth, fifth or sixth embodiment, wherein the complementary building module includes a panel having a first side and an opposing second side, and the first side provides an interior surface in the complementary building module and the second side provides an interior surface in the first unfolded building module.

25 A fourth specific embodiment is a building or house as described in the first, second, fourth, fifth or sixth embodiment having a steel structural frame, wherein a plurality of connected complementary unfolded building modules provides more than 50% of the steel structural frame of the building.

More particularly, the plurality of connected complementary unfolded building modules provides more than 75% of the steel structural frame of the building.

30 Even more particularly, the plurality of connected complementary unfolded building modules provides more than 90% of the steel structural frame of the building.

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Yet even more particularly, the plurality of connected complementary unfolded building modules provides substantially all of the steel structural frame of the building.

In a fifth specific embodiment, the first unfolded building module of the first, second, fourth, fifth or sixth embodiment has a core part and an unfolded part connected to the core part.

5 Particularly, the complementary building module is a second unfolded building module, and (i) the unfolded part of the first unfolded building module is connected to a complementary core part of the second unfolded building modules, or (ii) the core part of the first unfolded building module is connected to a complementary core part of the second unfolded building modules.

10 A sixth specific embodiment is a building or house as described in the first, second, fourth, fifth or sixth embodiment of the present invention, wherein the first unfolded building module and the complementary building module are connected at one side and positioned to share only part of the side.

15 A seventh specific embodiment is a building or house as described in the first, second, fourth, fifth or sixth embodiment of the present invention, wherein the first unfolded building module and the complementary building module are connected through a plurality of connection assemblies that (i) form from complementary panels of the building modules, and (ii) are in substantially finished condition when the panels are connected.

20 An eighth specific embodiment is a building or house as described in any of the preceding embodiments, wherein the first unfolded building module and the complementary building module are structurally interdependent.

A ninth specific embodiment is a building or house as described in any of the preceding embodiments, wherein the first unfolded building module and the complementary building module are connected without substantial structural redundancy.

25 A tenth specific embodiment is a building or house as described in any of the preceding embodiments, wherein the first unfolded building module and the complementary building module are not independently structurally stable when not connected to each other.

An 11th specific embodiment is a building or house as described in any of the preceding embodiments comprising a combined structural load carrying member formed from one or more

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structural load carrying members of the first unfolded building module and one or more structural load carrying members of the second unfolded building module.

A 12th specific embodiment is a building or house as described in any of the preceding embodiments, wherein the first and second unfolded building modules in folded configuration
5 are dimensioned and shaped such that they fit within a volume spanned by a length of 70', a width of 16' and a height of 15', while providing in combination a total floor area of between 300 and 5000 square feet. Particularly, a total floor area of between 300 and 3000 square feet is provided.

A 13th specific embodiment of the present invention is a building or house formed by the
10 method as described in the third embodiment.

A 14th specific embodiment of the present invention is a method for forming a building as described in the third embodiment, wherein the panels of the complementary building module and respective panels of the unfolded structure are connected without substantial structural redundancy.

15 In a more particular embodiment, the method further comprises setting and connecting further complementary building modules to the first and/or complementary building module.

Further teaching of the general folding building technology relevant to the present invention is described in International Patent Application No. PCT/US2010/050041, filed
20 September 23, 2010, and published as WO2011/038145, and in International Patent Application No. PCT/US2011/029643, filed March 23, 2011.

The relevant teachings of these patent applications, and all patents, published applications and references cited herein are incorporated by reference in their entirety.

25 While this invention has been particularly shown and described with references to example embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention encompassed by the appended claims.

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CLAIMS

What is claimed is:

1. A building formed at least in part from a first unfolded building module connected to a complementary building module.
- 5 2. The building of Claim 1, wherein the complementary building module is a second unfolded building module.
3. The building of Claim 1 or 2, wherein the complementary building module includes a
10 panel having a first side and an opposing second side, and the first side provides an interior surface in the complementary building module and the second side provides and interior surface in the first unfolded building module.
4. The building of Claim 1, 2 or 3 having a steel structural frame, wherein a plurality of
15 connected complementary unfolded building modules provide substantially all of the steel structural frame of the building.
5. The building of Claim 1, 2, 3, or 4, wherein a first structural load carrying member of a
20 panel of the first unfolded building module and a second structural load carrying member of a panel of the connected complementary building module form a combined structural load carrying member.
6. The building of Claim 1 or 2, wherein the first unfolded building module and the
25 complementary building module are structurally interdependent.
7. The building of any one of the preceding Claims, wherein the first unfolded building module and the complementary building module are connected without substantial structural redundancy.

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8. The building of Claim 1, 2, or 7, wherein the first unfolded building module and the complementary building module, when not connected, are not independently structurally stable.

5 9. The building of Claim 1, 2 or 8, wherein the first unfolded building modules, in unconnected and folded configuration, exhibits a box-type shape.

10. The building of any one of the preceding Claims, wherein the first unfolded building module has a core part and an unfolded part connected to the core part.

10

11. The building of Claim 10, wherein the complementary building module is a second unfolded building module, and (i) the unfolded part of the first unfolded building module is connected to a complementary core part of the second unfolded building modules, or (ii) the core part of the first unfolded building module is connected to a complementary core part of the second unfolded building modules.

15

12. The building of Claim 1 or 2, wherein the first unfolded building module and the complementary building module are connected at one side and positioned such to share only part of the side.

20

13. The building of any one of the preceding Claims, wherein the first unfolded building module and the complementary building module are connected through a plurality of connection assemblies that (i) form from complementary panels of the building modules, and (ii) are in substantially finished condition when the panels are connected.

25

14. A house formed at least in part from a first unfolded building module and a connected complementary second unfolded building module, wherein the first unfolded building module and the second unfolded building module, each independently, have a core part and an unfolded part attached to the respective core part; i) the unfolded part of the first unfolded building module is connected to a complementary core part of the second

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unfolded building module, ii) the unfolded part of the first unfolded building module is connected to the complementary unfolded part of the second unfolded building module, or iii) the core part of the first unfolded building module is connected to a complementary core part of the second unfolded building module; and the first unfolded building module and/or the second unfolded building module contain kitchen elements and/or bathroom elements in one or both of the respective core structures that were present in the respective folded building modules.

15. The house of Claim 14 having a structural frame, wherein the first and second unfolded building module provide the structural frame of the building.

16. The house of Claim 14 or 15, wherein the structural frame comprises a combined structural load carrying member formed from one or more structural load carrying members of the first unfolded building module and one or more structural load carrying members of the second unfolded building module.

17. The house of Claim 14, 15 or 16, wherein the first unfolded building module has a section that provides a first interior surface of the first unfolded building module and a second interior surface of the second unfolded building module, wherein the first and second interior surface are opposite sites of the section.

18. The house of Claim 14 or 17, wherein the connected unfolded building modules are not connected with a marriage wall.

19. The house of Claim 14, 15, 16 or 17, wherein the first and second unfolded building modules, when unconnected, are structurally independent in folded configuration and not structurally independent in unfolded configuration.

20. The house of anyone of the preceding Claims, wherein the first and second unfolded building modules in folded configuration are dimensioned and shaped such that fit within

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a volume spanned by a length of 70', a width of 16' and a height of 15', while providing in combination a total floor area of between 300 and 5000 square feet.

21. The house of anyone of the preceeding Claims, wherein the first and second unfolded
5 building modules are connected at one side and positioned such that they only share part of the side.
22. The house of anyone of the preceding Claims, wherein the building has a structural frame that is provided by up to five connected complementary unfolded building modules.
10
23. A method of forming a building comprising:
(a) setting a first folded building module on a foundation, the folded building module having a core structure and an unfoldable structure attached to the core structure, the unfoldable structure including a plurality of foldably connected panels;
15 (b) unfolding part or all of the unfoldable structure of the first folded building module to form an unfolded structure;
(c) setting a complementary building module on the foundation and positioned such that panels of the complementary building module complement respective panels of the unfolded structure;
20 (d) connecting the panels of the complementary building module and respective panels of the unfolded structure; and
(e) connecting one or more roof elements to the building modules.

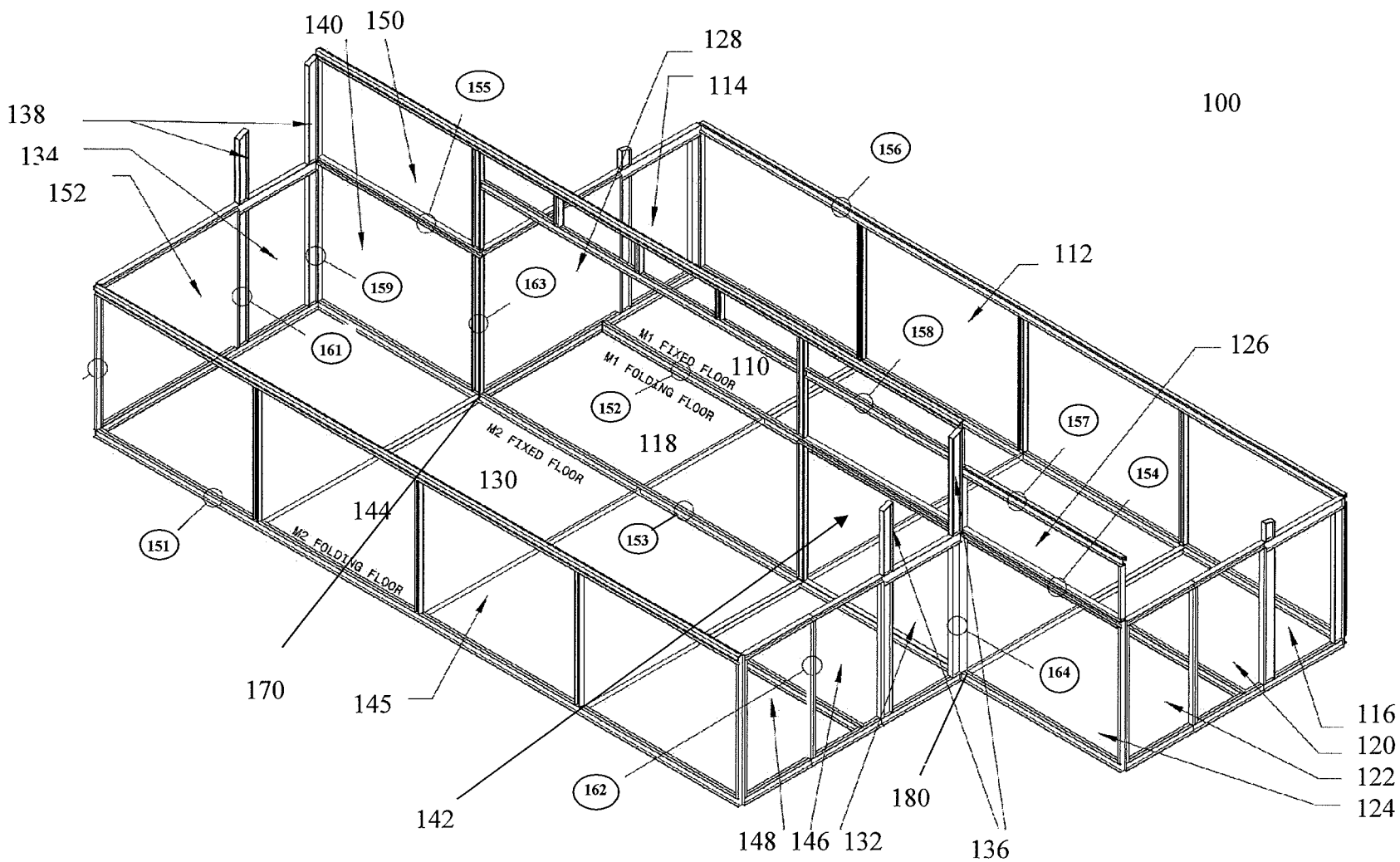


FIG. 1

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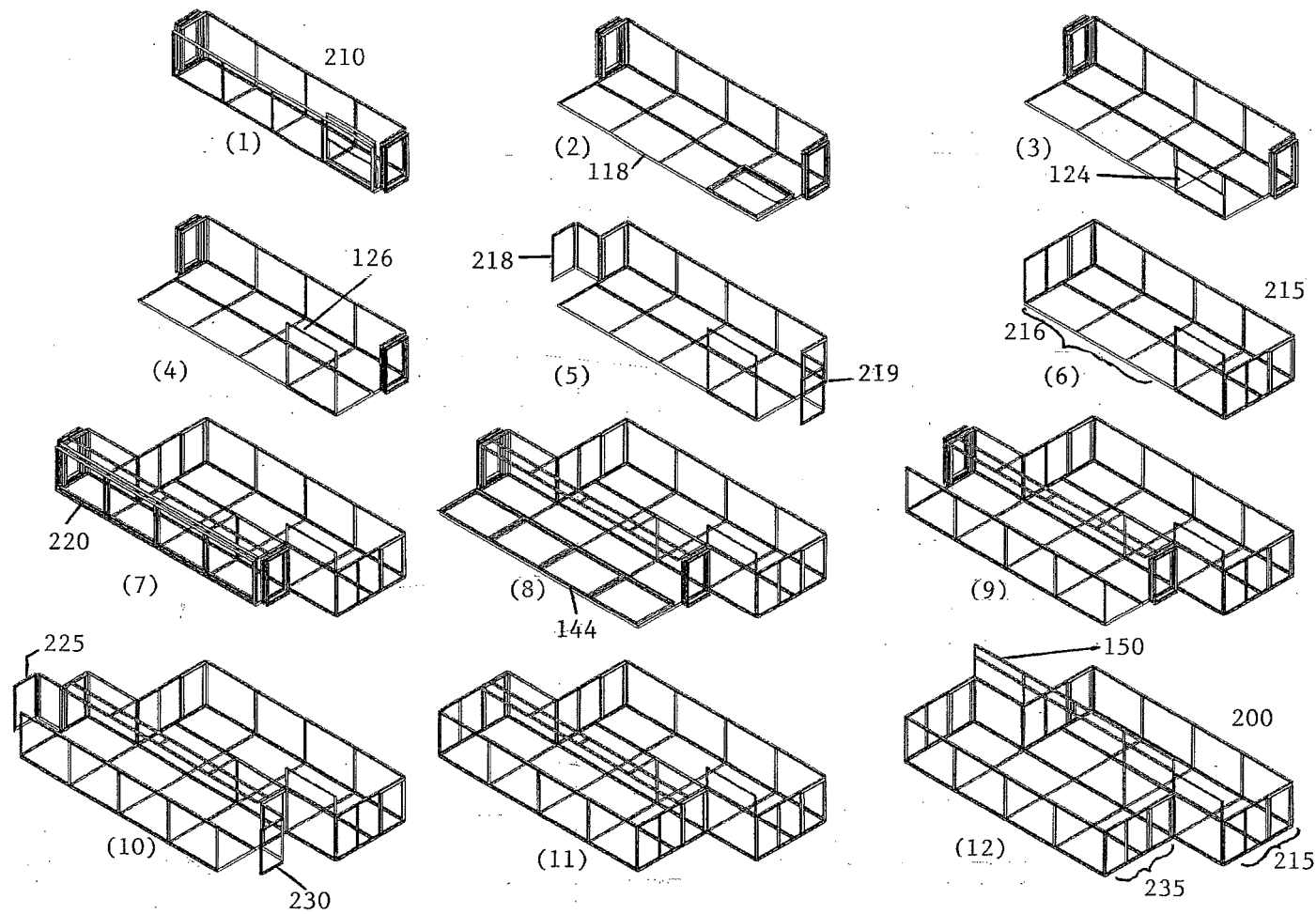


FIG. 2

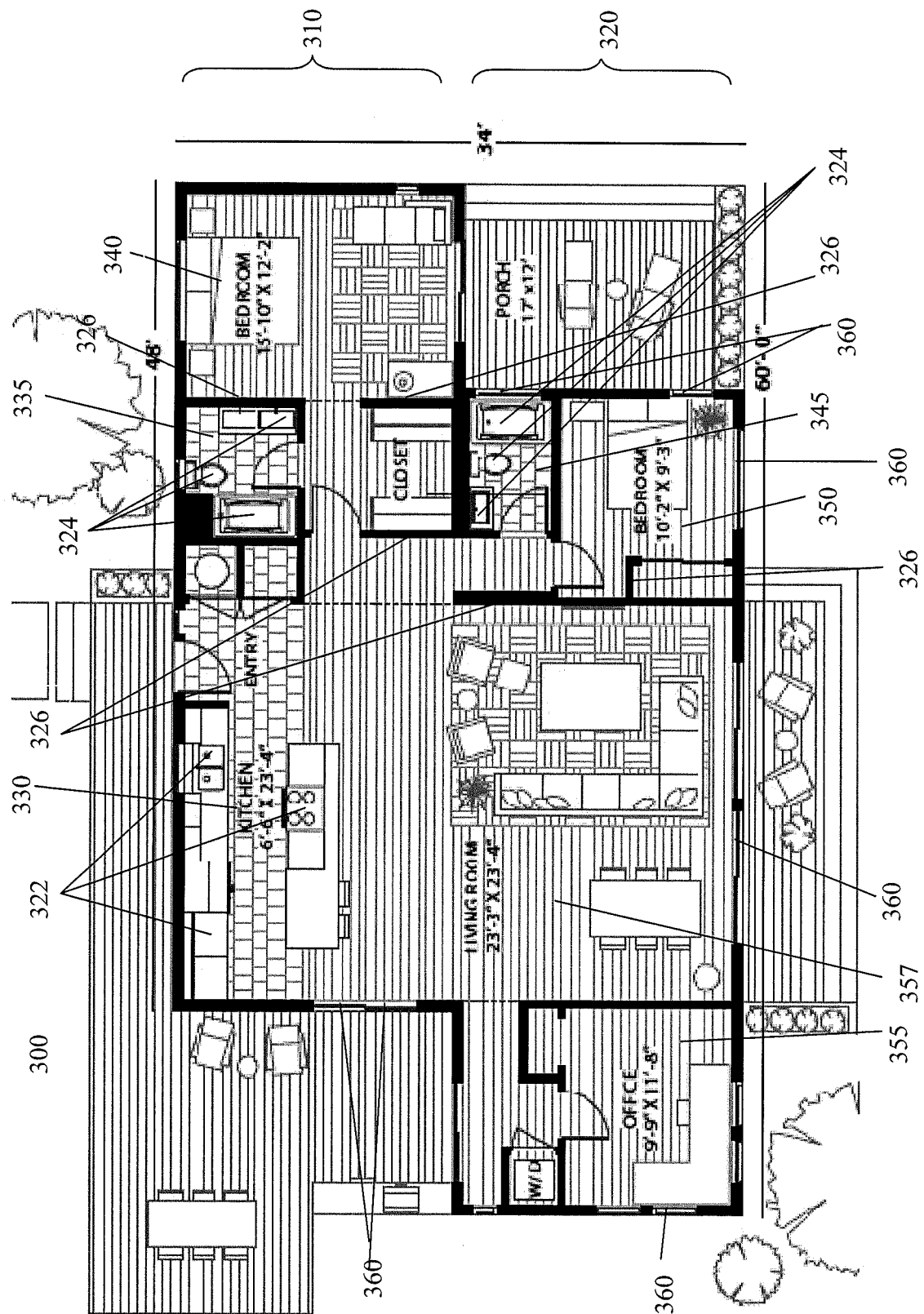


FIG. 3

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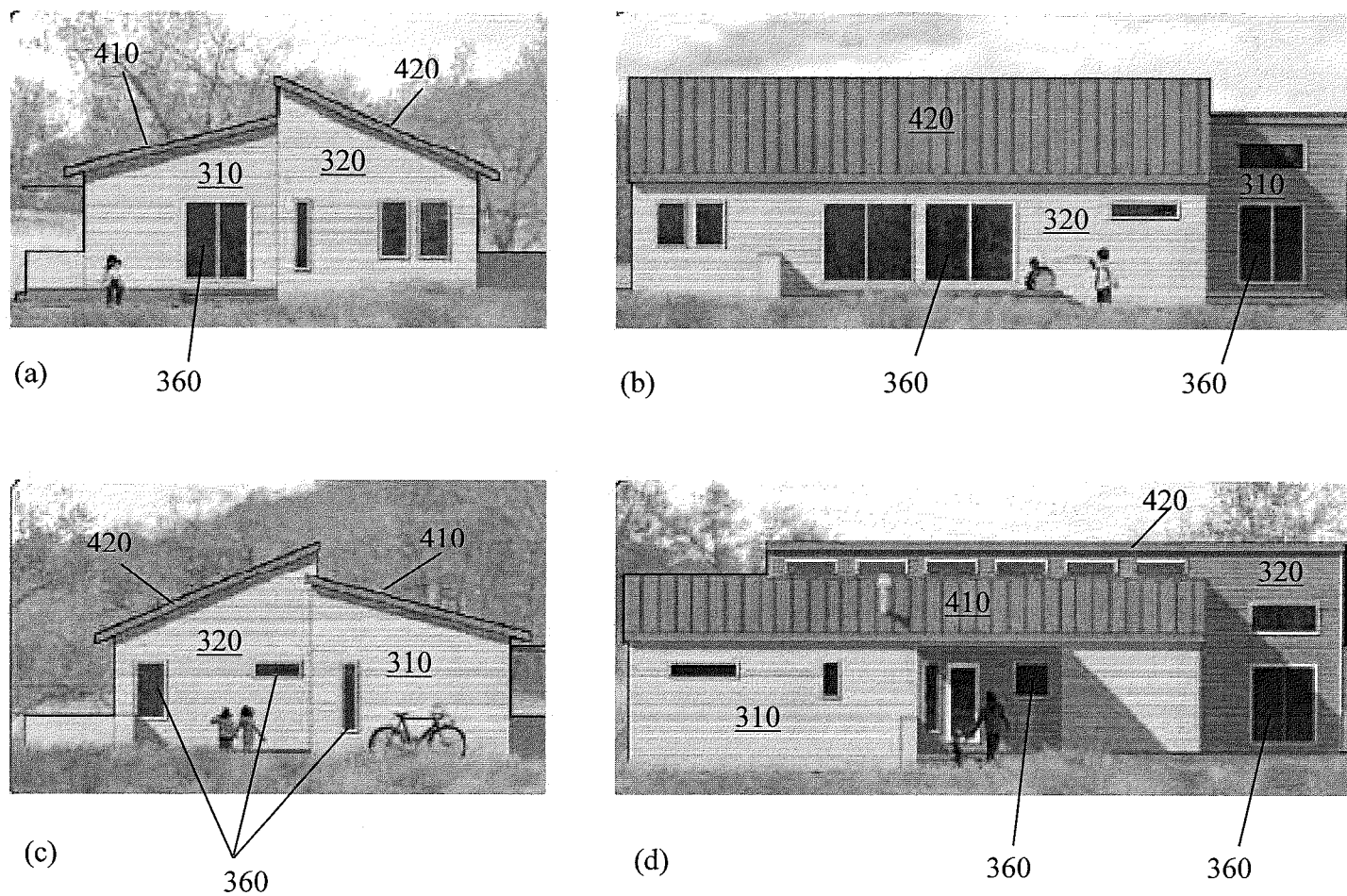


FIG. 4

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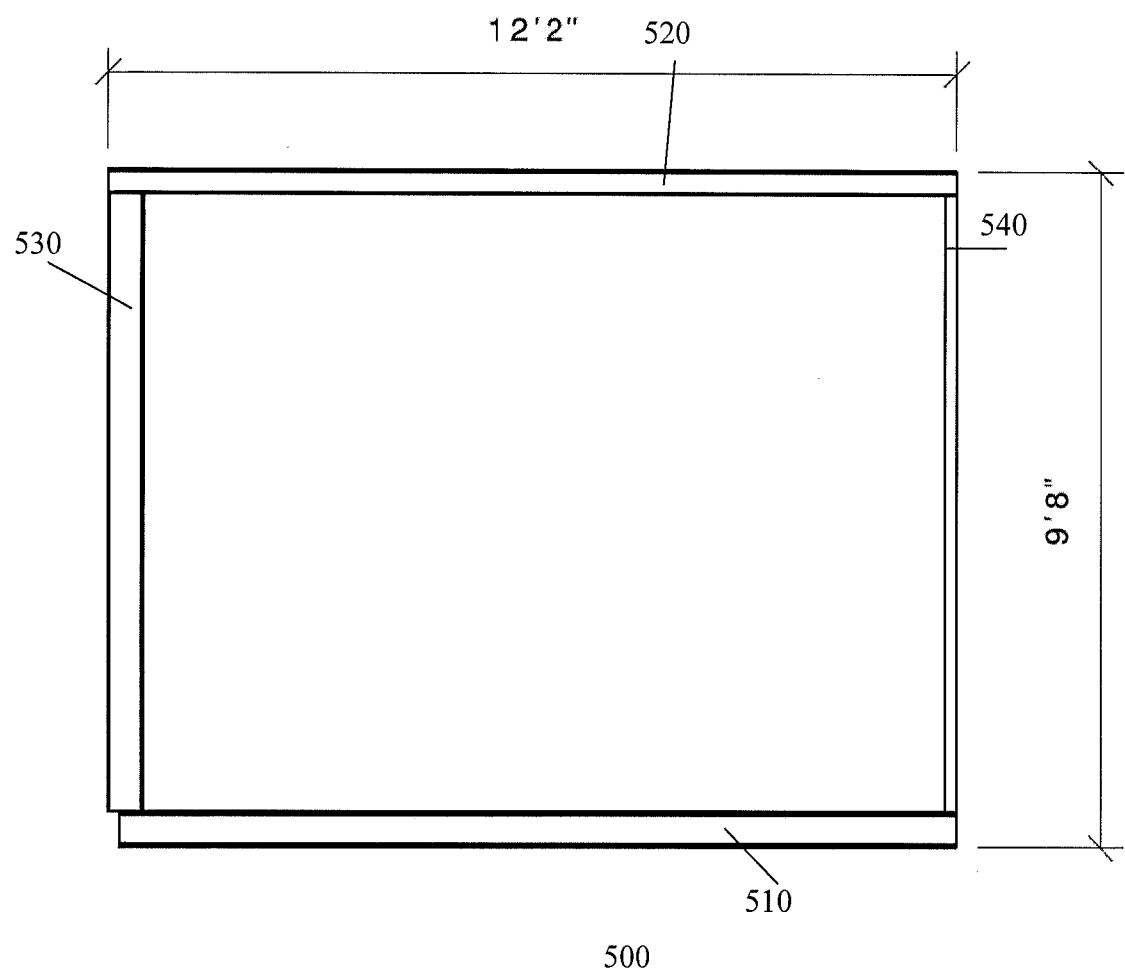


FIG. 5

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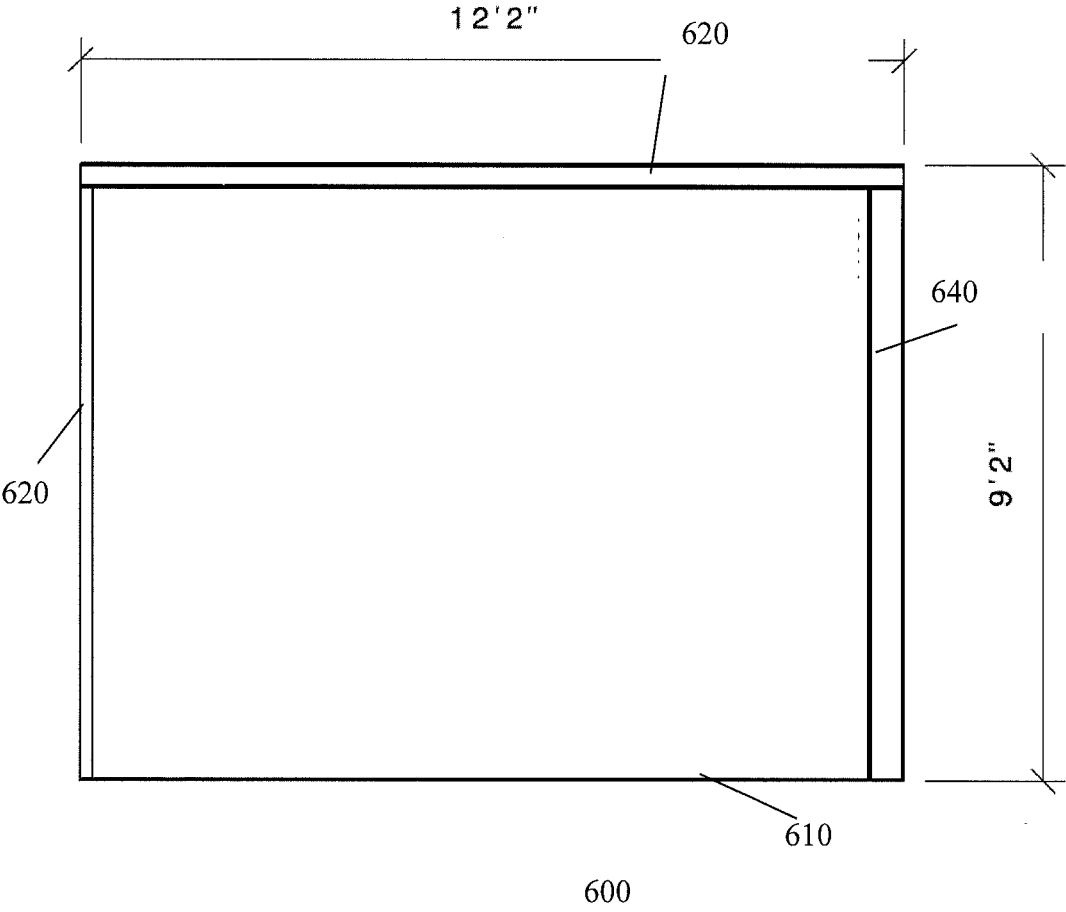


FIG. 6

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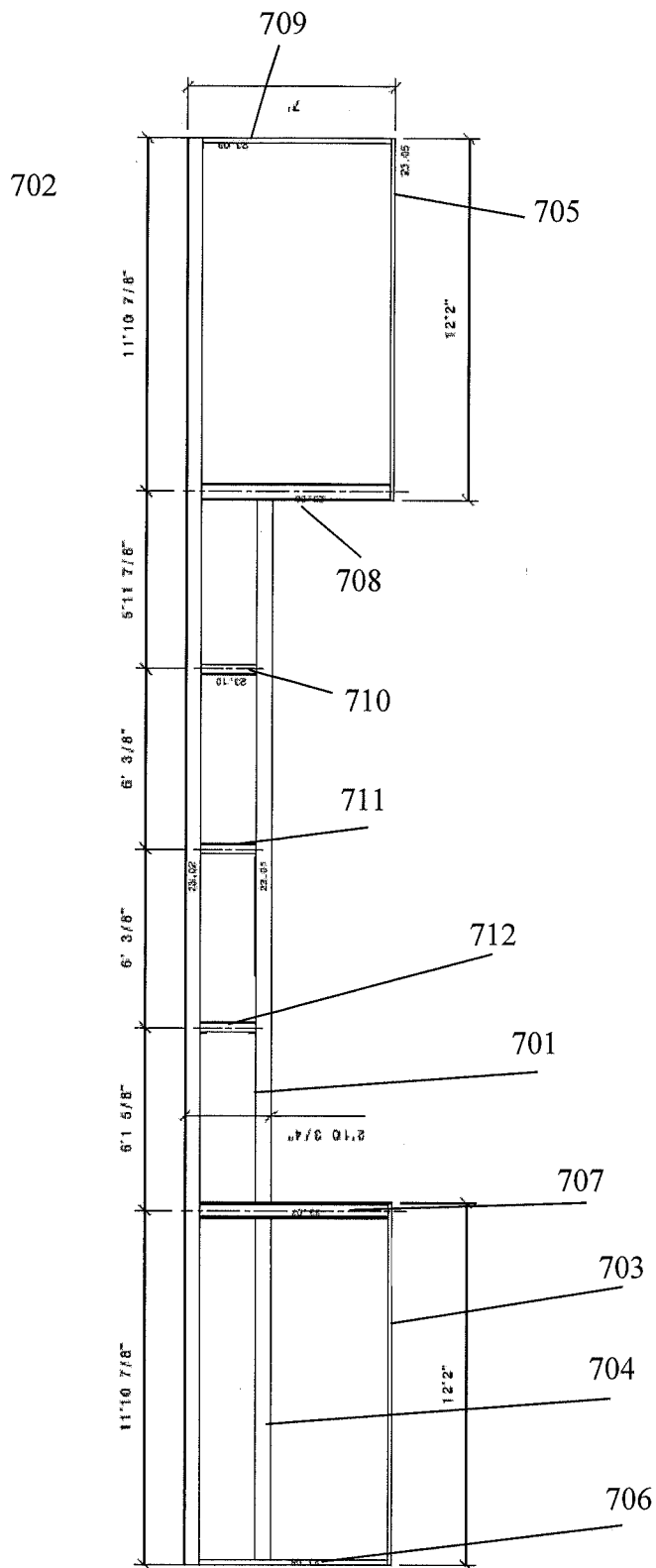


FIG. 7

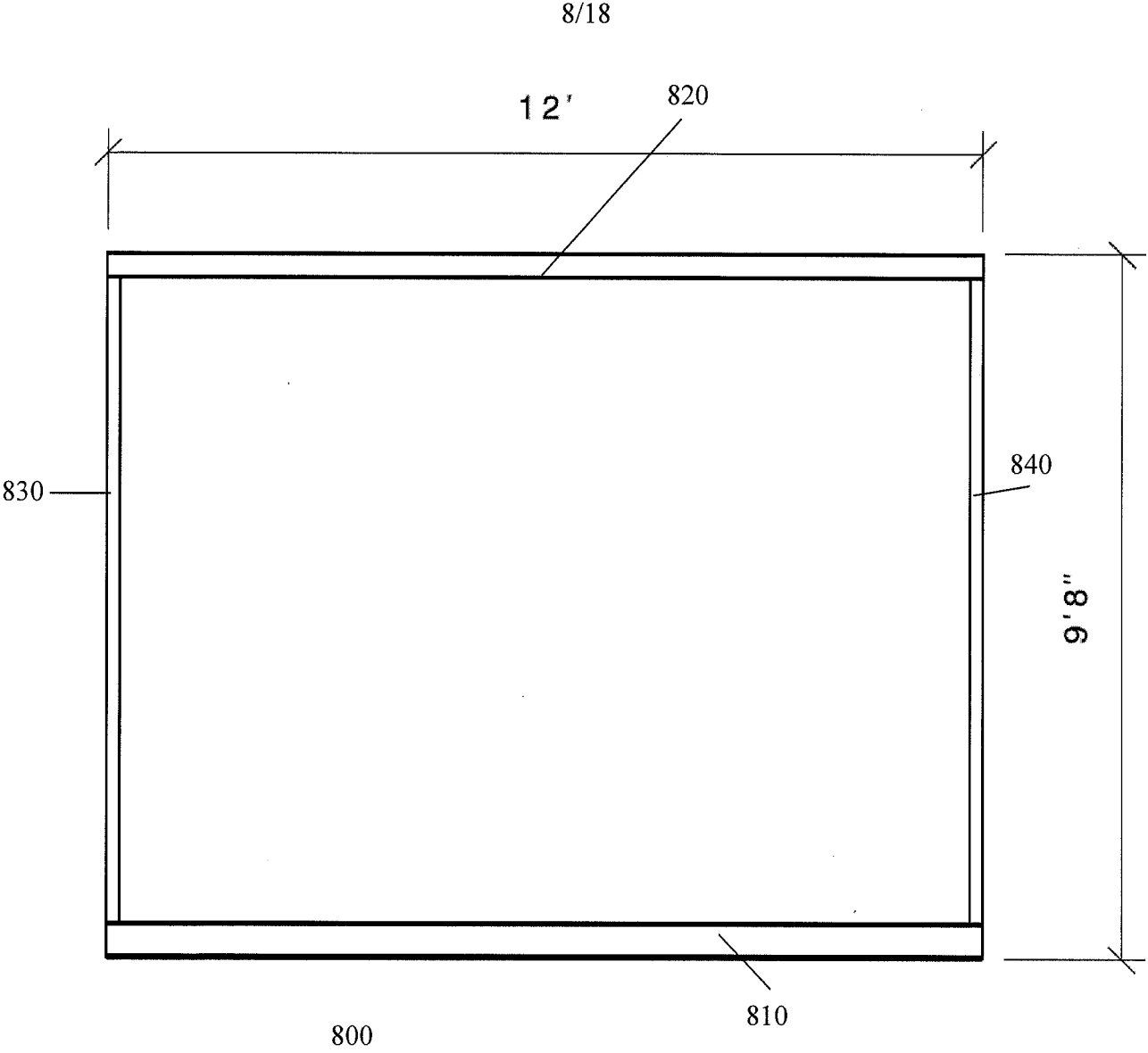


FIG. 8

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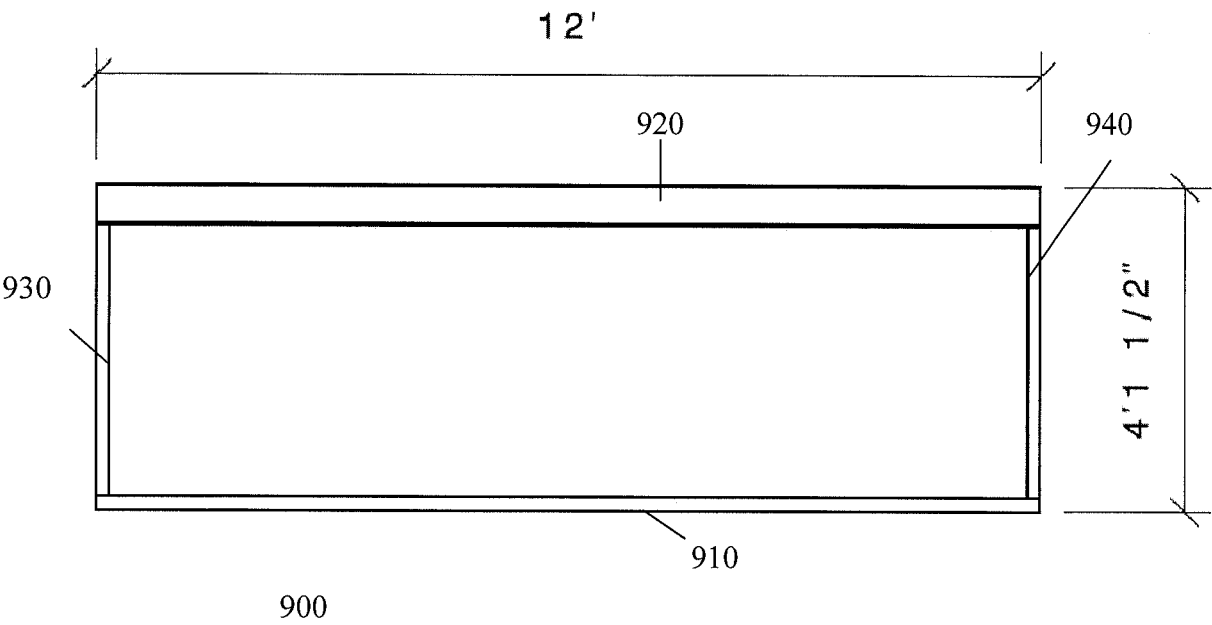


FIG. 9

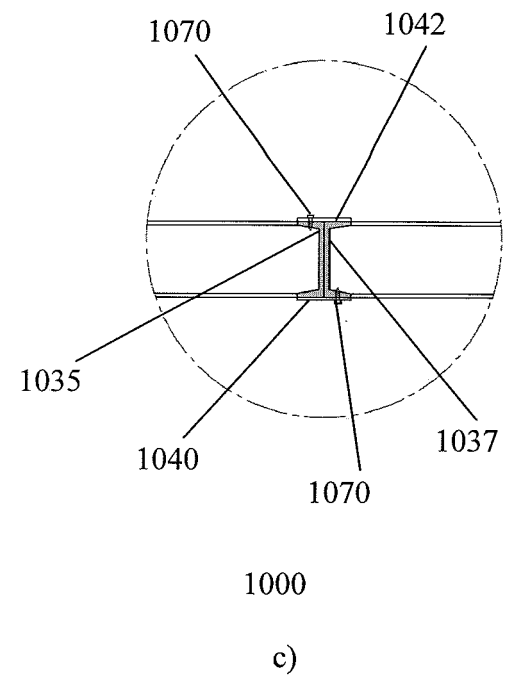
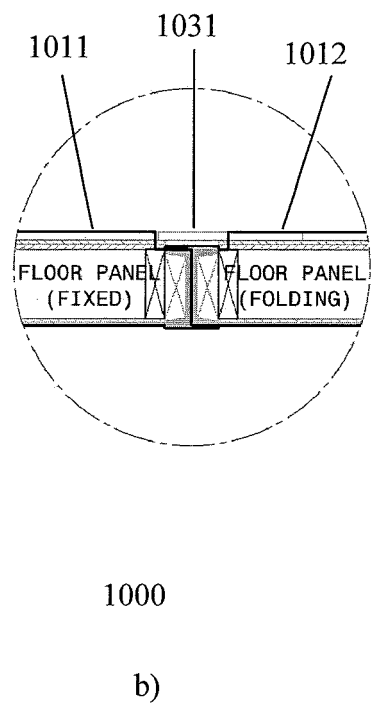
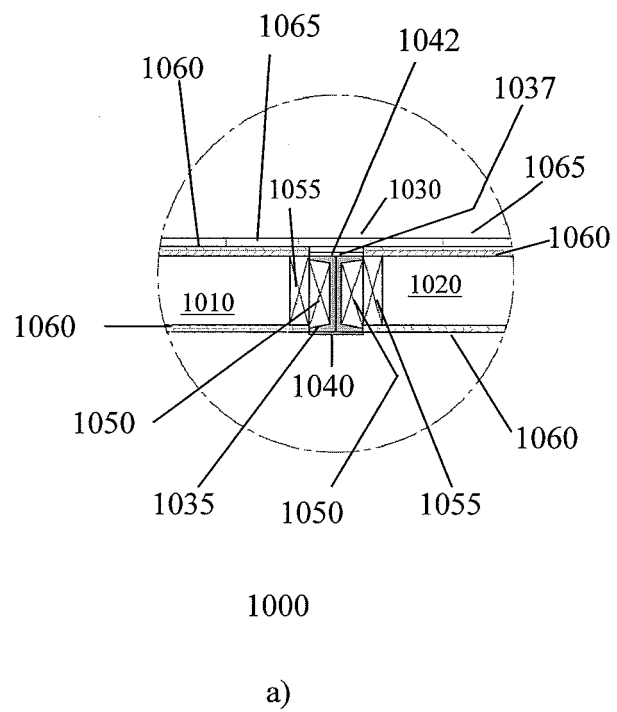


FIG. 10

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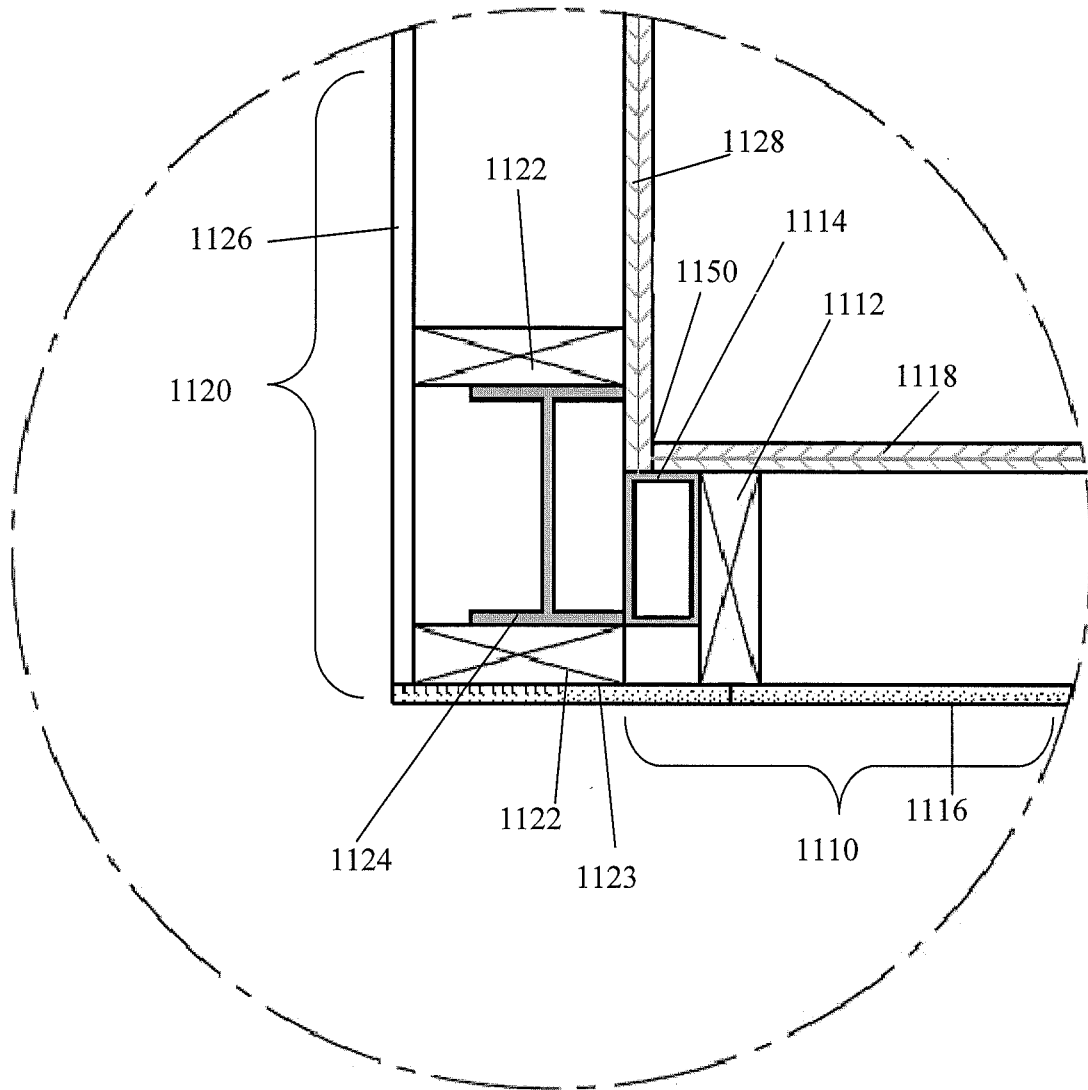
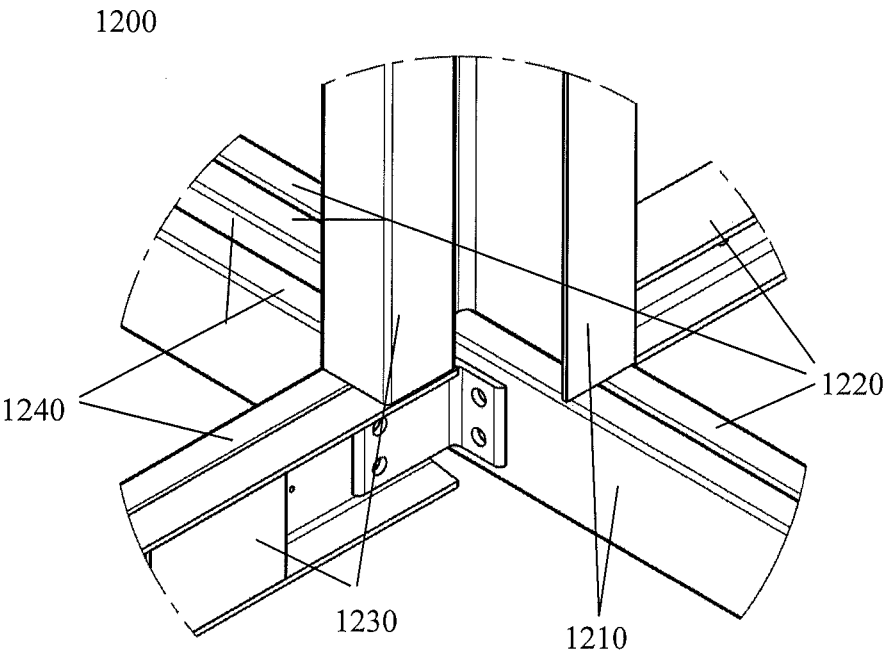


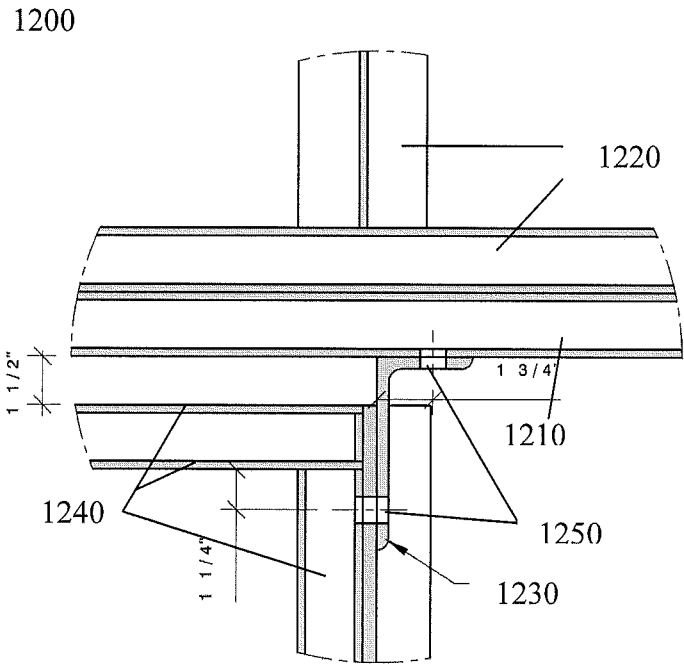
FIG. 11

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ANGLE CONNECTION

(a)



PLAN VIEW

(b)

FIG. 12

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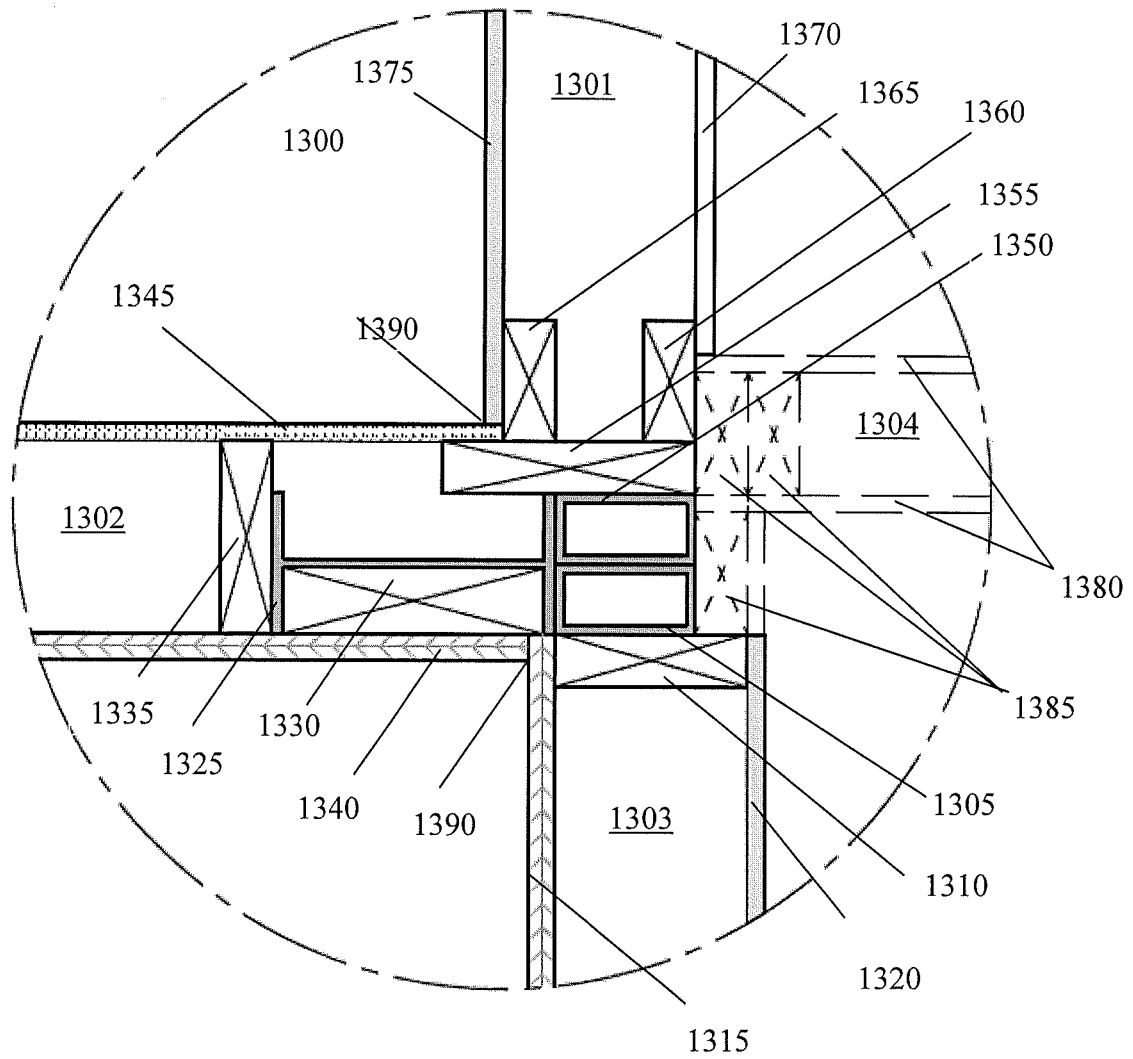


FIG. 13

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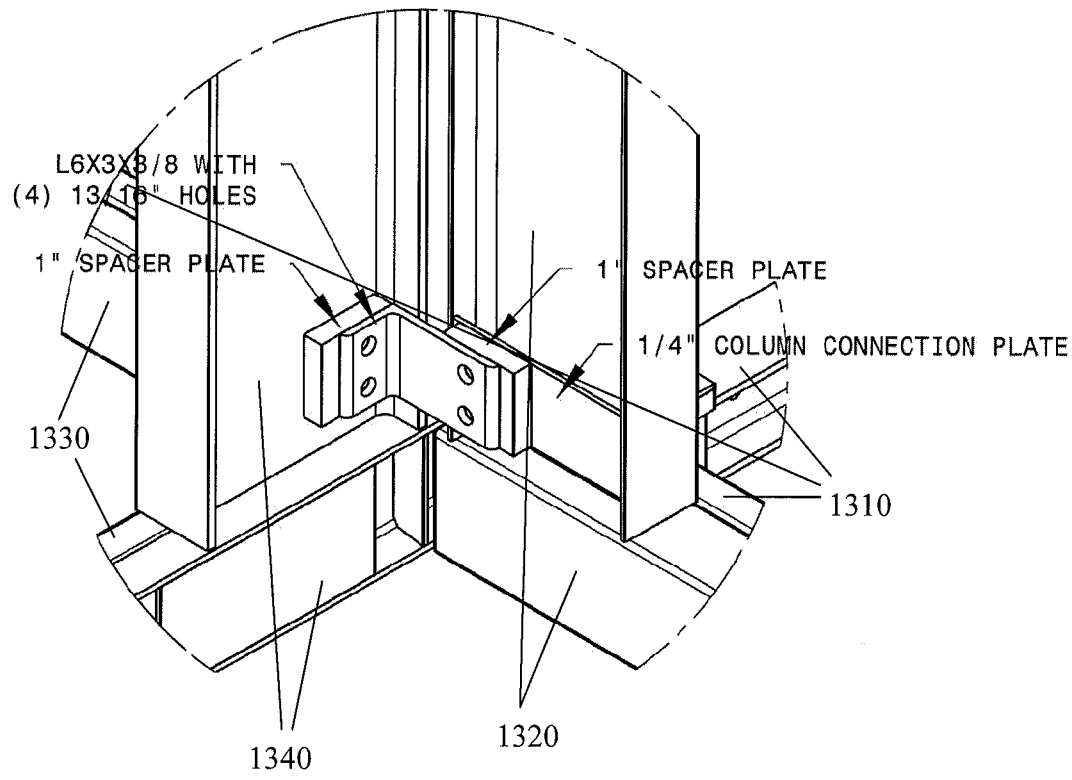


FIG. 14

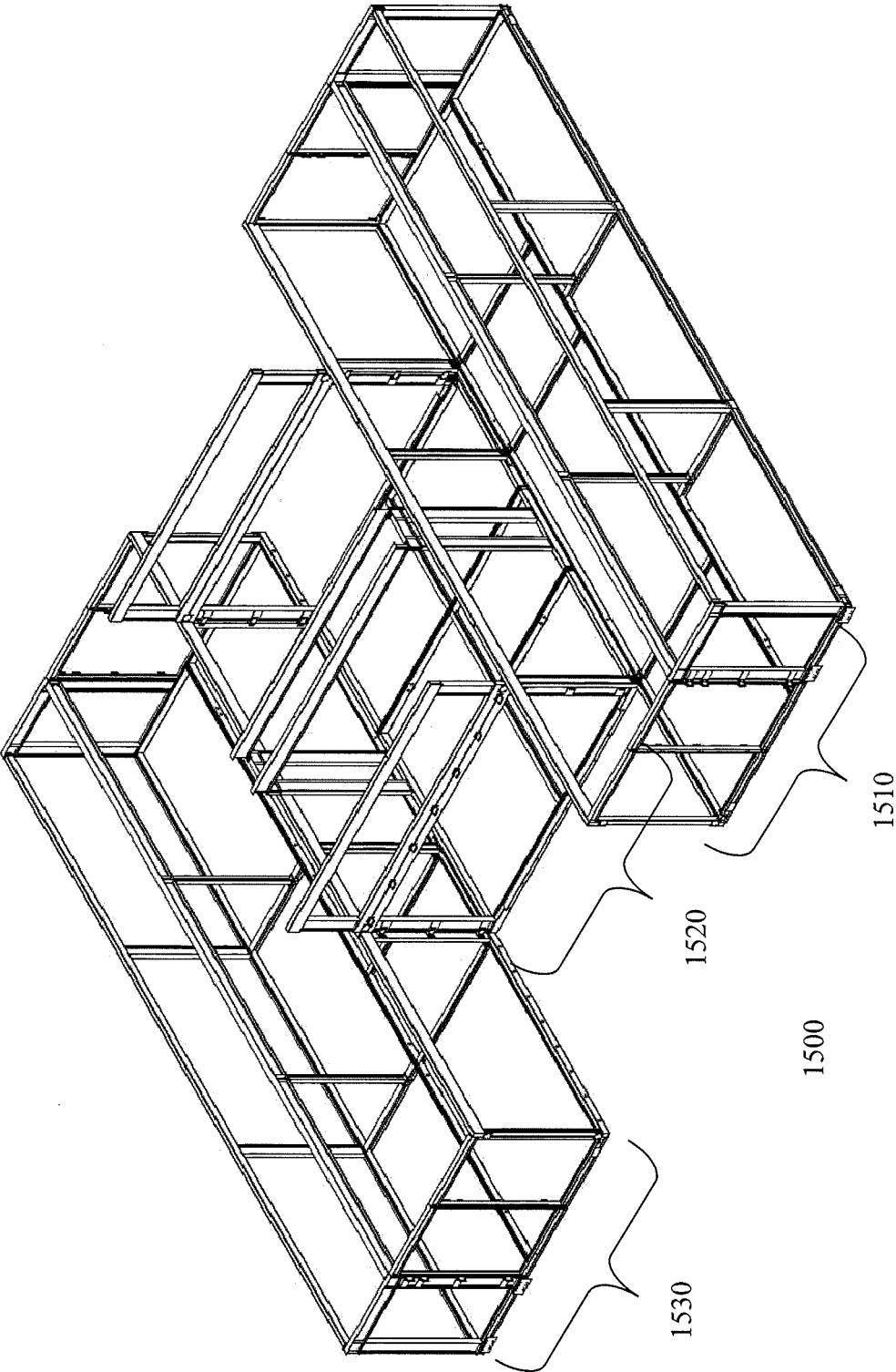


FIG. 15

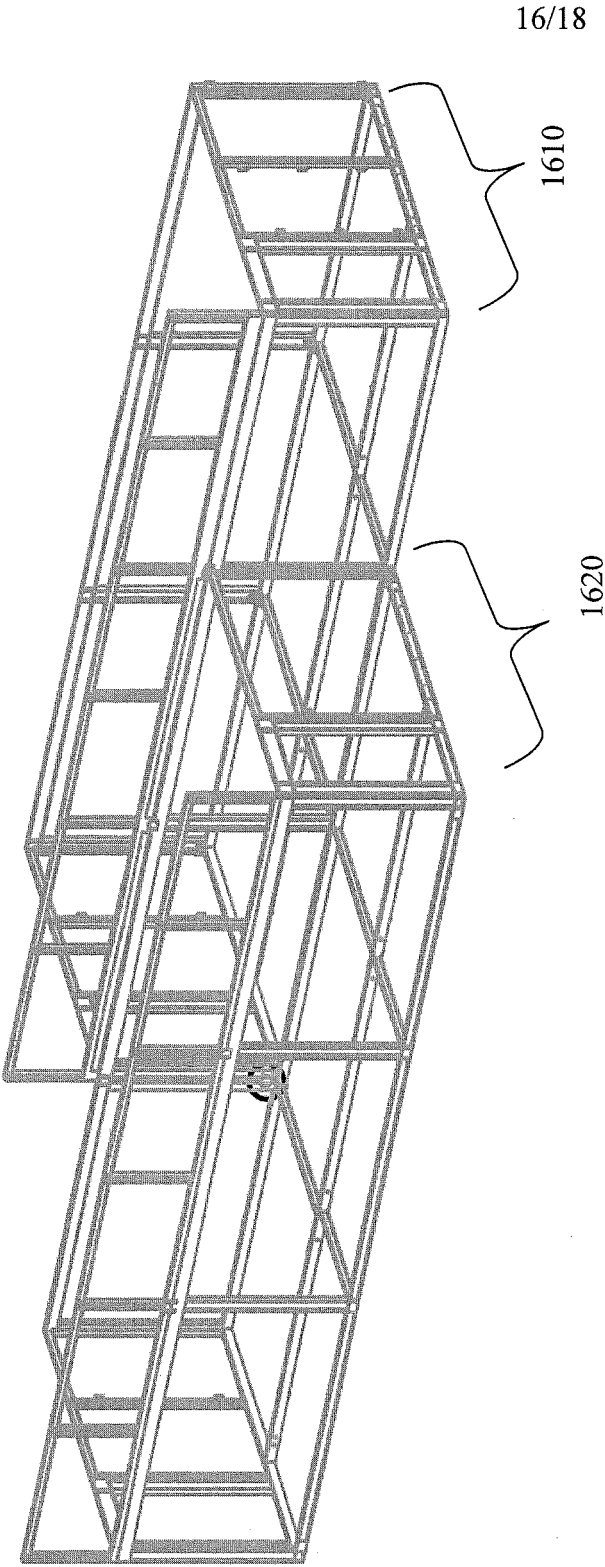


FIG. 16

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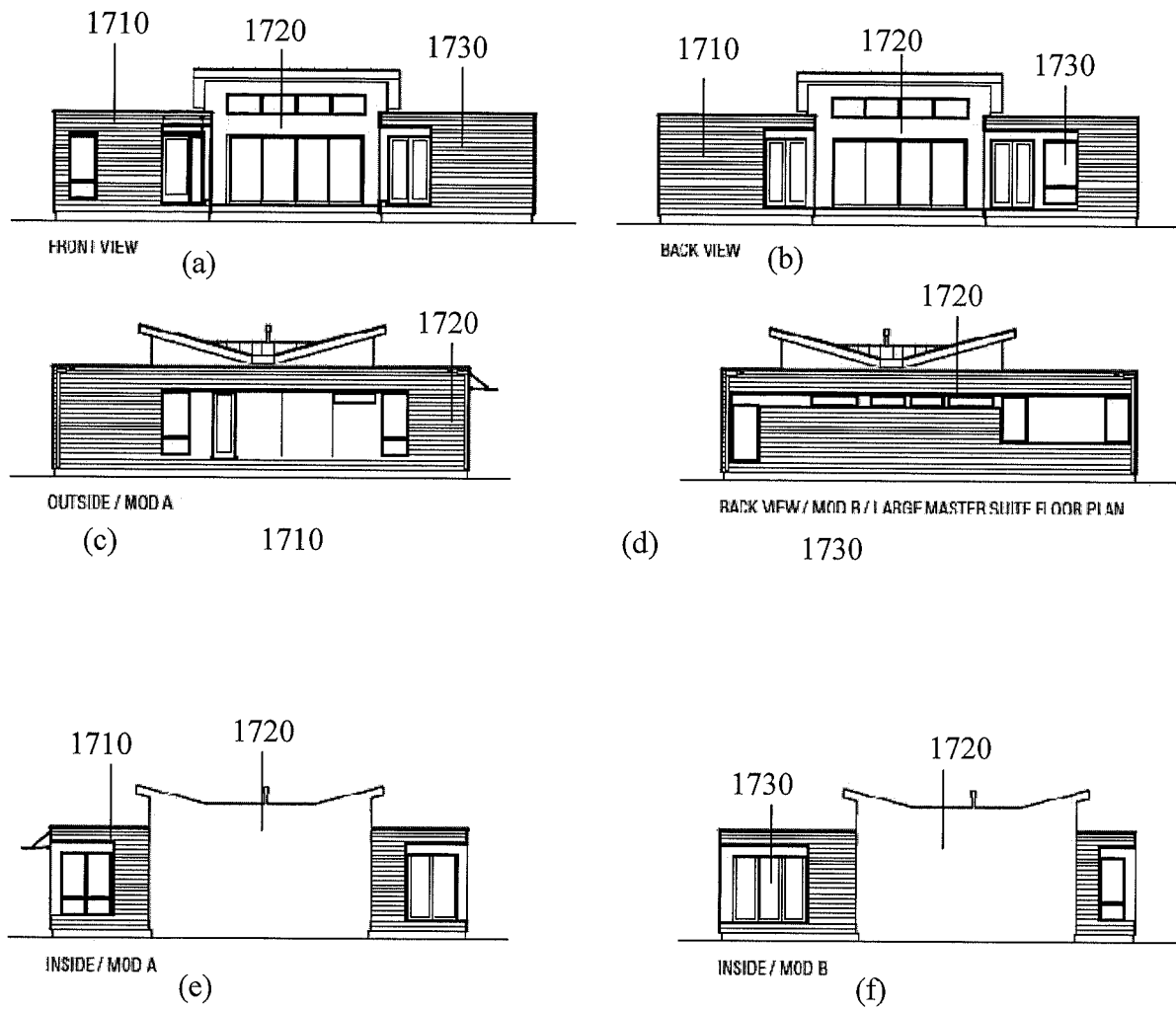


FIG. 17

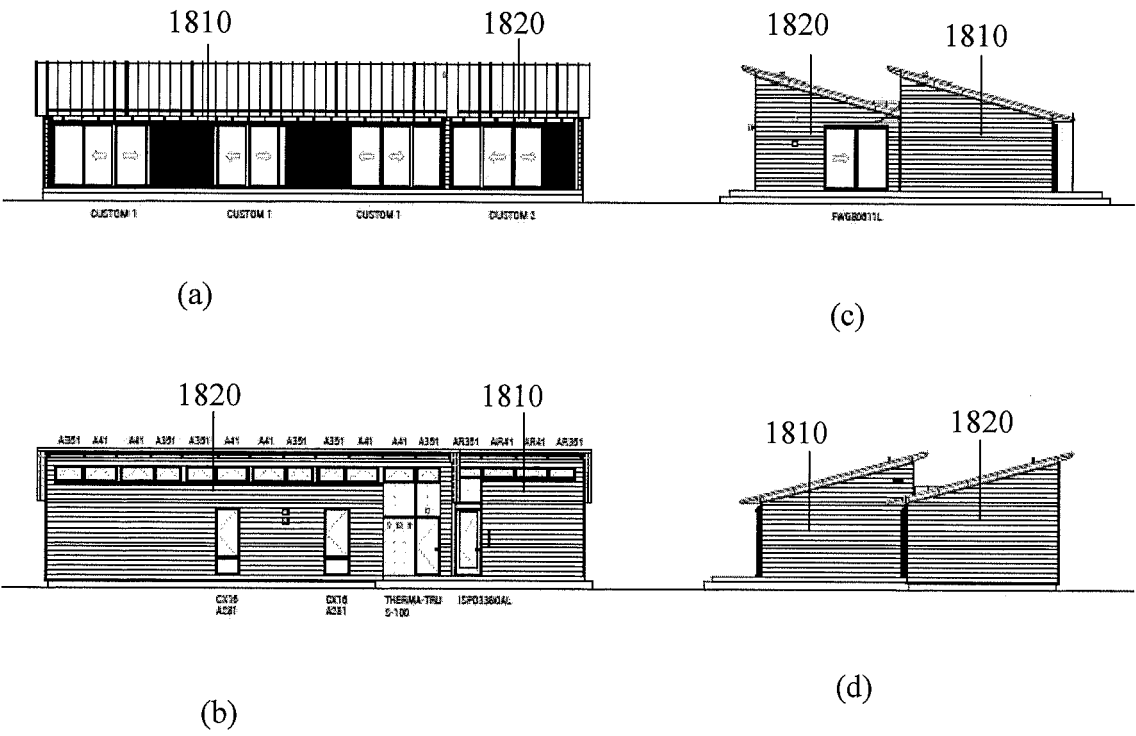


FIG. 18