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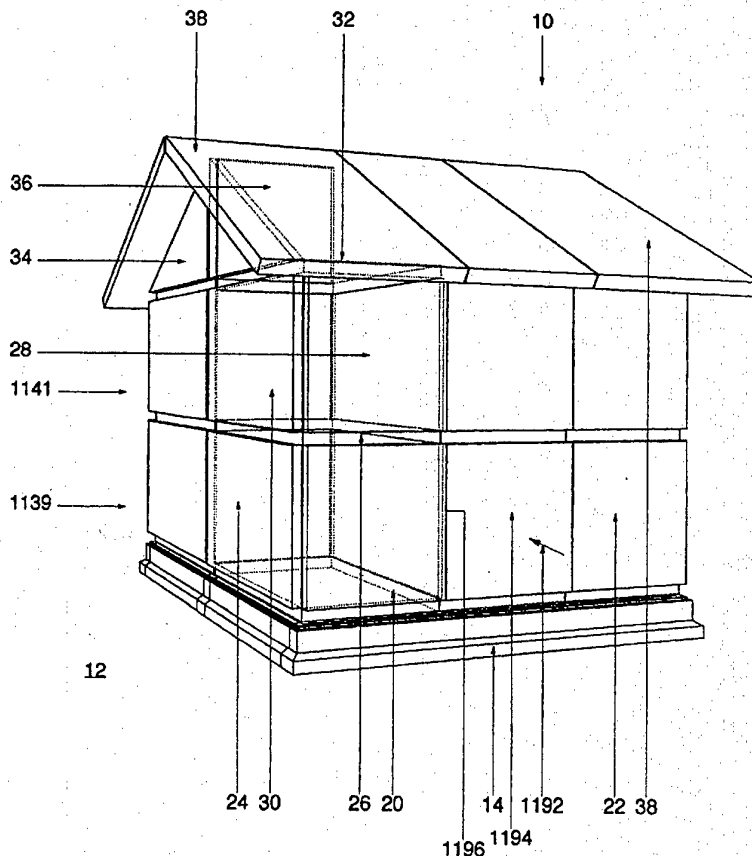
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(54) Title: EARTHQUAKE, WIND RESISTANT AND FIRE RESISTANT PRE-FABRICATED BUILDING PANELS AND STRUCTURES FORMED THEREFROM

(57) Abstract

An earthquake, fire and wind resistant pre-fabricated building panel comprises a plurality of frame members (150, 152-155). The frame members are connected together to form a frame lying in a frame plane, the frame defining a perimeter of the panel, the perimeter bounding an interior portion of the panel. At least some of the frame members are biased inwardly, generally in the frame plane, towards the interior portion of the panel. A first solidified castable substance (272) is cast in the interior portion of the frame, between the frame members. A three-dimensional structure such as a house is formed by connecting the panels together. The connections absorb and distribute seismic forces to the entire three-dimensional structure and the biased frame members act to absorb residual seismic forces reaching the individual panels. The castable substance and biased frame members permit the panel to withstand both positive and negative loading and render the panel fire resistant.



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EARTHQUAKE, WIND RESISTANT AND FIRE RESISTANT PRE-FABRICATED BUILDING PANELS AND STRUCTURES FORMED THEREFROM

BACKGROUND OF THE INVENTION

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This invention relates to an earthquake, fire and wind resistant pre-fabricated building panel for use in making a three-dimensional structure such as a house, apartment, office building or the like. A plurality of panels according to the invention is illustrated and described, a method of making such panels is described, examples of three dimensional structures according to the invention are described and a specially adapted shipping container for shipping components to build a three-dimensional structure is described.

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Prefabricated Panels

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Prefabricated building panels, in general, act as building components which can be quickly and easily fastened to a pre-erected frame structure. Many man-hours, however, are required to pre-erect the frame structure and prepare such structure for receipt of prefabricated panels. Dimension tolerances in both the pre-erected frame and the prefabricated panels can accumulate over large spans and ultimately, the panels may not properly fit on the pre-erected frame.

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In addition, conventional pre-fabricated panels are normally fastened to the exterior side of the pre-erected frame which enables such panels to withstand positive wind loading, however, negative wind loading such as created by hurricanes cannot be withstood.

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Negative loading normally results in the exteriorally fastened panels being ripped off of the frame structure. This also occurs with conventional plywood board sheathing which is also fastened to the exterior side of the frame. Examples of such prior art prefabricated panels susceptible to negative wind loading are given in U.S. Patent No. 4,841,702 to Huettemann and in U.S. Patent No. 4,937,993 to Hitchins. What is desirable therefore is a building panel or building system which can withstand both positive and negative dynamic loading.

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Three Dimensional Structure

A consideration in most building designs is the susceptibility of the building to seismic forces such as created by earthquake activity. Many conventional building designs include a solid,
5 unitary cast concrete foundation with engineered footings suitable for the soil upon which the building is to be erected. The building frame, in the form of integral wall portions connected together, is built upon the solid unitary foundation and plywood board sheathing or prefabricated panels are fastened to the frame. (Of course the plywood board sheathing and prefabricated panels suffer from the disadvantages pointed out above).

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The solid unitary foundation presents a problem under seismic forces because it is unitary and rigid. Although this permits such forces to be transmitted throughout the foundation, such a rigid foundation is unable to act sufficiently resiliently and elastically to absorb such forces without cracking or breaking. Cracks or breaks in the foundation are susceptible to water
15 ingress which can have a tendency to cause the crack or break to propagate through the foundation resulting in degradation of the foundation.

In addition, the integral wall portions of the frame of the structure typically are formed of wood which is nailed together. Often seismic forces are sufficient to rip apart nailed walls
20 resulting in localized failure of the frame leading to collapse of a wall and potential collapse of the building. While a wood frame of this type presents a relatively resilient elastic structure, typically the joints between frame portions are not sufficiently strong to hold the frame portions together under such loading and thus seismic forces cannot be properly distributed to other portions of the frame to help share the load. What is desirable therefore
25 is a sufficiently resilient elastic building foundation and a sufficiently resiliently elastic frame structure able to withstand and distribute seismic forces.

Hi-rise apartment or office buildings sometimes also suffer from a lack of a sufficiently resiliently elastic foundation and frame structure and, wall panels and partitions able to
30 withstand and distribute earthquake forces. Thus it is desirable to provide such ability in hi-rise apartment and office buildings or virtually in any structure exposed to such forces.

In addition to the need to withstand earthquake forces, there exists a need to provide prefabricated building structures capable of quick and easy erection with minimal labour
35 requirements. Presently, conventional easily erected building structures include prefabricated

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structures such as trailers, mobile homes etc., which are transported to the erection site. Transporting such structures is costly and requires an enormous amount of space on a ship, for example. If it were possible to ship individual components of a structure and then erect the structure quickly and easily, shipping or transportation costs would be reduced, labour requirements for erecting the structure would be reduced and the cost of erecting the structure itself would be reduced. Thus it is desirable to provide building components which are capable of providing these advantages.

Transportation

Further to the transportation of conventional prefabricated building structures such as trailers, mobile homes and modular houses, such items are normally stacked one upon the other during shipping. Typically, however, these structures are designed only to bear their own weight and cannot bear the weight of other such structures, especially while the ship on which they are carried is travelling in rough seas. Thus, additional structural support is required to stack such prefabricated structures or stacking must be eliminated, resulting in inefficient use of cargo space on the ship.

What is desirable, therefore, is a prefabricated building system which can be shipped and stacked without requiring additional structure, without damaging components of the building system and which makes efficient use of cargo space on a ship or other mode of transportation.

SUMMARY OF THE INVENTION

The above problems in the prior art are addressed by providing an earthquake-resistant, fire-resistant and wind-resistant pre-fabricated building panel comprising a plurality of frame members. The frame members are connected together to form a frame lying in a frame plane, the frame defining a perimeter of the panel, the perimeter bounding an interior portion of the panel. At least some of the frame members are biased inwardly, generally in the frame plane, towards the interior portion of the panel. A first solidified castable substance is cast in the interior portion of the frame, between the frame members.

Preferably, the frame members are biased inwardly by a resiliently extendable tension link extending between at least two of the frame members. More preferably, the flexible tension

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link has perpendicular portions lying in a first plane between the frame members and has diagonal portions lying in a second plane between the frame members, the second plane being spaced apart from the first plane. The castable substance is cast about the perpendicular and diagonal portions such that loads imposed on the castable substance, such as wind loads, are transferred to the tension link and hence are transferred to the frame members of the panel.

Also preferably, the panel includes a layer of flexible mesh material extending between at least two frame members and tensioned therebetween to further bias the frame members inwardly. The castable substance is cast about the flexible mesh material to further distribute forces imposed on the castable substance to the frame members.

Also preferably, at least two opposite frame members are loosely connected to adjacent frame members of the same panel such that the two opposite frame members are able to move relative to the adjacent frame members, at least in a direction parallel to the axes of the adjacent members.

A three-dimensional structure such as a house is formed by connecting panels, as described above, together. Connecting the panels together essentially connects together the individual frame members of each panel thereby forming a three-dimensional space-frame with the castable substance of each panel occupying the spaces between the frame members. The space frame is elastic and ductile and therefore is operable to distribute seismic and wind forces throughout the entire structure thus reducing the concentration of such forces at any given location and reducing the possibility of failure of any given member of the structure. In particular, the connections of the panels absorb and distribute seismic forces to the entire three-dimensional structure and the biased frame members act to absorb residual seismic forces reaching the cast portions of the individual panels. The castable substance, in cooperation with the biased frame members, permits the panel to withstand both positive and negative dynamic loading. Yet only a minimal amount of castable substance is used, in strategic locations which enhance the structural integrity of the panel. The castable substance also provides a fire-resistant layer operable to protect the panel and provides an excellent base for any architectural finish.

Transportation of the panels and components necessary to form a three-dimensional structure such as a house is preferably accomplished by forming a container by connecting together a plurality of panels, ultimately destined for use in fabrication of the structure, to form a rigid

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container into which the remaining panels and components necessary to form the structure may be placed. At least some of the panels of the structure therefore act as wall portions of a container used to transport the remaining panels and components necessary to build the structure. Some panels of the structure thus can be used to fulfil two different purposes; forming a container and forming portions of a structure whose components are transported in the container so formed.

BRIEF DESCRIPTION OF THE DRAWINGS

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Figure 1 is a perspective view of a house including a foundation, and floor, exterior wall, interior wall and roof panels according to various embodiments of the invention;

15 Foundation

Figure 2 is a plan view of a foundation according to a first embodiment of the invention;

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Figure 3 is a perspective view of a portion of the foundation shown in Figure 2;

Floor Panel

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Figure 4 is an exploded view of frame members included in a floor panel according to a second embodiment of the invention;

Figure 5 is a side view of an end portion of a top frame member shown in Figure 4;

Figure 6 is a bottom view of the end portion shown in Figure 5;

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Figure 7 is an end view of the end portion shown in Figure 5;

Figure 8 is a side view of an end portion of a side frame member shown in Figure 4;

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Figure 9 is a face view of the end portion shown in Figure 8;

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- Figure 10 is an end view of the end portion shown in Figure 8;
- Figure 11 is a plan view of the floor panel with insulation installed between the frame members;
- 5 Figure 12 is a cross-sectional view taken along lines 12-12 of Figure 11;
- Figure 13 is a cross-sectional view taken along lines 13-13 of Figure 11;
- 10 Figure 14 is a plan view of the floor panel illustrating horizontal, vertical and diagonal tension wire portions;
- Figure 15 is a cross-sectional view taken along lines 15-15 of Figure 14;
- 15 Figure 16 is a plan view of the floor panel with mesh portions covering the insulating material;
- Figure 17 is a cross-sectional view taken along lines 17-17 of Figure 16;
- 20 Figure 18 is a cross-sectional view of a portion of the floor panel illustrating the formation of a planar portion and a rib portion in cast concrete;
- Figure 19 is a cross-sectional view of a portion of the floor panel illustrating first and second cast portions of concrete;
- 25 Figure 20 is a plan view of the completed floor panel;
- Figure 21 is an exploded view illustrating a connection of the floor panel shown in Figure 20 with interior and exterior panels according to the invention, and
- 30 with the foundation shown in Figure 3;

Exterior Panel

- 35 Figure 22 is a plan view of frame members included in an exterior panel according to a third embodiment of the invention;

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- Figure 23 is a side view of a portion of a side frame member shown in Figure 22;
- Figure 24 is a face view of the frame portion shown in Figure 23;
- 5 Figure 25 is a bottom view of the frame portion shown in Figure 23;
- Figure 26 is a face view of a portion of a top frame member shown in Figure 22;
- Figure 27 is a plan view illustrating a first assembly step in assembling the exterior
10 panel;
- Figure 28 is a plan view illustrating a second assembly step in which the frame
members are placed upon an insulating portion;
- 15 Figure 29 is a plan view illustrating a third assembly step in assembling the exterior
panel, in which tension cables are routed between frame members;
- Figure 30 is a plan view illustrating a fourth step in assembling the exterior panel, in
which mesh portions are connected over panel portions of the panel;
- 20 Figure 31 is a plan view of a completed exterior panel according to the third
embodiment of the invention;
- Figure 32 is a cross-sectional view of the completed exterior panel taken along lines 32-
25 32 of Figure 31.

Interior Panel

- Figure 33 is a plan view of frame members included in an interior panel according to
30 a fourth embodiment of the invention;
- Figure 34 is a side view of a portion of a side frame member shown in Figure 33;
- Figure 35 is a face view of the frame portion shown in Figure 34;
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- Figure 36 is a face view of a frame portion of a top frame member shown in Figure 33;
- Figure 37 is an end view of the frame portion shown in Figure 36;
- 5 Figure 38 is a plan view illustrating the connection of the frame portion of Figure 34 with the frame portion of Figure 36;
- Figure 39 is a plan view of an assembly step in forming the interior panel, including the routing of tension cables between frame members;
- 10 Figure 40 is a plan view of an assembly step in forming the interior panel, including the connection of mesh material between the frame members;
- Figure 41 is a plan view of a finished interior panel;
- 15 Figure 42 is a cross-sectional view taken along lines 42-42 of the interior panel shown in Figure 41;

Roof Panels

- 20 Figure 43 is a plan view of frame members included in a roof panel according to a fifth embodiment of the invention;
- Figure 44 is a side view of a frame portion of a top frame member shown in Figure 43;
- 25 Figure 45 is a face view of the frame portion shown in Figure 44;
- Figure 46 is a side view of a connecting portion of the top frame member shown in Figure 43;
- 30 Figure 47 is a face view of the connecting portion shown in Figure 46;
- Figure 48 is a side view of a top end portion of a side frame member of Figure 43;
- 35 Figure 49 is a face view of the top end portion shown in Figure 48;

- Figure 50 is a plan view of an assembly step in forming the roof panel, in which the frame members are placed on an insulating material;
- Figure 51 is a plan view of an assembly step in forming the roof panel wherein tension cables are connected between frame members;
- Figure 52 is a plan view of an assembly step in forming the roof panel wherein a first layer of mesh material is connected between frame members;
- Figure 53 is a cross-sectional view of a completed roof panel according to the fifth embodiment of the invention;
- Figure 54 is a plan view of a completed roof panel according to the fifth embodiment of the invention;

Assembly of Panels

- Figure 55 is an exploded view illustrating the assembly of roof, floor and wall panels according to the invention;
- Figure 56 is a cross-sectional view taken along lines 56-56 of Figure 55;
- Figure 57 is a cross-sectional view taken along line 57-57 of Figure 55;

Hi-Rise Structure

- Figure 58 is a perspective view of a hi-rise structure, illustrating a use of panels according to the invention to form units of the structure;

Shipping Container

- Figure 59 is a perspective view of a shipping container illustrating a further use of panels according to the invention;
- Figure 60a is a fragmented side view of a mid-portion of the container of Figure 59;

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- Figure 60b is a fragmented perspective view of the mid-portion shown in Figure 60a;
- Figure 60c is a fragmented perspective view of the mid-portion shown in Figures 60a and 60b, in a partially assembled state;
- 5 Figure 60d is a fragmented perspective view of the mid-portion shown in Figures 60a, 60b, and 60c in a completed state;
- Figure 60e is a fragmented perspective view of a corner portion of the container shown in Figure 59;
- 10 Figure 60f is a fragmented side view of the corner portion shown in Figure 60e;
- Figure 60g is a fragmented perspective view of the corner portion shown in Figures 60e and 60f, in a partially completed state;
- 15 Figure 60h is a fragmented perspective view of the corner portion shown in Figures 60e, 60f, and 60g shown in a completed state;
- 20 Figure 61 is a plan view of a house built from components shipped in the container shown in Figures 59 and 60;
- Figure 62 is a side view of the house of Figure 61;
- 25 Panel Finishing
- Figure 63 is a layered view of an exterior panel according to the third embodiment of the invention, illustrating a method of securing an architectural finishing material to the panel;
- 30 Panel Variations
- Figure 64 (a) - (x) illustrates a plurality of plan views of panel configurations having various dimensions;
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Curved Components

Figure 65 is a perspective view of a curved corner foundation member according to a sixth embodiment of the invention;

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Curved Floor Panel

Figure 66 is a plan view of frame members included in a floor panel having a curved corner portion, according to a seventh embodiment of the invention;

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Figure 67 is a plan view of an assembly step in forming the panel according to the seventh embodiment, in which the frame members are placed on an insulating material;

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Figure 68 is a plan view of an assembly step in forming the panel according to the seventh embodiment wherein tension cables are connected between frame members;

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Figure 69 is a plan view of an assembly step in forming the panel according to the seventh embodiment wherein a first layer of mesh material is connected between frame members;

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Figure 70 is a plan view of a completed floor panel according to the seventh embodiment of the invention;

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Curved Exterior Wall Panel

Figure 71 is a plan view of frame members included in a curved exterior wall panel according to an eighth embodiment of the invention;

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Figure 72 is a bottom view of a first curved frame member shown in Figure 71;

Figure 73 is a top view of a curved styrofoam slab according to the eighth embodiment of the invention;

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- Figure 74 is a plan view of an assembly step in forming the panel according to the eighth embodiment wherein the curved styrofoam slab of Figure 73 is placed upon a layer of mesh material and a water impermeable membrane;
- 5 Figure 75 is a plan view of an assembly step in forming the panel according to the eighth embodiment wherein a tension cable is routed between opposite curved frame members and wherein the mesh and water impermeable membrane are wrapped around edges of end frame members of the panel;
- 10 Figure 76 is a plan view of an assembly step in forming the panel according to the eighth embodiment wherein a second layer of mesh material is laid between the frame members to form a concave inner surface and wherein a concrete retaining edge form is secured to the frame members;
- 15 Figure 77 is a cross-sectional view of the panel taken along lines 77-77 of Figure 76;
- Figure 78 is a cross-sectional view of the curved wall panel;
- Figure 79 is a plan view of the completed curved wall panel; and
- 20 Figure 80 is a perspective view of a corner of a structure having a curved foundation portion, a floor panel with a curved portion and a curved exterior wall portion according to the sixth, seventh and eighth embodiments of the invention.

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This application contains 87 drawing figures.

DETAILED DESCRIPTION

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Building structure and pre-fabricated panels

Figure 1

- Referring to Figure 1, a pre-fabricated house formed of foundation members and panels
- 35 according to the invention is shown generally at 10 on a building site 12.

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The house includes a foundation shown generally at 14, a first plurality of pre-fabricated first floor panels 20, a first plurality of pre-fabricated exterior wall panels 22, a first plurality of pre-fabricated interior wall panels 24, a second plurality of pre-fabricated second floor panels 26 a second plurality of pre-fabricated exterior wall panels 28, a second plurality of pre-fabricated interior wall panels 30, a third plurality of pre-fabricated floor panels 32, a third plurality of pre-fabricated exterior panels 34, a third plurality of pre-fabricated interior panels 36 and a plurality of pre-fabricated roof panels 38.

Foundation

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Figure 2

Referring to Figure 2, the foundation 14 is shown in accordance with a first embodiment of the invention and includes side, end and centre foundation members designated 40, 42 and 44, respectively. Each foundation member is formed by casting concrete, to include a footing portion for resting on the ground and a support portion for supporting a building structure. The support portion is cast about a pre-assembled hollow steel beam. Each foundation member is also formed such that the side, end and centre foundation members have engaging faces 41 which mate with each other and can be connected to each other.

20 Side foundation members

The side foundation members 40 have first and second opposite end portions 46 and 48 and a middle portion 50 disposed therebetween. The first and second end portions 46 and 48 have first and second short steel tubing portions 52 and 54, respectively while the middle portion has a relatively long steel tubing portion 56 which is welded to and extends between the first and second end portions. The long portion 56 is in communication with the short portions such that a duct 58 is formed between the first tubing portion 52 and the second tubing portion 54. As the tubing portions are welded together, a unitary length of structural tubing is formed. The duct is operable to hold utility service conduits for water, electricity, etc.

30 Figure 3

Referring to Figure 3, the side foundation member 40 is formed with a concrete footing portion 60 and a concrete support portion 62 which encircle the steel tubing portions 52, 54, and 56 to form a structural support for the steel tubing portions. The steel tubing extends lengthwise in the support portion 62. A hollow conduit 64 is formed in the footing portion 60 and is filled with insulating material (not shown) such as styrofoam to provide insulating

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properties to the member and prevent ingress of moisture in the event that the concrete becomes cracked. The insulating material also renders the foundation member lighter in weight.

- 5 The first and second end portions 46 and 48, only portion 48 being shown in Figure 3, have first and second vertically extending duct portions 66 and 68, respectively which are in immediate communication with the long steel tubing portion 56 and the second steel tubing portion 54, respectively. The first and second vertically extending duct portions have foundation connecting flanges 70 and 72, respectively which act as connecting means for
- 10 connecting floor panels and wall panels to the foundation members. The middle portion 50 also has first and second vertically extending duct portions 74 and 76 which are disposed approximately midway between the first and second end portions and which are in immediate communication with the long steel tubing portion 56 and which have respective foundation connecting flanges 78 and 80. Each of the foundation connecting flanges 70, 72, 78 and 80
- 15 has a respective opening 82 for permitting access to, and for communication with its respective vertical duct and each flange has a respective threaded opening 84 for permitting a fastening member to be received therein for use in connecting the floor panels to the foundation members.
- 20 Referring to Figures 2 and 3, the first and second end portions 46 and 48 also have first and second connecting flanges 86 and 88 which are flush with respective end engaging faces of the side foundation member. The first and second connecting flanges 86 and 88 are used to connect the side foundation member to an adjacent end foundation member 42. The horizontal duct formed by the hollow tubing has end openings 89 and 91 which are accessible
- 25 at respective engaging faces 41.

End foundation members

- Referring to Figure 2, the end foundation members 42 are similar to the side foundation members in that they include a hollow steel tubing portion 90, have footing and support
- 30 portions 92 and 94, respectively and have an insulation filled conduit 96, shown best in Figure 3. Referring back to Figure 2, the end foundation members also have first and second end portions 98 and 100 to which are rigidly connected first and second elastically deformable connecting flanges 102 and 104 which extend from the hollow steel tubing portion 90 for mating engagement with and bolting to co-operating connecting flanges of an adjacent
- 35 side foundation member (such as 86, 88 and 142).

Centre foundation member

Still referring to Figure 2, the centre foundation member 44 has a central portion 106 and first and second "T"-shaped end portions 108 and 110. The central portion 106 includes a relatively long hollow steel tubing portion 112 which is connected to first and second hollow steel end members 114 and 116 disposed at right angles to the long steel tubing portion 112 and connected so as to permit communication between the first and second hollow steel members 114 and 116.

Each end portion 108 and 110 has first, second and third vertically extending ducts 118, 120 and 122, respectively. The first vertically extending duct 118 is in direct communication with the long steel tubing portion 112 while the second and third vertically extending ducts are in direct communication with the first (and second) steel end member 114. Each of the first, second and third ducts has a respective duct connecting flange 124 having an opening 126 in communication with its respective duct and a threaded opening 127 for receiving a threaded fastener for use in connecting an adjacent floor member to the centre foundation member.

The central portion 106 also has first and second vertically extending duct portions 128 and 130 which are disposed approximately midway between the first and second end portions 108 and 110 and which are in immediate communication with the long steel tubing portion 112. These duct portions also have respective foundation connecting flanges 132 and 134. Each of the foundation connecting flanges has a respective opening 136 for communication with its respective vertical duct and each flange has a respective threaded opening 138 for permitting a fastening member to be received therein for use in connecting the floor panels to the foundation members.

The centre foundation member further includes first and second connecting flanges 140 and 142 on opposite sides of the member for use in connecting the centre foundation member to adjacent end members 42.

In the preferred embodiment, all steel components of respective foundation members are welded to adjacent steel members of the same foundation member such that the steel components form a rigid structure within the foundation portion. The concrete footing portions and wall portions are then formed about the rigid structure to form the individual foundation members depicted in the drawings. If desired, the concrete curing process may be accelerated by passing the members through an oven or by the use of steam. Desired

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finishes and waterproofing can also be added at this time. The individual foundation members are then connected together using the elastically deformable connecting flanges on each member to form a foundation for the entire building structure as shown in Figure 2. The connecting flanges also connect together the steel tubing members of the foundation members, thus forming a space frame lying in a flat plane, with the tubing members of each of the foundation members acting as the space frame members.

Floor panel

Figure 4

- 10 Referring to Figure 4, the fabrication of a floor panel according to a second embodiment of the invention is begun by cutting to length first, second, third, fourth and fifth 2" X 4" hollow steel tubing frame members as shown at 150, 152, 153, 154 and 155, although it will be appreciated that the steel tubing may be of any suitable size to meet any desired structural loading requirement. The steel tubing members act as frame members for the panel. Frame members 152 and 154 form a pair of adjacent sides of the frame and frame members 150 and 155 form a pair of opposite sides of the frame, the pair of opposite sides extending between the pair of adjacent sides. Frame member 153 extends between frame members 150 and 155 at a central location between members 152 and 154.
- 15
- 20 Frame members 150 and 155 have respective opposite end portions 156, 158, 160 and 162, respectively. Only end portion 156 will be described, it being understood that end portions 158, 160 and 162 are similar.

Figures 5, 6 and 7

- 25 Referring to Figures 5, 6 and 7, end portion 156 is shown in greater detail. Frame member 150 has a longitudinal axis 164, an outside face 165, an inside face 190 and an end face 166. The outside face 165 extends the length of the frame member and forms an outer edge of the ultimate panel. The inside face 190 faces inwards toward an interior portion of the frame. Secured to the end face 166 is a plate 168 extending to cover the end portion of the steel frame member 150. Plate 168 has first and second service openings 176 and 178 which provide access to a hollow portion 180 within the longitudinal frame member 150 and extending the length thereof. The plate also has openings 182 and 184 for receiving threaded fasteners to permit the plate and hence the longitudinal frame member 150 to be fastened to an adjacent member of an adjacent panel.
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Referring to Figure 5, a parallel member 170 extends in a direction parallel to the longitudinal axis 164. The parallel member 170 is welded to the longitudinal frame member 150 and is welded to the plate 168. A flange 172 extending perpendicular to the plate 168 and perpendicular to the parallel extending member 170 is connected to the parallel member 170 and the plate 166. The flange 172 has an opening 174 of sufficient size to receive electrical conduits and/or water service conduits (not shown).

Figure 6

Referring to Figure 6, inside face 190 has pin receptacles 186 and 188. Beginning adjacent the receptacle 186 on the inside face 190, a first plurality of steel plates 192, to which are fastened respective pre-welded steel hooks 196, extends in a first hook plane 308, longitudinally along the frame member 150. Referring to Figure 4, the hooks 196 are located at spaced apart intervals along the frame member 150.

Referring back to Figure 6, a second plurality of steel plates 194 to which are fastened respective hooks 198, also extends in a second hook plane 312, longitudinally along the frame member 150. The first and second hook planes 308 and 312 are parallel and spaced apart and extend symmetrically on opposite sides of a transversely extending longitudinal plane 197 intersecting the longitudinal axis 164 of Figure 5.

Referring to Figure 7, the longitudinal plane 197 divides the frame member into two portions comprising a side one portion 199 and a side two portion 201. Thus, the hooks 196 lying in the first hook plane 308 are on the side one portion and the hooks 198 lying in the second hook plane 312 are on the side two portion. In the present embodiment, the side one portion 199 will ultimately form the "floor" surface of the panel and the side two portion 201 will ultimately face the ground beneath the house.

Figures 6 and 7

Referring to Figures 6 and 7, there is further secured to the inside face 190 a first plurality of pre-cut bent chair bolster hooks 204, each having first and second opposing portions 206 and 208, respectively, shown best in Figure 7. The first portions 206 of the hooks are disposed in spaced apart relation in a third hook plane 310 extending longitudinally along the side one portion 199 of the frame member. The third hook plane is parallel to and spaced apart from the first and second hook planes 308 and 312.

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A second plurality of pre-cut bent chair bolster hooks **210** also having first and second opposing hook portions **212** and **214**, respectively are disposed in spaced apart relation along the side two portion **201** of the frame member. The first hook portions **212** are disposed in a fourth hook plane parallel to and spaced apart from the first, second and third hook planes **308**, **310** and **312**.

Referring to Figure 4, it will be appreciated that the members **150** and **155** are mirror images of each other and therefore frame member **155** has a similar arrangement of hooks **196** and chair bolster hooks **204** (and **210** not shown).

10

Still referring to Figure 4, the side members **152** and **154** have first and second end portions respectively, the end portions being designated **216** and **218**, respectively. The end portions are similar and therefore only end portion **216** will be described.

15 Figure 8

Referring to Figure 8, frame member **152** has an outer face **220**, an inner face **222** and a longitudinal axis **225**, the longitudinal axis **225** lying in the same longitudinal plane **197** as the longitudinal axis **164** of frame member **150**. An end face **226** is formed at end portion **216** and lies in an end face plane **217**. To the inner face **222** is secured a transversely extending angle member **224** having a projecting portion **228** and a parallel portion **229**. The projecting portion **228** extends in the end face plane **217** and the projecting portion **229** is welded to the inner face **222**.

Figure 9

Referring to Figure 9 the projecting portion **228** has a first transversely extending hook **230** extending perpendicularly to the end face plane **217**. The hook has a first shank portion **232** extending past the end face plane **217** and has a first hook portion **234** extending opposite the first shank portion **232**, parallel and adjacent to the parallel portion **229**. The first hook portion **234** lies in a fifth hook plane **340** extending parallel to and spaced apart from the longitudinal plane **197**, adjacent a side one portion **221** of the frame member. The fifth hook plane is also parallel to and spaced apart from the first, second, third and fourth hook planes **308**, **312**, **310** and **314**.

Still referring to Figure 9, the end portion **216** also has a second hook **236** on a portion of the angle member opposite the first hook **230**, the second hook has a second shank portion

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238 and has a second hook portion 240. The second shank portion 238 extends parallel to the first shank portion 232 and is spaced apart therefrom. The second hook portion 240 lies in a sixth hook plane 341 extending parallel to and spaced apart from the longitudinal plane 197, adjacent a side two portion 223 of the frame member. The sixth hook plane is also
5 parallel to and spaced apart from the first, second, third, fourth and fifth hook planes 308, 312, 310, 314 and 340.

Figures 9 and 10

Referring to Figures 9 and 10, secured to the side one portion 221 of the inner face 222 is
10 a first plurality of chair bolster hooks 242. The chair bolster hooks 242 are secured in spaced apart relation longitudinally along the frame member 152 and are similar to the chair bolster hooks 204 described previously and shown in Figures 5, 6 and 7. Referring back to Figures 9 and 10 each of the hooks 242 has a first portion 244 which lies in the third hook plane 310.

15 Similarly, secured to the side two portion 223 of the inside face is a second plurality of chair bolster hooks 248. The chair bolster hooks 248 are also secured in spaced apart relation longitudinally along the frame member 152 and are similar to the chair bolster hooks 210 described previously and shown in Figures 5, 6 and 7. Referring back to Figures 9 and 10,
20 each of the hooks 248 has a first portion 243 which lies in the fourth hook plane 314.

Referring back to Figure 4, frame member 153 is similar to frame members 152 and 154 with the exception that frame member 153 has two inside faces 245 and 247 each with a respective plurality of chair bolster hooks 260 disposed such that hook portions thereof lie in
25 the third and fourth hook planes 310 and 314, respectively. In addition, frame member 153 has first and second end portions 262 and 264, respectively, each with four hooks and extending shank portions similar to shank portions 232 and 238 in Figures 9 and 10, only two of such hooks being shown in Figure 4 at 266 and 268.

30 To assemble the frame members together, the shank portions 232 and 238 shown in Figures 9 and 10 are received in receptacles 186 and 188 of the frame member 150 shown in Figure 6. A similar insertion is performed at each of the remaining corners of the frame. In addition, the four hook portions, only two of which are shown at 266 and 268 in Figure 4, are received within corresponding receptacles (not shown) in longitudinal frame member 150.

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No screws or rivets are used to connect the frame members together. The shank portions at each joint are merely loosely held in their receptacles and thus the opposite members 150 and 155 are permitted to move in a direction parallel with the longitudinal axes of adjacent frame members 152, 153 and 154. This is important as it permits the frame to absorb forces exerted on the ultimate panel which renders the panel effective in absorbing dynamic forces such as seismic forces due to earthquakes, hurricanes, heat stresses from fire, and forces due to flooding.

Figure 11

Referring to Figure 11, the frame members are connected together in the loosely connected arrangement described above to form a frame lying in a frame plane. In the embodiment shown, the frame members define the perimeter of the panel, the perimeter bounding first and second interior portions of the panel 270 and 272. On side one of the panel, within the first interior portion 270, is disposed a first preformed or pre-cast insulating slab 274 of styrofoam. The styrofoam slab has outer dimensions which permit the slab to fit snugly within the interior portion, between the frame members 150, 152, 153 and 155.

The styrofoam slab is preformed or pre-cast to have a plurality of longitudinally extending recesses 276, 278, 280, 282, 284 and 286. The slab also has first and second laterally extending recesses 288 and 290 which extend laterally of the slab between opposite sides thereof. The slab also has first and second diagonal recesses 292 and 294 which form an "X" shape in the slab. The recesses are formed in what will ultimately form an interior side 296 of the panel. An exterior side (not shown) opposite the interior side is formed in a similar manner.

Figure 12

Referring to Figure 12, recess 278 is representative of the remaining recesses and is generally truncated triangular in shape. Each recess has first and second sloping side portions 298 and 300 connected by a bottom portion 302.

Each of the four sides of the insulating slab, adjacent the frame members 150, 152, 153 and 155 is formed with a projecting portion 304 having a thickness defined as the distance between opposing bottom portions of immediately adjacent recesses on opposite sides of the slab. The thickness is designated 306 in Figure 12 and is proportional to the desired insulative or "R" value of the panel.

Figure 13

Referring to Figure 13, the thickness 306 of the projecting portion 304 is formed such that the projecting portion is received between the first and second pluralities of hooks 196 and 198 on the upper and lower portions of the inside face of member 150. The projecting portions on the remaining sides of the slab are received between corresponding hook members on adjacent frame members. The first and second pluralities of hooks 196 and 198 thus serve to locate the slab relative to the frame. Consequently, it is important that the hooks 196 and 198 and similar hooks on the other frame members are located symmetrically about the longitudinal axis of respective frame members to ensure that the insulating slab is located centrally between sides one and two of the panel.

Figure 14

Referring to Figure 14, a turnbuckle 316 is connected to a hook 196 adjacent recess 284. A unitary, resiliently extendable cable 318 is connected to the turnbuckle 316 and is routed in recess 284 past the hook 196 on frame member 155 opposite frame member 150. The cable is then routed in recess 290 to an adjacent hook 196 adjacent recess 282 and is then further routed in recess 282 back to a hook 196 on frame member 150. The cable is routed in similar fashion between the frame members 150 and 155 until a first corner 322 of the panel is reached. It will be appreciated that as all of the hooks 196 lie in the first hook plane 308, shown best in Figure 13, the portion of the tension cable 318 routed thus far also lies in the first hook plane 308.

Figure 15

Referring to Figure 15, when the cable is routed to the corner 322, the cable is routed from hook 196 upwards to first shank portion 232. From here, referring back to Figure 14, the cable is routed through a diagonal path in diagonal recess 292 to a diagonally opposite second corner 324 of the panel. As the first shank portion 232 in the corner 322 and corresponding first shank portion 232 in corner 324 lie in the fifth hook plane 340, shown in Figure 15, the cable in diagonal recess 292 of Figure 14 also lies in the fifth hook plane 340.

Referring back to Figure 14, the cable is then routed downwards in corner 324 to an adjacent hook 196 lying in the first hook plane 308 (not shown in Figure 14) and extends in recess 286 to hook 196 in an opposite third corner 326. The portion of the cable extending in recess 286 thus lies in the first plane 308. At corner 326, the cable is routed upwards to the first shank

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portion 232 lying in the fifth hook plane 340 and then extends diagonally in diagonal recess 294 to a diagonally opposite fourth corner 328 whereupon the cable is fastened to first shank portion 232. This diagonal extending portion of the cable thus also lies in the fifth hook plane 340.

5

The turnbuckle 316, which acts as tightening and tensioning means for tensioning the cable, is then tightened to tighten and tension the cable 318 to approximately 600 lbs., although the tension may be higher or lower to suit the particular structural loading expected to be imposed on the panel.

10

Tightening and tensioning of the cable biases the opposite frame members 150 and 155 inwards towards the interior portion 270 of the panel. The cable and turnbuckle thus act as biasing means for biasing at least some of the frame members inwardly, generally in the frame plane, towards the interior portion of the panel.

15

It will be appreciated that the cable 318 has longitudinally and transversely extending portions which extend within the longitudinally and transversely extending recesses and has diagonally extending portions which extend within the diagonally extending recesses. Referring to Figure 15, it will be appreciated that the longitudinally and transversely extending portions

20 lie in a first plane (308) whereas the diagonally extending portions lie in a second plane (340), the second plane being spaced apart from the first plane. Generally, the spacing between the first and second planes should be increased with increased structural loading and decreased with decreased structural loading.

25 A similar procedure of installing styrofoam and a tension cable is followed for the second interior portion 272 of the panel.

Figure 16

Referring to Figure 16, a first layer of wire mesh 330 is cut to fit within the interior portion

30 270 and has first, second, third and fourth edges 332, 334, 336 and 338. The wire mesh 330 is tensioned, through the use of a conventional tensioning tool, to tighten it between at least two frame members. The edges 332, 334, 336 and 338 are connected to the chair bolster hook portions lying in the third plane 310 on each of the frame members 150, 152, 153 and 155.

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Figure 17

Referring to Figure 17, the first layer of wire mesh **330** thus lies in the third hook plane **310** and is spaced apart from the remaining planes. It will be appreciated that the diagonal cable portions lying in the fifth hook plane **340** which is immediately adjacent, act as supports for the mesh. Tie wires (not shown) may be used to connect the mesh to the diagonal cables to prevent the mesh from movement during subsequent steps.

Referring back to Figure 16, the second interior portion **272** also includes its own first layer of wire mesh material similar to that of the first interior portion.

10

Still referring to Figure 16, a concrete form edge retaining member **343** is connected to the frame members to further define an outer perimeter of the panel. The retaining member is connected by means of rivets, screws or point welding to the frame members **150**, **152**, **154** and **155**. Concrete is then poured onto the mesh **330**, to fill the recesses in the styrofoam slab, and is bounded by the form edge retaining member **343**.

15

The concrete used in construction of the panel may be of virtually any mix. The ratio of gypsum to gravel in the mix can be selected to suit the particular conditions under which the panel is to be used. Preferably, the mix includes a waterproofing agent such as epoxy resin which imparts to the resulting concrete an ability to prevent moisture ingress and a resilient flexibility useful in absorbing energy imparted to the panel by seismic activity or even shell-fire. In one embodiment in which the panel was used in the Pacific Northwest, the ratio of cement to sand to gravel to water to epoxy was approximately **1:2:4:1:0.05**.

20

It will be appreciated that chips of marble, granite, crystallized sand mixed with water and any colour of cement may be used in the mixture to produce a good architectural base suitable for finishing.

25

Figure 18

Referring to Figure 18 the concrete passes through the mesh and flows into the recesses such as **276** of the insulating slab such that the concrete extends about the tension cable **318** and about the first layer of mesh **330**. The concrete thus has a planar portion shown generally at **342** and has a plurality of rib portions **344**. The rib portions extend perpendicularly from the planar portion **342** to form transverse, longitudinal and diagonal ribs defined by the recess portions of the insulating slab. As the recesses extend substantially between the opposite

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frame members, so do the concrete ribs. The width of the recesses may be widened to increase the overall strength of the panel and if the bottom portion is widened the slope of the first and second sloping side portions is preferably reduced. Effectively, the shapes of the recesses are optimized in cross-sectional area and section shape to optimize strength of the panel and to optimize the position of the neutral axis of the section for a given loading. The concrete ribs have embedded therein, portions of the tension cable which act as positive reinforcement when loads are applied to the panel and the planar portion has embedded therein the first layer of mesh which also acts as positive reinforcement. The diagonal ribs with embedded portions of the cables and the mesh in the planar portion also act to distribute dynamic and static stresses to the frame members when positive loading is applied centrally of the panel. The embedded portion of the cables and mesh also can act as negative reinforcement and distribute dynamic and static stresses when negative loading is applied centrally of the panel.

The concrete acts as a first solidified castable substance cast in the interior portion of the frame, between the frame members and about the biasing means such that loads imposed on the solidified castable substance (concrete) are transferred by the biasing means to the frame members.

Figure 19

Referring to Figure 19, side two 201 of the panel is finished in a manner similar to side one 199 and includes recesses similar to those on side one, includes a second turnbuckle, a second resiliently extendable tension cable having a second perpendicular portion 348 and a second diagonal portion 350, the second perpendicular portion lying in the second plane 312 and the second diagonal portion lying in the sixth hook plane 341. The second cable is routed in a manner similar to the first cable, about hooks 198 and 234 of Figure 13.

Side two 201 further includes a second layer of wire mesh material 346 extending in the fourth hook plane 314. Side two also has a second concrete retaining edge 358 and concrete 360 is poured over the second layer of mesh material 346 about the perpendicular and diagonal portions of the second resiliently extendable cable 348 and 350, into the recesses 288 formed in the second side of the insulating material. The concrete on the second side thus has a second planar portion 362 and a plurality of ribs 364 extending perpendicularly to the planar portion, in a manner similar to the concrete on side one 199.

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The concrete on sides one and two may be finished to have any desired surface to suit the placement of the panel. If side one 199 is used to form the ground floor of the house, it preferably will be finished with a smooth surface to which finishing such as tile, carpet terrazzo, chips of marble, etc., may be fastened. Side two 201, which will ultimately face the ground when installed, need not be finished smooth but is preferably coated and sealed with a conventional water proofing compound.

Figure 20

Referring to Figure 20, a completed floor panel manufactured according to the steps above is shown generally at 370. The panel has first and second opposite longitudinal edges 372 and 374, respectively and has first and second opposite transverse edges 376 and 378, respectively which form a perimeter of the panel. These edges also define first, second, third and fourth corners of the panels designated 171, 173, 175 and 177, respectively. The parallel members 170 and flanges 172 on each of the end portions of the frame members 150 and 155 extend beyond the perimeter of the panel and are used for lifting and handling the panel and for connecting the panel to the foundation members and wall panels.

The parallel members 170 and flanges 172 act as co-operating connecting means for connecting the panel to a co-operating connecting means of an adjacent building panel. As the parallel members and flanges are formed from plate steel they are operable to deform elastically when subjected to dynamic forces imposed on the panel. Due to this elastic deformability, the parallel members and flanges are operable to absorb seismic forces and due to the rigid connection of the parallel members and flanges to the adjacent frame member residual seismic forces are transmitted throughout the frame and to adjacent frame members of an adjacent panel.

Connection of Floor Panel to Foundation

Figure 21

Referring to Figure 21, the floor panel 370 is in position for connection with the foundation members. The panel is positioned such that the first transverse edge 376 is adjacent the side foundation member 40 and the second longitudinal edge 374 is adjacent the end foundation member 42.

Prior to connecting the floor panel to the foundation members, a first corner connecting flange 380 is secured to the parallel member 170 adjacent the first transverse edge 376 and

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the second longitudinal edge 374 and a second corner connecting flange 382 is secured to the parallel member 170 adjacent the second transverse edge 378 and the second longitudinal edge 374. These corner connecting flanges are fastened by welding. Only the second longitudinal edge 374 of the panel, which faces outwardly of the house has corner flanges connected thereto. The first longitudinal edge which faces inwardly, has no such corner flanges.

The first and second corner connecting flanges have respective parallel flange portions 384 and 386 which extend parallel to the second transverse edge and right angled flange portions 388 and 390 which extend perpendicular to the second transverse edge.

10

The parallel flange portions 384 and 386 have respective utility conduit openings 392 and 394 and respective adjacent fastener openings 396 and 398. The utility conduit openings 392 and 394 permit utility service conduits (not shown) to pass therethrough. The fastener openings 396 and 398 are for use in receiving a threaded fastener for fastening the panel to the foundation members.

15

Installation of the floor panel 370 onto the foundation members is effected by positioning the floor panel, using a crane (not shown), such that flange 172 and parallel flange portion 384 are received directly on top of the foundation connecting flanges 70 and 72, respectively. In addition, the panel is positioned such that the remaining flanges extending from the panel are disposed directly on top of corresponding foundation connecting flanges on corresponding foundation members below.

20

In this position, the utility service conduit openings in flanges 172 and 384 are in axial alignment with the openings 82 in foundation connecting flanges 70 and 72 and are thus in communication with the interior of the steel tubing in the foundation members. Similarly, the fastener openings 176 and 396 are in axial alignment with corresponding threaded openings 84 in the foundation connecting flanges 70 and 72. Other fastener openings in other flanges on the panel are also in axial alignment with respective threaded openings in corresponding foundation connecting flanges. Threaded fasteners are then used in the threaded openings to securely fasten the panel to the foundation members, particularly if the floor is to be a deck portion of the house, with no wall panels connected thereto. If wall panels are to be connected however, the threaded fasteners would not be installed at this time.

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Other floor panels constructed as explained above are similarly connected to the remaining duct flanges extending from the remaining foundation members. A first floor 400 of the house is thus formed by a plurality of floor panel members so connected to the foundation members.

5

In the embodiment depicted in the figures thus far, the dimensions of a single floor panel are 8' X 8'. It will be appreciated, however, that the floor panel may be virtually any size. Interior and exterior wall panels, portions of which are shown at 402, 404 (interior) and 406, 408, 410 and 412 (exterior), respectively are connected to respective plates 168 extending
10 from respective corners of the floor panels 370.

As floor panel 370 measures 8' X 8', the installation of the interior and exterior wall panels 402, 404, 406, 408 and 412 define a first room which has dimensions of at least 8' X 16' as no interior panel is installed adjacent the first longitudinal edge 372 of the first floor panel.
15 Alternatively, an interior panel may be installed at this location in which case a room having the dimensions of 8' X 8' would be defined. Also alternatively, the room may be made larger in the longitudinal direction of the floor panels by cutting off the plates at the third corner 175 of the floor panel 370 and omitting the installation of the interior panel 402.

20 Omitting the installation of interior panel 402 would leave a gap 414 between adjacent transverse sides of adjacent panels, however, such gap may be filled with concrete or water impermeable sealant such as silicone to provide a smooth floor surface. Various finishes such as linoleum or carpeting etc., may then be placed upon this smooth surface.

Before describing the specific connection of the interior and exterior panels to the floor
25 panels, each of these panels will be described.

Exterior Panel

Figure 22

Referring to Figure 22, the fabrication of an exterior panel according to the invention is
30 begun by cutting to length first, second, third, fourth, fifth, sixth and seventh 2" X 4" hollow steel tubing members as shown at 420, 422, 424, 426, 428, 430 and 432, respectively. The steel tubing members act as frame members for the panel and are arranged to provide a window opening 434 and first, second and third panel portions 436, 438 and 440.

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Frame members 420 and 432 have respective opposite end portions 442, 444, and 446, 448, respectively. Each of the end portions is similar and therefore only end portion 444 will be described but will be considered representative of each end portion.

5 Figure 23

Referring to Figure 23, end portion 444 of frame member 420 is shown in greater detail. The frame member 420 has a longitudinal axis 450 extending centrally of the member. Inside and outside faces of the member are shown generally at 452 and 454, respectively, the inside face being directed towards an interior of the first panel portion 436 and the outside face
10 being directed outwards from the panel and forming a portion of an outer perimeter of the panel. The frame member 420 also has a side one face 456 and a side two face 458, best seen in Figure 24. The side one face ultimately faces the interior of the house and the side two face ultimately faces the exterior of the house.

15 Figures 23, 24 and 25

Referring to Figures 23, 24 and 25, the end portion 444 of Frame member 420 has secured thereto, a transversely extending plate 460. The plate has a cover portion 462 for covering the end portion of the frame member and has a lip portion 464 which extends inwards, towards the interior portion of the panel. The cover portion 462 has an opening 466 which
20 permits access to a hollow interior portion 468 of the frame member. As with the floor panel, described previously, the hollow interior portion of the frame member permits utility service conduits to be routed therein.

Referring to Figures 23 and 24, the end portion 444 further includes a first transversely
25 extending opening 470 in the side one face 456, a second transversely extending opening 472 in the side two face and a third opening 475 in the inside face 452 and first and second threaded openings 474 and 476 provided by first and second nuts 478 and 480 which are welded behind the side one 456 and side two 458 faces, respectively.

30 The inside face 452 has secured thereto a right angled member 482 having a mounting portion 484 and an extending portion 486. The mounting portion is welded to the inside face while the extending portion 486 projects perpendicularly to the inside face, toward the interior of the first panel portion 436. The extending portion has secured thereto a hook 488 having a hook portion 490 which is disposed in a first hook plane 492 adjacent the side one face 456,

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and a projecting pin portion 491 which projects parallel to the longitudinal axis 450, toward the plate 460.

5 The inside face also has secured thereto a plurality of chair bolster hooks 494 similar to the chair bolster hooks depicted as Items 204 and 210 in Figure 7. Referring to Figure 22, the chair bolster hooks 494 are disposed in spaced apart relation, longitudinally along the frame member 420 and extend between the opposite end portions 442 and 444. Referring back to Figures 24 and 25, the chair bolster hooks have respective hook portions 496 disposed in a second hook plane 498 between the side one face 456 and the first hook plane 492.

10

The plate 460 acts as a foot for supporting the frame member, the openings 466, 470, 472, and 475 provide access to utility service conduits inside the frame member. The threaded openings 474 and 476 are for securing the resulting panel to an adjacent panel and the extending portion 486 is for cooperating with an adjacent frame member of the same panel.

15 The hook 488 is for cooperating with a tension cable for holding the panel together and the chair bolster hooks 494 are for holding a wire mesh in the second hook plane.

Referring back to Figure 22, the frame member 432 is similar to the frame member 420 and therefore requires no further description. Frame members 422 and 426 are however, slightly

20 different from frame members 420 and 432 and therefore will now be described.

Frame members 422 and 426 form upper and lower portions of the outer perimeter of the panel. Frame member 422 is divided into a first portion 500, a second portion 502 and a third portion 504. Frame member 426 is similarly divided into a first portion 506, a second

25 portion 508 and a third portion 510.

The first portions 500 and 506 form part of the first panel portion 436 while the second portions 502 and 508 form portions of the second panel portion 438. The third portion 504 of member 422 forms a portion of a window frame about window opening 434 and the third

30 portion 510 of member 426 acts as a frame portion of the third panel portion 440. With the exception of the third portion 504 of member 422 adjacent the window opening 434, each of the above described portions has a respective plurality of chair bolster hooks, each indicated at 512 and has a plurality of tension cable hooks, each indicated at 514.

35

Figure 26

Referring to Figure 26, the chair bolster hooks **512** each have respective hook portions **513** which lie in the second plane **498**. In addition, the tension cable hooks **514** have respective hook portions **515** which lie in a third hook plane **517**. The third plane **517** is parallel to and
5 spaced apart from the first and second planes **492** and **498**, respectively.

Referring back to Figure 22, the exterior panel further includes the frame members **424**, **428** and **430** which are disposed intermediate the frame members **422**, **424**, **426** and **432**. Frame members **424** and **430** are similar, mirror images of each other and therefore only member
10 **424** will be described.

Frame member **424** extends between frame members **422** and **426**. Member **424** has a longitudinal axis **519**, a first end portion and a second end portion **520** and **522**. The first end portion **520** has a hook **524** which is similar to the hook **488** shown in Figure 24. The
15 hook **524** has a hook portion **526** which lies in the same, first hook plane **492** as the hook **488** shown in Figure 24. Referring back to Figure 22, the hook **524** also has a projecting pin portion **528** which extends parallel to the longitudinal axis **519** and which projects past the end portion **520** of the member.

20 The second end portion **522** of frame member **424** has first and second hooks **530** and **532** similar to hook **524**, disposed on opposite sides of the end portion. Each of these hooks also has respective hook portions **534** and **536** lying in the first hook plane **492** (not shown in Figure 22) and has respective projecting portions **538** and **540** projecting past the end portion **522**.

25 A right angled member **542** is secured to a side of the frame member **424**. The right angled member has a projecting portion **546** which projects inwards towards the third panel portion **440**. A further hook **548** having a projecting portion **550** and a hook portion **552** is secured to the projecting portion. The projecting portion **550** extends parallel to the longitudinal axis
30 **519**, toward the window opening **434**. The hook portion **552** extends toward the third panel portion **440** and lies in the first hook plane **492** (not shown in Figure 22).

The frame member **424** has a first intermediate portion **554** which is disposed between the first and second end portions **520** and **522** and has a second intermediate portion **556** which
35 is disposed between the right angled member **542** and the second end portion **522**. The first

intermediate portion has a plurality of chair bolster hooks 558 secured thereto in spaced apart relation along the length thereof. Similarly, the second intermediate portion 556 has a second plurality of chair bolster hooks 560. Both the first and second pluralities of chair bolster hooks have hook portions disposed in the second hook plane 498 (not shown in Figure 22).

5

Frame member 428 extends between frame members 424 and 430 and has a plurality of hooks 562 having hook portions (not shown) lying in the third hook plane 517 seen best in Figure 26. In addition, referring to Figures 22 and 26, frame member 428 has a plurality of chair bolster hooks 564 which have hook portions lying in the second hook plane 498. Frame member 428 also has openings indicated at 566 and 568 for receiving the projecting pin portions 550 of adjacent frame members 424 and 430. In addition, frame members 422 and 426 have respective openings 570 for receiving the projecting pin portions 491, 528, 538, 540, 532 and 530 of frame members 420, 424, 430 and 532, respectively.

15 Figure 27

Referring to Figure 27, before the frame members are connected together, a sheet of wire mesh 572 is cut into a "U" shape corresponding to the ultimate shape of the exterior panel. A vapour barrier 574 is similarly cut to shape and is placed on top of the mesh material 572. A styrofoam slab 576 having first 578, second 580 and third 582 panel portions is laid on top of the vapour barrier 574. The first, second and third panel portions 578, 580 and 582 are similar and therefore only panel portion 578 will be described.

Panel portion 578 includes a plurality of longitudinally extending recesses 583 and cross-diagonal recesses 584 and 586, respectively. The panel portion also has longitudinal edge portions 588 and 590 which are recessed for receiving the frame members 420 and 424, respectively as will be described further below.

Panel portions 580 and 582 have a similar construction and include a plurality of longitudinally extending recesses 592 and cross diagonal recesses 594 and 596, respectively.

30

Figure 28

Referring to Figure 28, frame members 420, 422, 424, 426, 428, 430 and 432 are placed in corresponding recesses of the styrofoam slab 576. Respective projecting portions 491, 538 and 540 on each of the frame members are received in corresponding openings 570 in frame

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member 426. Frame member 428 is then installed between frame members 424 and 430, the projecting portions 550 being received in openings 566 and 568 on opposite end portions of member 428, respectively. Finally, member 422 is placed adjacent the frame members 420, 424, 430 and 432 such that the projecting portions 528 and projecting portions 491 of
5 respective frame members are received in corresponding openings 570 in frame member 422. At this point therefore, the frame is loosely connected together and lies in a flat frame plane parallel to the plane of the drawing sheet.

At this time in the fabrication process, a recess 598 is cut longitudinally into a centre portion
10 of the second panel portion 580 for receiving an electrical conduit 600 therein. The electrical conduit is connected to the frame member 426 by an electrical box 610 and is terminated in a second electrical box 612 operable to receive a standard wall socket cover. The conduit 600 is in communication with the hollow interior portion of frame member 426 and therefore electrical service conductors disposed in frame member 426 can be routed via conduit 600
15 to electrical box 612 to provide electrical service to a conventional wall receptacle (not shown) thereon.

Figure 29

Referring to Figure 29, first, second and third tension cables 614, 616 and 618 are routed in
20 longitudinal and cross diagonal recesses of respective panel portions. Separate turnbuckles 620, 622 and 624 are used to tension respective tension cables 614, 616 and 618. The tension cable 614 is routed between the hooks 530, 526, 488, 514 in the first panel portion 436 such that portions of the cable lie in the diagonal recesses and portions of the cable lie in the longitudinal and transversely extending recesses. The second and third cables 616 and
25 618 are routed in a similar manner.

Referring back to Figure 26, the portions of the tension cables in the longitudinal extending recesses 583 and 592, respectively extend in the third hook plane 517 whereas the tension cables extending in the cross-diagonal recesses 586 and 596 lie in the first hook plane 492.
30 Referring back to Figure 29, the first, second and third tension cables 614, 616 and 618 act as biasing means for biasing the frame members inwardly, generally in the frame plane, towards the interior portion of the panel.

The edge portions of the mesh material, indicated at 572 and 574 (in Figure 27) are then bent
35 over the adjacent frame members such as shown generally at 626 in Figure 29. The edge

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portions are hooked onto the chair bolster hooks **494**, **512** and **562** on adjacent frame members.

Figure 30

- 5 Referring to Figure 30, first, second and third individual rectangular pieces of flexible mesh material **628**, **630** and **632** are then cut to fit respective first, second and third portions **578**, **580** and **582** and are placed over such portions. Edge portions of respective portions of the pieces of flexible mesh material are hooked onto adjacent hook portions of chair bolster hooks on respective adjacent frame members. Referring back to Figure 26, these hook portions
- 10 such as indicated at **513** lie in the second hook plane **498** and thus the mesh material also lies in the second hook plane **498**.

- Referring back to Figure 30, a concrete retaining edge **634** is then welded to respective frame members bounding the first, second and third panel portions, respectively. A concrete mix
- 15 as described above is then poured over the mesh material **628**, **630** and **632** such that the concrete flows through the mesh and into the longitudinal and cross-diagonal recesses of each panel portion. The concrete is poured and finished flush with the concrete retaining edge **634**. The concrete thus has a finished planar surface (not shown) which is parallel to the plane of the drawing page of Figure 30. This smooth surface will ultimately face the interior
- 20 of the house.

Figure 31

- Referring to Figure 31, the panel is then turned upside down relative to its orientation depicted in Figure 30, whereupon a layer of stucco **636** is applied to the wire mesh **572**
- 25 covering the first, second and third panel portions **436**, **438** and **440**, respectively. The manufacture of the panel is thus completed.

- A window **638** may then be installed in the window opening **434**. Alternatively, the window **638** may be installed after the panels are assembled to form the house.

- 30 The finished exterior panel includes a generally rectangular portion **640** with first, second, third and fourth panel connecting portions **642**, **646**, **648** and **650**, respectively. Referring to Figure 23, the connecting portions are portions of corresponding end portions of the longitudinal frame members **420** and **432**.

35

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Figure 32

Referring to Figure 32, it may be seen that the portions of the tension cable 616 which extend in the longitudinally extending recesses 583 lie in the third plane 517, portions of the tension cable which lie in the diagonal recesses lie in the first plane 492 while the mesh 630 lies in the second plane 498. Each of the planes 492, 498 and 517 are parallel and spaced apart from each other.

In addition, the concrete has a planar portion 660 in which the mesh 630 and the diagonal portions of the tension cable 616 are disposed. Rib portions such as shown at 662 extend perpendicularly to the planar portion 660, in the longitudinally extending recesses and in the diagonally extending recesses of the styrofoam slab 576. This is similar to that described with respect to the floor panel and thus the exterior wall panel has the same advantages of the floor panel which includes the ability to withstand positive and negative loads.

Interior PanelFigure 33

Referring to Figure 33, the fabrication of an interior panel according to the invention is begun by cutting to length first, second, third and fourth panel frame members 670, 672, 674 and 676 and first, second, third and fourth door frame members 678, 680, 682 and 684.

Panel frame members 670 and 672 are similar and form longitudinal edge portions of the panel. Panel frame members 674 and 676 are similar and form transverse edge portions of the panel.

Frame members 670 and 672 have respective first and second similar end portions 686 and 688, respectively. End portion 686 is representative of each of the end portions and therefore will be described, it being understood that remaining end portions are similar.

Figure 34

Referring to Figure 34, end portion 686 has a longitudinal axis 690 extending centrally of the member. The end portion has inside and outside faces designated generally at 692 and 694, respectively. The inside face 692 is directed towards an interior of the panel portion and the outside face 694 is directed outwards from the panel and forms a portion of an outer perimeter of the panel.

Figure 35

Referring to Figure 35, the end portion also has a side one face 696 and a side two face 698. The side one face ultimately faces the interior of a first room of the house and the side two face ultimately faces the interior of a second, adjacent room of the house.

5

The end portion 686 is similar to the end portion 444 illustrated in Figures 23, 24 and 25. In this regard, referring to Figure 35, the end portion has openings 700, 702, and 703 which are similar to openings 470, 472 and 475, respectively. The end portion also has first and second threaded openings 704 and 706 which correspond to threaded openings 474 and 476 of Figure 24.

10

The end portion 686, is also similar to the end portion described in Figures 23, 24 and 25 in that it has an end plate 708 which covers the end portion 686 and which has a projecting portion 709. Face 692 has a right-angled member 710 secured thereto. The right-angled member has a connecting portion 712 and a projecting portion 714. Referring to Figure 35, the connecting portion 712 and the projecting portion 714 extend the full width of the member between faces 696 and 698. First and second hook members 716 and 718 are connected to the projecting portion 714 in parallel spaced apart relationship. First hook member 716 has a first hook portion 720 which lies in a first hook plane 722. Similarly, the second hook 718 has a hook portion 723 which lies in a second hook plane 724. In addition, hook 716 has a projecting pin portion 726, the projecting pin portion projecting in a direction parallel to the first hook plane 722. Similarly, the second hook 718 has a projecting portion 728 which is parallel to the projecting portion pin 726 and parallel to the second hook plane 724.

15

20

The frame member further includes a plurality of chair bolster hooks 730 which are disposed transversely across the frame member. The chair bolster hooks each have first and second hook portions 732 and 734, respectively. The first hook portion lies in a third hook plane 736 while the second hook portion 734 lies in a fourth hook plane 738. The first, second, third and fourth hook planes 722, 724, 736 and 738 are parallel and spaced apart relative to each other.

30

Referring back to Figure 33, frame members 676 and 674 have respective opposite end portions 740 and 742. The end portions 740 and 742 are similar and therefore only end portion 740 will be described, it being understood that end portion 742 is similar.

35

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Figure 36

Referring to Figure 36, end portion 740 has first and second openings 744 and 746 for receiving the pin portions 726 and 728 of the hooks 716 and 718 shown in Figure 35. Referring back to Figure 36, the end portion 740 further includes a plate 748 extending
5 transversely of the frame member, the plate having first and second upstanding hooks portions 750 and 752 depending therefrom.

Figure 37

Referring to Figure 37, the first and second hooks 750 and 752 have respective hook portions
10 754 and 756 which lie in third and fourth parallel spaced apart planes 758 and 760, respectively.

Referring back to Figure 36, the frame member further includes a plurality of chair bolster hooks 762 having first and second hook portions 764 and 766. The hook portion 764 lies in
15 a fifth hook plane 768 while the second hook portion lies in a sixth hook plane 770.

Figure 38

Referring to Figure 38, end portions 686 and 740 are connected together as shown generally at 772. Pin portions 726 and 728 (not shown) are received in openings 744 and 746 (not
20 shown), respectively, such that the end portion 740 rests on the projecting portion 714 of the right angled member 710. Hooks 720 and 752 are therefore disposed parallel to and adjacent to each other.

Figure 39

Referring to Figure 39, a styrofoam slab 774 is inserted within an area bounded by the frame
25 members 670, 672, 674 and 676. The styrofoam slab has a plurality of longitudinally extending recesses 776, 778, 780, 782, 784, 786 and 788, first and second cross-diagonal recesses 790 and 792 and transversely extending recesses 794 and 796. A turnbuckle 798 is connected to hook 752 on frame member 676. A resiliently extendable flexible tension cable 800 is secured to the turnbuckle and routed in recesses 786, 794, 784, 796, 782, 794, 780,
30 796, 778, 794 and 776. The cable is then routed to hook portion 720 on frame member 670 and is then routed in cross-diagonal recess 790 to the corresponding hook portion 720 on frame member 672, in a diagonally opposite corner of the panel. The cable is then routed to hook 752 on frame member 674 and is routed longitudinally of the panel in recess 788 to a corresponding hook 752 on frame member 676. The cable is then routed to hook portion
35 720 on member 672 immediately adjacent hook 752, and is routed in cross diagonal recess

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792 to hook portion 720 on member 670, in the diagonally opposite corner of the panel. Turnbuckle 798 is tightened to place the cable under tension such that the frame members 670, 672, 674 and 676 are drawn inwardly towards the interior portion of the panel. Frame members 678, 680, 682 and 684 are welded together to form a door opening 802, with
5 member 678 being welded longitudinally to frame member 672. A second insulating slab 804 is inserted between members 678, 680, 682 and 684.

Figure 40

Referring to Figure 40, a first layer of wire mesh 806 is placed between the frame members
10 670, 672, 674 and 676. Edge portions of the mesh material 806 are fastened to the first hook portions 732 of the chair bolster hooks 730 on frame members 670 and 672 and are connected to the second hook portions 766 of the chair bolster hooks 762 of members 674 and 676. The wire mesh is thus secured to the frame members. A second layer of wire mesh 808 is connected to frame members 678, 680, 682 and 684, respectively. A concrete retaining edge
15 810 is then connected to the frame members 670, 672, 674 and 676 to form an outer perimeter of the panel. Similarly, a second concrete retaining edge 810 is connected to frame members 678, 680, 682 and 684 to form a second retaining edge above the door opening 802.

Figure 41

Referring to Figure 41, a concrete mix as described above is then poured over the first and second layers of mesh material 806 and 808 and finished to form smooth surfaces indicated generally at 814 and 816, respectively. After pouring the concrete, the panel has first, second, third and fourth connecting members 818, 820, 822 and 824 corresponding to
20 respective end portions of frame members 670 and 672 (not shown), for connecting the panel to adjacent panels and to floor and ceiling panels as will be described below. In addition, these members 818 - 824 may be used for handling and lifting the panel on the job site.

The panel is then turned upside-down relative to its orientation shown in Figure 41 whereupon the side two portion of the panel is completed in a manner similar to the side one
30 portion. Effectively therefore, the steps discussed above in forming the side one portion are repeated in forming the side two portion.

Figure 42

Referring to Figure 42, a cross-section of a completed interior panel according to the
35 invention is shown generally at 826. The finished panel thus includes wire mesh 806 on a

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side one portion 828 of the panel and includes a further wire mesh 830 adjacent a side two portion 832 of the panel. The mesh 806 lies in the sixth plane 770 while the mesh portion 830 lies in the fifth plane 768. As stated earlier, the fifth and sixth planes 768 and 770 are parallel and spaced apart from each other and therefore the wire mesh portions 806 and 830 are also parallel and spaced apart.

The concrete poured on each side of the panel includes respective planar portions 834 and 835 and respective rib portions 836 and 837, the rib portions being formed by concrete flowing into the recessed portions such as shown at 778, of the styrofoam slab 774. The planar portions 834 and 835 extend about the mesh material 806 and 830, respectively. In addition, the planar portions extend about diagonally extending portions 838 and 840 of the flexible cable associated with the side one portion 828 and the planar portion of the concrete on the side two portion 832 extends about the diagonal portion 840 of the flexible cable on the side two portion 832. Similarly, the rib portions 836 extend about longitudinally extending portions of the flexible cable indicated at 842 for the side one portion 828 and 846 for the side two portion 832. It should be apparent that the diagonal portions of the cable 838 lie in the second plane 724 while the longitudinally extending portions and transversely extending portions of the cable 842 lie in the fourth plane 760. The second plane and the fourth plane 724 and 760 are parallel to and spaced apart from each other.

By routing the flexible cable in the manner described i.e. using diagonal portions and longitudinally and transverse portions in spaced apart planes, the panel is rendered with the ability to withstand positive and negative dynamic loading.

25 Roof Panel

Figure 43

Referring to Figure 43, the fabrication of a roof panel according to the invention is begun by cutting to length first, second, third, fourth and fifth panel frame members 850, 852, 853, 854 and 856. Frame members 850 and 852 are similar and frame members 854 and 856 are similar. All frame members are formed from steel tubing but may be formed from generally any alloy operable to withstand any desired loading.

Frame member 850 has a first end portion 860 and a second end portion 862. The frame member also has a main roof portion illustrated generally at 864 and an overhang portion illustrated generally at 866. The main roof portion 864 and overhang portion 866 are

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separated by a connecting portion 868. The main roof portion has a plurality of hooks 870 for securing a tensioned resiliently flexible cable to the frame member and has a plurality of chair bolster hooks 872 for securing wire mesh as will be described below. The overhang portion also has a plurality of tension cable hooks 874 and chair bolster hooks 876 for similar purposes. As frame member 852 is similar to frame member 850, frame member 852 also includes similar chair bolster hooks and main roof portions, connecting portions and overhang portions and therefore these components are labelled with the same numbers as corresponding components on member 850.

10 Frame member 854 also has first and second opposite end portions 878 and 880 and has an intermediate portion shown generally at 882 having a plurality of chair bolster hooks 884. Frame member 856 is similar to frame member 854 and has similar components. Similar components are labelled with the same numerical reference numbers as those indicated on frame member 854. Frame member 858 also has first and second opposite end portions 886
15 and 888 and has an intermediate portion 890 with a roof side 892 and an overhang side 894. The roof side 892 has a plurality of chair bolster hooks 896 mounted thereon and the overhang side has a plurality of chair bolster hooks 898 mounted thereon.

Figures 44 and 45

20 Referring to Figures 44 and 45, end portion 860 of frame member 850 is shown. Referring to Figure 44, frame member 850 has an outside face 900 and an inside face 902. Referring to Figure 45, the frame member has a roof side 904 and a ceiling side 906. The end portion 860 is cut at an angle 908 which determines the slope of the roof relative to the vertical. The end portion 860 includes an end plate 912 which is fastened by welding to a cut face 910 of
25 the longitudinal member 850. The end plate 912 extends flush with the roof side 904 and has a connecting portion 914 which extends past the ceiling side 906. The connecting portion 914 has an opening 916 for receiving a connector such as a bolt therethrough.

The end portion further includes a flat horizontal plate 918 having an extending portion 920
30 and a flat connecting portion 922. The flat connecting portion 922 is secured to the outside face 900 of the end portion 860. The flat plate has an axis 924 which extends at right angles to the plate 912. A connecting plate 926 is further connected to the extending portion 920 and the plate 912 such that it is disposed at right angles to both the extending portion 920 and the plate 912. The connecting plate has an opening 928 extending therethrough for receiving
35 a connector such as a bolt therethrough.

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The end portion further includes a hook plate 930 secured to the inside face 902. A hook 932 having a hook portion 934 disposed in a first hook plane 936 is secured to the plate 930. The plate 930 is disposed immediately adjacent a chair bolster hook 872. The hook 932 corresponds to hook 870 illustrated in Figure 43.

5

The end portion further includes a pair of laterally spaced apart openings in the face 902, the openings being designated 938 and 940, respectively. Opening 938 is disposed adjacent ceiling side 906 while opening 940 is disposed adjacent roof side 904.

10 Figures 46 and 47

Referring to Figures 46 and 47, the connecting portion 868 is shown in greater detail. The connecting portion 868 includes an open space 942 disposed between the pluralities of chair bolster hooks on the roof portion 864 and the overhang portion 868. The open space includes transversely and longitudinally spaced apart openings 944, 946, 948 and 950 for receiving
15 pins on the end portion 886 of frame member 858 shown in Figure 43. Referring back to Figure 47, immediately adjacent the openings 944 and 950, adjacent the ceiling side 906, a plate 952 is secured to the ceiling side 906. An angularly extending portion 954 is connected to the plate 952. The angularly extending portion 954 includes a portion of 4" X 4" steel tubing. The extending portion 954 extends at an angle 956 which is the same as angle 908
20 of Figure 45. The extending portion 954 has an end plate 958 secured thereto for covering the end portion of the extending portion 954. The extending portion 954 further includes first and second threaded openings 960 and 962 for receiving fasteners therethrough.

Figure 48 and 49

25 Referring to Figures 48 and 49, end portion 878 of Frame member 854 is shown in greater detail. The end portion includes a roof surface designated 964, an inner surface 966, an outer surface 968 and a ceiling surface 970. Referring to Figure 49, the end portion 878 has a transversely extending angle member 972 having a connecting portion 974 and a projecting portion 976, the projecting portion 976 projecting at right angles to the inner surface 966.
30 A pin 978 is secured to the projecting portion 976 adjacent the roof surface 964. A hook 980 having a pin portion 982 and a hook portion 984 is also connected to the projecting portion 976 in parallel spaced apart relation to the pin 978. Both the pin 978 and the pin portion 982 extend parallel to a longitudinal axis 986 of the member 854. In connecting the panel together, pin 978 and pin portion 982 are received in openings 940 and 938, respectively,
35 shown in Figure 45.

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Figure 50

Referring to Figure 50, a sheet of wire mesh material 988 is laid flat and cut to the approximate size of a finished roof panel. A membrane such as tar paper 990 is also cut to size and laid upon the wire mesh 988. A first styrofoam slab 992 having a roof portion 994 and an overhang portion 996 is laid upon the tar paper 990. The styrofoam slab has longitudinal recesses 998 and 1000 extending along edges thereof and has a plurality of transversely extending recesses 1002, 1004, 1006, 1008, 1010, 1012 and 1014. In addition, the styrofoam slab has first and second cross diagonally extending recesses 1016 and 1018 and has third and fourth cross diagonal recesses 1020 and 1022. The cross diagonal recesses 1018 and 1016 extend between diagonally opposite corners of the roof portion 994. The cross diagonal recesses 1020 and 1022 extend between diagonally opposite corners of the overhang portion 996.

The styrofoam slab 992 further has frame holding recesses (not shown) in which frame members 850, 852, 854, 856 and 858 are received. When the frame members are placed into the recesses, the pin 978 and pin portion 982 depicted in Figure 49 are received in openings 940 and 938 depicted in Figure 45. Similarly, projecting pins on frame member 858 in Figure 50 are received in openings 944, 946, 948 and 950, respectively in Figure 47 and projecting pins on frame member 856 are received in corresponding openings (not shown) in end portion 862.

Figure 51

Referring to Figure 51, a turnbuckle 1024 is connected to one of the hooks 870. A resiliently extendible flexible tension cable 1026 is secured to the turnbuckle 1024 and is routed between hooks 870 on frame member 850 and 852 such that the cable has a plurality of portions lying in the first and second longitudinally extending recesses and in each of the transversely extending recesses. In addition, the cable has portions 1030 and 1032 extending in the cross diagonal recesses 1016 and 1018.

Similarly, the overhang portion has a turnbuckle 1034 connected to a hook 872 and a resiliently extendible flexible cable 1036 is fastened to the turnbuckle 1034. The cable 1036 is routed between hooks 872 and 874 on frame members 852 and 850, respectively such that the cable has portions 1038 which lie in the transversely extending and longitudinally extending recesses and has portions 1040 and 1042 which lie in the cross diagonally extending recesses 1020 and 1022, respectively.

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Upon fastening the cables, edge portions of the tar paper 990 and wire mesh material 988 are bent over respective adjacent frame members 854, 856, 850 and 852.

Figure 52

- 5 Referring to Figure 52, the panel further includes first and second portions of mesh material portions 1044 and 1046, respectively. The first portion 1044 is cut to fit between respective chair bolster hooks 872 on frame members 850 and 852 and between chair bolster hooks 884 and 896 on frame members 854 and 858. The second layer of mesh material 1046 is cut to extend between chair bolster hooks 876 on the overhang portion 866 of frame member 850 and 852. In addition, the second wire mesh extends between chair bolster hooks 898 and 884 on frame members 858 and 856, respectively. A concrete retaining edge 1048 extending the entire perimeter of the panel comprising both the roof portion and the overhang portion is then secured to respective perimeter frame members 854, 856, 850 and 852.
- 10
- 15 A concrete mix as described above is then poured over the mesh material portions 1044 and 1046 such that the concrete flows through the mesh material portion 1044 into the transversely, longitudinally, and cross diagonally extending recesses in the roof and overhang portions of the styrofoam slab. The ceiling side of the roof panel is thus completed.
- 20 The panel is then turned upside-down relative to its orientation depicted in Figure 52 and concrete is poured over the wire mesh (999 not shown) to form a roof surface (not shown).

Figure 53

- 25 Referring to Figure 53, a portion of the roof panel is shown in cross-section and includes a ceiling side 1050 and a roof side 1052. The ceiling side includes the concrete which has a planar portion 1056 which extends the entire width and length of the panel and has a rib portion 1054 which extends perpendicularly to the planar portion in recess 1002. The remaining recesses in the styrofoam slab also have similar rib portions. The mesh material portion 1044 is disposed within a first plane 1058 while the cross diagonally extending portions of the flexible cable are disposed in a second plane 1060. The longitudinally and transversely extending portions of the cable 1026 lie in a third plane 1062. The first, second and third planes are parallel and spaced apart from each other. The cable 1026 lying in the third plane 1062 is thus spaced apart from the cable portion 1032 lying in the second plane
- 30
- 35 1060. This provides positive and negative reinforcement of the panel. The exterior mesh 999

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lies in a fourth plane **1064**. Concrete, such as shown at **1066**, forms a roof surface of the panel and is embedded within minor exterior recesses **1068** formed in the styrofoam slab **992**.

Figure 54

5 Referring to Figure **54**, a finished panel according to the invention is shown generally at **1070**. The finished panel includes a ceiling surface **1072**, first and second peak connecting portions **1074** and **1076**, first and second wall connecting portions **1078** and **1080** and first and second gutter connecting portions **1082** and **1084**. The first and second peak connecting portions **1074** and **1076** connect the panel to an adjacent panel to form a peak of the roof of
10 the house. The second peak connecting portions **1074** and **1076** correspond to the end portion **860** of frame members **850** and **852**. Similarly, the wall connecting portions **1078** and **1080** correspond to the connecting portions depicted in Figures **46** and **47** and shown at **868** in Figure **43**.

15 Connecting Panels Together

Referring back to Figure **21**, two exterior panels such as shown in Figure **31** are shown generally at **406** and **408**. The third and fourth projecting portions **646** and **648** of panel **406** project downwardly for engagement with flanges **382** and **380**, respectively. The third and fourth projecting portions of panel **408** project downwardly for engagement with flanges **172**.

20 To facilitate connection of the exterior panels to the flanges, W-shaped and T-shaped connectors shown at **1090** and **1092**, respectively are used. The W-shaped connectors **1090** are used in corners formed by abutting exterior panels while the T-shaped connectors **1092** are used to connect aligned, adjacent exterior panels.

25 The W-shaped connectors include first and second flat portions **1094** and **1096** and a W-shaped wall portion shown generally at **1098**. The flat portions **1094** and **1096** have respective conduit openings **1100** and **1102** and have respective threaded openings **1104** and **1106**. The wall portions have openings **1108** and **1110**, respectively.

30 Similarly, the T-shaped connector has first and second flat portions **1112** and **1114** and an upstanding wall portion **1116** with the characteristic T-shape. Each of the flat portions has respective conduit openings **1118** and **1120** and has respective connecting openings **1122** and **1124**. In addition, the wall portion **1116** has first and second openings **1126** and **1128**
35 adjacent the first and second flat portions **1112** and **1114**, respectively.

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The exterior panels are connected to the floor panel 370 by first connecting the W-shaped connector and T-shaped connectors to corners and side portions, respectively. The panels 406 and 408 are placed in position whereupon the connecting portions 646 and 648 of panel 406 are placed upon the flat portions 1114 and 1094, respectively. Similarly, the connecting portions 646 and 648 of panel 408 are placed upon the flat portions 1096 and 1112, respectively.

Referring specifically to panel 408, the openings 474 in the connecting portions 646 align with openings 1110 and 1126, respectively. As the openings 474 are threaded, a bolt may simply be inserted through opening 1110 and a second bolt can be inserted through opening 1126 and threadedly engaged with openings 474 on opposite end portions of the panel respectively. The panel is thus secured to the W-shaped and T-shaped connectors.

In the case of the corner, the upstanding plate 168 of the floor panel 370 has an opening 182 which engages with a corresponding opening (476 not shown in Figure 21) on an opposite side of the connecting portion 646 of the panel 408. A bolt is received through the opening 182 and is threadedly engaged with the opening (476) on the opposite side of the connecting portion 646. The opposite end portion of panel 408 is secured to corner 171 in a similar manner. Panel 406 is secured to the corners 177 and 173 in a similar manner. The exterior panels are thus connected to the floor panels and foundation.

Connection of Interior Panels

The interior panels are connected to the floor panels in a manner similar to the way in which the exterior panels are connected. The interior panels, shown best in Figure 41, have respective downwardly projecting connecting portions 820 and 824. Each of the downwardly projecting connecting portions 820 and 824 has a respective threaded opening 704. A corresponding opening 706 (not shown) is available on an opposite side of the projecting portions as shown in Figure 35.

Referring back to Figure 21, to install the interior panels, the projecting portions 820 and 824 are placed in receptacles 1130 and 1132 formed between respective plates 168 of adjacent floor panels. Each of the plates has a respective opening 182 which is aligned with the opening 704 (and 706) when the interior panel is properly in place. A threaded fastener such as a bolt may be inserted through the openings 182 and threadedly engaged with openings 704

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and 706, respectively to secure the interior panel to the floor panels. A similar procedure is performed to secure other interior panels to the floor panels.

It will be appreciated that the downward projecting connecting portions 820 and 824 have
5 openings shown best in Figure 34 at 700, 702 and 703 for routing conduits from the foundation members to the individual interior panels.

Referring back to Figure 1, with the interior and exterior panels fastened to the floor and foundation members, a first storey 1139 of the house is completed. Additional exterior and
10 interior panels may be secured to the panels forming the first storey in order to form a second storey 1141 of the house.

Referring to Figures 31 and 41, both the exterior panel shown in Figure 31 and the interior panel shown in Figure 41 have upwardly projecting panel connecting portions. With regard
15 to the exterior panel in Figure 31, the connecting portions are shown at 642 and 650, respectively. With regard to the interior panel shown in Figure 41, the connecting portions are shown at 818 and 822, respectively.

The connecting portions 642, 650, 818 and 822 of Figures 31 and 41, respectively, are
20 similar to the vertically extending duct portions 66 and 76 shown in Figure 3. Thus, a floor panel member will act as a ceiling to a room on the first floor of the house and will act as a floor of a second floor of the house. Such a floor panel member is installed on the connecting members similar to the manner in which the floor panel 370 was installed on the foundation members as depicted in Figure 21. Referring to Figure 1, a second plurality of
25 pre-fabricated exterior wall panels 28 are thus installed upon the panels of the first storey 1139.

Figure 55

Referring to Figure 55, the second plurality of pre-fabricated exterior and interior panels 28
30 and 30 forms an arrangement of connecting portions 642, 650, 818, the arrangement being similar to the upstanding flanges 70, 72, 124 shown in Figure 3. Additional panels similar to the first and second pluralities of interior and exterior panels may be secured to these upstanding connecting portions 642, 650, 818 and 822 to create a house or structure having any number of storeys. In a preferred embodiment however, the house includes first and

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second storeys only and therefore the plurality of roof panels is installed above the second storey panels 28.

With the second plurality of second storey exterior panels 28 in place, the third floor panel 32 is secured to the upstanding connecting portions 642, 650, 818 and 822, respectively. The third floor panel 32 acts as a ceiling for a room enclosed by the exterior panels 28 and the interior panels 30. The third floor 32 however, has an upper surface 1140 which acts as a floor surface of an attic portion of the house.

An attic panel 1142, similar in construction to the interior panel described in Figures 33 through 41 has connecting portions 1144, 1146, 1148 and 1150. These connecting portions are similar to connecting portions 818, 820, 822 and 824 shown in Figure 41. The attic panel 1142 has the same longitudinal dimension as the interior panel of Figure 41, however, the attic panel 1142 has approximately one-half the vertical dimension of the interior panel shown in Figure 41. The roof panel 1070 shown in Figure 54 is then installed with second peak connecting portions 1074 and 1076 (not shown) connected to connecting portions 1144 and 1148 and with connecting portions 1078 and 1080 (not shown) being connected to the connecting portions 650 and 642 of the second storey exterior panel 28.

20 Figure 56

Referring to Figure 56, the connecting portion 1144 has first, second and third threaded openings 1152, 1154 and 1156, respectively. To install roof panels 1070 and 1158, the plate connecting portions 914 are abutted against opposite sides 1160 and 1162. In this position, the connecting plates 926 of respective roof panels 1070 and 1158 are received on top of the connecting portion 1144, such that openings 928 in the respective flange portions are aligned. This enables a bolt 1164 to be inserted through the openings 928 and secured in the threaded opening 1156. In addition, openings 916 in plate connecting portions 914 are aligned with the first and second threaded openings 1152 and 1154, respectively which enables first and second bolts 1166 and 1168 to be threadably engaged with the threaded openings 1152 and 1154 to secure the roof panels in place.

Figure 57

Referring to Figure 57, to install the connecting portion 1078 of roof panel 38, a T-shaped connector 1170 having a horizontal portion 1172 and first and second vertical portions 1174 and 1176 is placed on top of the flange 172 of the third floor panel 32. The horizontal

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portion 1172 rests on the flange portion 172 and plate 958 of the extending portion 954 rests upon the horizontal portion 1172. With the T-shaped connector 1170 and the extending portion 954 and the floor panel 32 disposed as shown in Figure 7, opening 962 is aligned with opening 182 in the plate 168 of the floor panel 32 and therefore a bolt 1178 may be
5 inserted through the opening 182 to threadedly engage with the threaded opening 962. Similarly, first and second openings 1180 and 1182 are disposed in the first and second vertical portions 1174 and 1176 of the T-shaped member 1170. Opening 1180 is in alignment with threaded opening 960 in the extending portion 954 and therefore is operable to receive a bolt 1184 therethrough to threadedly engage the bolt with the threaded opening 960 to
10 secure the extending portion 954 to the T-shaped connector 1170. Similarly, opening 1182 is in axial alignment with threaded opening 1186 in the connecting portion 642 of panel 28.

In addition, opening 182 in the plate 168 is axially aligned with a threaded opening 1188 on
15 an inside portion of the connecting portion 642 and thus a bolt 1190 may be inserted through the opening 182 to threadedly engage with the threaded opening 1188 to secure the third floor panel to the connecting portion 642. The roof panel 32 is thus secured to the third floor panel 32 and the connecting portion 642. Other roof panels are secured in a similar manner.

20 Referring back to Figure 1, the house 10 is formed by assembly of a plurality of panels. It will be appreciated that small gaps 1196 exist between adjacent panels and thus continuous wall portions extending an entire side or end of the house are eliminated. Rather, the sides and ends of the house are formed from a plurality of discrete panel portions connected together. This permits the panels to move slightly relative to each other which, in effect,
25 permits portions of the wall formed by the discrete panels to move relative to each other. As there is no one continuous wall, such movement is less likely to permit the formation of cracks in the surfaces of the wall and thus the structural integrity of the wall and appearance of the wall is maintained. There are, however, small gaps 1196 which, at the time of assembly, are filled with a fire-proof elastic sealant such as silicone with ceramic thread or
30 with expandable elastic foam which permits the panels to move relative to each other while maintaining an air tight seal in the gaps.

Co-operation of the assembled panels

A structure according to the invention disclosed herein is particularly well adapted to
35 withstand moments created by seismic forces or shell-blast forces. Referring back to Figure

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2, it will be appreciated that the foundation of the house is formed from a plurality of foundation members connected together. This renders the foundation ductile which serves to absorb moments, imposed at one location on the foundation, in a plurality of locations on the foundation. The joints between adjacent foundation members serve to absorb such moments. This is an advantage over conventional one-piece rigid, continuous foundation designs wherein a moment applied to, say, one corner of such a foundation may cause the foundation to crack due to its inability to absorb such moments.

Referring back to Figure 1, it will be appreciated that as each panel member has a solid frame member forming an outer perimeter of each panel, when the panels are connected together as explained above, the connected frame members form a three-dimensional, ductile, space frame. As the space frame is comprised of essentially the frame members bolted together, the members of the space frame are not rigidly connected together, but rather, provide some ductility and thus provide for some absorption of moments and forces transmitted to the space frame, such as from seismic forces or shell-blast forces travelling in the ground, through the foundation to the space frame or from shell-fire adjacent the building.

Thus, the panels are able to move slightly, relative to each other to absorb such forces. Thus the panels act elastically relative to each other. It will be appreciated that the horizontal portions of each of the wall panels are essentially connected to the vertical portions of the wall panels by pins which permit vertical movement of the horizontal frame members relative to the vertical members. In addition, as the tension cables in each panel are used to bias the frame members inwards towards an interior portion of each panel, the tension cables are operable to extend or contract slightly in the event of positive or negative loading on the panels and thus forces exerted on the panels and the frame members can be further absorbed in the resiliency of the tension cable. This is particularly provided by the use of diagonally extending tension cables in a plane parallel to and spaced apart from the transversely and longitudinally extending portions of the tension cables.

Seismic forces exerted on the foundation are absorbed by the joints in the foundation. Residual moments and forces are transmitted to the panels connected to the foundation and hence to the space frame structure formed by the connected panels. Further residual forces are transmitted to the structure in each panel, specifically, the mesh, the cables and concrete thereof. The mesh and cables are resilient and act to absorb most of the residual forces and moments. Thus, the magnitude of forces and moments finally reaching the concrete forming

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the panel is minimized, which reduces the risk of creating cracks in the concrete panel portions. The floor, wall and ceiling surfaces of the house thus remain virtually crack free, even after seismic activity or nearby shell-fire.

- 5 In addition, the invention presents a structure which is dynamically stable in various wind conditions. As the structure is comprised of a plurality of panels, the surface area over which the wind effects can act is reduced, relative to a unitary wall of a conventional house structure. Each panel itself can withstand both tension and compression and hence can absorb inwardly directed forces (positive loading) and outwardly directed forces (negative loading).

10

For example, an inward force in direction of arrow 1192 exerts positive loading on an exterior wall panel. A central portion of the panel, indicated generally at 1194, is permitted to move slightly inwards thereby stretching the tension cables on both the side one and side two portions of the panel, the tension cables resiliently resisting such stretching and absorbing
15 the force accordingly. A force applied in a direction opposite to arrow 1192 represents negative loading and is absorbed in a similar manner, with the central portion of the panel moving slightly outwards to absorb the force, and then returning to its original position.

The above panels, foundation members and connectors permit a three-dimensional building
20 structure such as the house shown in Figure 1 to be quickly and efficiently erected. As the panels are pre-fabricated, the entire manufacturing process of the panels can be completed in the factory. In particular, the aggregates used in forming the concrete can be selected and controlled to ensure uniformity, the concrete can be cured under controlled conditions, and can be ground, painted, baked or any other architectural finish can be applied.

25

In addition structural steel components can be precisely cut and formed using computer control techniques. Furthermore, the job-site on which the structure is being erected need only be provided with the necessary bolts and wrenches to fasten the panels together, a crane for lifting the panels into place, and a cutting torch for selectively cutting any undesired
30 protruding connecting portions of panels. Furthermore, the panels are sufficiently robust that they may be shipped easily in a specially designed shipping container having conventional shipping container dimensions. Thus, the prefabricated panels are easily transported from the factory to the job-site.

35

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Other uses for the panelsHi-rise StructureFigure 58

Referring to Figure 58, a further use of the panels according to the invention is realized in
5 co-operation with the conventional hi-rise office or apartment building structure. A
conventional hi-rise structure typically includes a plurality of vertical columns 1200 arranged
in a rectangular array when viewed from above and a plurality of horizontal cross members
1202 arranged in a plurality of horizontally spaced apart planes 1204, 1206, 1208, 1210,
1212, 1214 along the vertical columns.

10

The vertical columns 1200 and horizontal cross members 1202 form the main structural
components of the hi-rise and are conventional in design. By dimensioning the cross
members for structural integrity and by suitable spacing of the planes, exterior 1216, interior
1218, and floor 1220 panels according to the invention can be connected together to form a
15 module 1222, say, three storeys high, three units wide and four units long where each unit
is an individual apartment or office.

The hi-rise can thus be built in a modular form, eliminating the pouring of each concrete
floor of the hi-rise as is conventionally done.

20

Individual outer, or boundary panels, which lie adjacent the vertical columns or cross
members are connected, using the connecting means associated with each panel, to respective
adjacent vertical and horizontal members 1200 and 1202 such that a space frame is formed
by the frame members of each panel and by the vertical and horizontal members of the hi-
rise. A relatively large, unitary space frame is thus formed, the space frame defining an
25 array of tenantable units between the spaced apart vertical planes. The projecting portions
extending from the panels in a direction parallel to the edge portion of the panel act as the
connecting means and are operable to deform elastically under seismic forces, the space frame
having all of the benefits described earlier, including the ability to absorb moments and forces
30 created by seismic activity or shell- fire. In addition, all of the benefits of the panels
including the ability to absorb residual moments without cracking the concrete surface and
the ability to withstand and distribute wind loading forces are obtained in the hi-rise.

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Shipping ContainerFigure 59

Referring to Figure 59, transportation of the panels forming a house can be easily accomplished by connecting floor panels of the house together to form a 16'X 8'X 9' shipping container as shown at 1230, with panels and other components of the house shown in broken outline, inside the container. The floor panels are connected together to form eight container corners, only seven of which are shown at 1232, 1234, 1236, 1238, 1240, 1242 and 1244, and four mid-portion connectors, only three of which are shown at 1248, 1250 and 1252.

10

Figures 60a-h

Referring to Figures 60a and 60b, mid-portion connector 1248 is illustrated. First and second floor panels 1256 and 1258 are shown butted together end to end, in a horizontal plane. Similarly, third and fourth floor panels 1260 and 1262 are butted together end to end in a vertical plane. Plate portions 1264 and 1266 of the first and second floor panels 1256 and 1258 are bent at respective right angles to lie flat against respective undersides of the first and second floor panels. This allows respective edges 1268 and 1270 of the third and fourth panels to lie immediately adjacent the undersides of the first and second floor panels, respectively. In this configuration, respective flanges 1272 and 1274 and parallel members 1276 and 1278 abut with a relatively large top gap 1280 being formed between end edges 1282 and 1284 of the first and second floor panels, respectively. Opposite portions 1286 and 1288 of the plate portions are left to project vertically upward.

Similarly, parallel members 1290 and 1292 and flanges 1294 and 1296 on the third and fourth panels 1260 and 1262 abut, leaving a side gap 1298 and plate portions 1300 and 1302 projecting horizontally outward from the panels.

Referring to Figure 60c, a top, middle wooden member 1304 is pre-notched to rest on the flanges (1272 and 1274 of Figure 60a and Figure 60b) such that a top surface 1306 thereof is approximately flush with the adjacent outer surfaces 1308 and 1310 of the first and second floor panels 1256 and 1258 and such that an end surface 1312 thereof is approximately flush with the parallel members 1276 and 1278. The plate portions 1286 and 1288 are then bent at right angles to overlap and secure the wooden member 1304 in the top gap.

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A similar procedure is followed with a side middle wooden member **1314** such that an outer surface **1316** thereof is approximately flush with adjacent outer surfaces **1318** and **1320** of the third and fourth panels **1260** and **1262**. The plate portions **1300** and **1302** are then bent at right angles to overlap and secure the side middle wooden member inside the side gap.

5

Referring to Figure **60d**, first and second plate portions **1322** and **1324** are secured across the top and side gaps, to the first and second floor panels **1256** and **1258** and to the third and fourth floor panels **1260** and **1262** respectively. Preferably, pre-threaded openings (not shown) are provided in the respective portions of the first and second floor panels, respectively, to receive bolts **1326** for securing plate portion **1322** to floor panels **1256** and **1258** and for securing plate portion **1324** to floor panels **1260** and **1262**. The plates rigidly secure the floor panels together.

Referring to Figures **60e** and **60f**, the first container corner is shown generally at **1232**. The corner is formed by the first and third panels **1256** and **1262** which are 8' X 16' floor panels. These panels are connected to a fifth floor panel **1328** having a square shape and measuring 8' X 8'. The fifth floor panel acts as an end portion of the container. A first plate portion **1330** of the first panel is bent parallel to the underside of the floor panel to permit an edge **1332** of the third panel **1262** to lie closely adjacent to the underside of the first floor panel **1256**. A second plate portion **1334** is left upstanding.

Similarly, a first plate portion of the third panel **1262** is bent as shown generally at **1336**, in broken outline. The first plate portion is bent to extend parallel to an inside surface of the third panel **1262**, while a second plate portion **1338** of the third panel **1262** is permitted to extend outwardly. In this configuration, respective parallel members **1340** and **1342** and respective flange members **1344** and **1346** are spaced apart and do not interfere with each other.

The fifth floor panel **1328** has first and second plate portions, the first plate portion being shown in broken outline at **1348** in Figure **60e** and the second plate portion being shown in solid outline at **1350** in Figures **60e** and **60f**. The first plate portion **1348** extends under the first panel **1256** while the second plate portion **1350** extends outwardly. The panel also has a parallel member **1352** and a flange member **1354** which project vertically upwardly relative to an edge **1356** of the panel **1328**. Thus, a top edge gap **1358** and a side edge gap **1360** are

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formed at respective interfaces of the first and fifth panels **1256** and **1328** and the third and fifth panels **1262** and **1328**.

Referring to Figure **60g**, the top edge gap is filled by a wooden top edge member **1362** suitably notched to accommodate the parallel and flange members (**1340**, **1344** and **1352**, **1354** of Figures **60e** and **60f**) of the first and fifth panels, respectively. This permits first and second sides **1364** and **1366** of the top wooden member **1362** to lie flush with respective surfaces **1308** and **1368** of the first and fifth panels and permits an end face **1370** thereof to lie flush with the edge surface **1372** of the first panel **1256**. The second plate portions **1334** and **1350** are then bent over the wooden member **1362** to secure it in place.

Similarly, a wooden side edge member **1374** is suitably notched (not shown) to accommodate the parallel and flange members **1342** and **1346** shown in Figure **60f**, such that first and second side surfaces **1376** and **1378** thereof lie generally flush with adjacent surfaces **1380** and **1382** respectively when placed in the edge gap **1360** shown in Figure **60e**. Referring back to Figure **60g**, the second plate portion **1338** is bent over the wooden side edge member **1374** to secure it in position.

Referring to Figure **60h**, a corner connector is shown generally at **1384**. The corner connector is installed over the corner portion of the container after preparing the corner portion as shown in Figure **60g**. The corner connector includes a first right angled member **1386** and a top plate member **1388** to which is welded a crane adapter **1390**. The first right angled member **1386** has first and second portions designated at **1392** and **1394** respectively. The first and second portions **1392** and **1394** are oriented at right angles to each other such that the first portion **1392** is operable to extend parallel to surface **1366** while the second portion is operable to extend parallel to surface **1372**. The first and second members are secured to their respective adjacent surfaces by lag bolts **1400** extending into the nearby wooden member and by carriage bolts **1402** threaded into preformed threaded openings (not shown) in the edge surface **1372** and into preformed threaded openings in the fifth panel **1328** and in the third panel **1262**.

The top plate member **1388** has first and second portions **1404** and **1406** which rest on the wooden surface **1364** and on panel surface **1310**, respectively. The first portion **1404** is secured to the wooden surface **1364** by lag bolts **1408** while the second portion is secured to the first panel by carriage bolts **1410** cooperating with threaded openings (not shown) in a

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frame members (such as 1412 shown in broken outline) of the panel 1256. The right angled crane adapter 1390 has portions extending parallel to the surfaces 1366, 1310 and edge surface 1372 and allows a conventional container lifting crane found in most shipping ports to engage the corner.

5

Referring back to Figure 59 it will be appreciated that the remaining container corners 1234, 1236, 1238, 1240, 1242 and 1244 (and the one not shown) are formed in the same manner as described above with respect to corner 1232. Similarly, the remaining mid-portion connectors 1250, 1252 (and the one not shown) are formed as described above with respect to mid-portion connector 1248. Thus, the floor panels of the house are effectively connected together to form a shipping container capable of holding all of the components necessary to build the house. The floor panels which are used to form the container are also used in building the house, after straightening or cutting off the bent plate portions 1264, 1266, 1286, 1288, 1300 and 1302 in Figure 60c and 1334, 1336, 1338 and 1350 in Figure 60e.

15

Referring back to Figure 59, The container thus forms an open "box" into which the various other panels and components necessary to form the house are placed as indicated by the following list of components:

20

Floors

2001. floor, underside of container

2002. floor c/w plumbing connections, underside of container

2003. floor, topside of container

2004. floor, topside of container

25

1256. floor, side of container

1258. patio, side of container

1260. patio, side of container

1262. front porch, side of container

1328. deck, end of container

30

2010. deck, end of container

Exterior Walls

2011. back left corner c/w window

2012. back left c/w glass doors

35

2013. back centre

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2014. back right c/w window
2015. back right corner c/w window
2016. front left corner c/w window
2017. front left c/w window
- 5 2018. front centre c/w frosted window and door
2019. front right c/w window
2020. front right corner c/w window
2021. left back c/w window
2022. left centre c/w window
- 10 2023. left front c/w window
2024. right back c/w glass doors
2025. right centre c/w window
2026. right front c/w window

- 15 Roof
2027. gable end left back
2028. middle left
2029. gable end left front
2030. gable end right back
- 20 2031. middle right
2032. gable and right front

Interior Walls and Partitions

2033. full height wall
- 25 2034. 8' high wall c/w door
2035. wall above 2034. & 2101.
2036. full height wall
2037. full height wall c/w door
2038. full height wall
- 30 2039. 8' high partition c/w door
2040. (a & b) partition above 2101.
2041. full height wall
2042. full height wall
2043. (a & b) partition above 2101.
- 35 2044. 8' high partition c/w closet doors

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- 2044. t. top of closet
- 2045. 8' high partition c/w closet doors
- 2045. t. top of closet

5 Cabinets and Equipment

- 2100. Kitchen Unit
- 2101. Bathroom Unit
- 2102. Refrigerator/Freezer
- 2103. Washer Dryer
- 10 2104. Hot Water Heater

The container thus contains all of the components required to build the house. The crane adapters **1390** on each corner permit the container to be handled using conventional container handling equipment as commonly found on the docks of major shipping ports and therefore
 15 act as means for cooperating with a handling crane for lifting the container. As the containers themselves are formed from panels comprising a steel frame and concrete interior portions, a plurality of containers may be stacked, one upon the other, on the deck or in the shipping hold of an ocean going vessel without fear of damaging the containers due to listing of the vessel during a voyage. Typically, the foundation members for the house are shipped
 20 separately or manufactured near the job site on which the house is to be installed.

Figures 61 and 62

When a container as shown in Figure **59** is received on a job site, the components inside the container and the panels forming the container are assembled to form a house according to
 25 the invention. In the embodiment disclosed herein, the house provides more than **800** square feet of living space using **6** inch floor panels, **4.75** inch exterior wall panels, **7** inch roof panels, **3** inch interior wall panels and **2** inch interior partitions.

Assuming the foundation members have already been shipped and installed on site, the house
 30 is assembled as described above. As best seen in the plan view of Figure **61**, the floor, sides, ends and top (**2001-2010**) of the shipping container form the floor (**2001-2005**), patio (**2006** and **2007**), front porch (**2008**) and deck (**2009**) of the house while the components which were inside the container form the house itself. The invention thus provides a shipping container capable of holding all components necessary to build a house with the components of the
 35 container itself also forming components of the house in the final assembly thereof. Thus,

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efficient use of materials and space is provided while at the same time providing a convenient, strong shipping container for the house components.

The projecting portions on each panel act as connecting means for connecting each of the panels to a co-operating connecting means of an adjacent panel. As described above, these projecting portions are operable to deform elastically under severe forces imposed on the panel.

Alternatives

10 Figure 63

Referring to Figure 63, an alternative finish to the smooth finish imparted to the concrete, described above, is formed using a plurality of pre-formed conventional rectangular marble tiles, one of which is shown at 3000. The tiles are pre-fitted with a plurality of hooks shown generally at 3002 which are secured to the adhesive side of the conventional marble tile.

15 Each hook has a flat backing surface portion 3004 which is glued to the adhesive or backing side of the tile. A projecting portion 3006 extends normal to the flat surface portion, away from the tile. The projecting portion is terminated in a hook portion 3008 which is arranged to project downward, toward the floor when the tile is used on a wall panel. The hook 3002 is preformed such that the distance between the adhesive side of the tile and the hook portion

20 3008 is equal to the approximate thickness of the concrete, designated in Figure 63 as 3010.

To use the marble tiles, the tiles are pre-fitted with hooks 3002. Then, after the concrete 3010 has been poured over the mesh 3012 of the panel, but before the concrete cures, the tiles are placed on the concrete such that the hook portions 3008 project into the uncured

25 concrete until the backing surface rests on the surface of the uncured concrete. In this position the hooks engage with the mesh 3012, while the adhesive side of the tile contacts the uncured concrete. The panel is then left undisturbed while the concrete cures. The cured concrete firmly sets about the hooks and secures the hooks 3002 to the mesh 3012 and the tiles are securely fixed to the panel. It will be appreciated that the tiles need not necessarily

30 be marble but may be of any suitable architectural finish such as rock, granite, slate, wood siding etc.

Figure 64

In the embodiment described above the panels were stated to measure 8'x 8'. Similar benefits to those available using an 8'x 8' panel, as described above are available in panels of various other dimensions. Examples of panels with other dimensions are shown in Figure 64.

5

All of the panels shown in Figure 64 measure 8' in height. The smallest practical panel (a) able to achieve the stated benefits is 6" wide and includes only vertical tension cables. The 12" and 18" panels (b) and (c) are similar. The 2' through 3'6" panels (d,e,f,g,) each include diagonal portions of tension cable although each forms a reverse "K" form rather than an "X" form as described in the embodiment described above. The remaining panels each include at least one "X" form of diagonal cables with some panels including a combination of an "X" form and a "K" form (m,n,q,s,u,w). The indicated forms are preferable for the panel dimensions indicated in order to achieve the structural, seismic and wind benefits described above.

15

Curved Foundation and PanelsFigure 65

Referring to Figure 65, a curved foundation portion is shown generally at 4000. To use the curved foundation portion, an end foundation adapter portion 4002 and a side foundation adapter portion 4004 are used. The end foundation adapter portion 4002 includes a length of end foundation similar to the foundation portion designated 42 in Figure 3, but with first and second upstanding connecting portions 4008 and 4010 extending vertically upward, adjacent the curved foundation portion 4000. The first and second upstanding connecting portions 4008 and 4010 are similar to the vertically extending duct portions 74 and 76 on the side member 40 of Figure 3 and thus have respective plates 4012 and 4014 having respective conduit and threaded openings 4016, 4018 and 4020, 4022, respectively.

25

The side foundation adapter 4004 is similar to the side foundation member 40 of Figure 3 with the exception that it does not have the right angled end portion 48 shown in Figure 3. Rather, the side foundation adapter 4004 has a straight end portion 4024 which has first and second upstanding channel portions 4026 and 4028, respectively. The first and second upstanding channel portions extend vertically upwards relative to the end portion 4024, the channel portions being similar to channel portions 4008 and 4010 just described.

30

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The first and second channel portions 4026 and 4028 are terminated in respective plates 4030 and 4032. Each plate has a respective conduit and threaded opening 4034, 4036 and 4038, 4040.

- 5 The curved foundation member 4000 extends through 90 degrees, following an arc of a circle of radius 5 feet. The member has first and second end portions 4042 and 4044 which mate flush with respective end portions of the end foundation adapter portion 4002 and the side foundation adapter portion 4004. Adjacent end portions are connected together using respective mating connectors 4046 and 4048 similar to connecting flanges 86 shown in Figure 3.

Referring to Figure 65, the end foundation adapter portion 4002, curved foundation member 4000 and side foundation adapter 4004 each has a respective conduit 4001, 4003 and 4005 which is in communication with the conduits (as shown at 56 in Figure 3) of adjacent foundation members. Thus, electrical service cables can be routed in the conduits of the various foundation members and can be accessed through openings 4016, 4020, 4034, 4038. Electrical service can, therefore, be provided to panels connected to plates 4012, 4014, 4030 and 4032.

20 Floor Panel With Curved Corner

Figure 66

Referring to Figure 66, a plurality of frame members of a floor panel with a curved corner portion are shown generally at 5000. The plurality of frame members includes first, second, third, fourth, fifth and sixth frame members 5002, 5004, 5006, 5008, 5010 and 5012, respectively. Frame members 5002, 5004 and 5006 are similar to frame members 150, 152 and 153 of Figure 4 and therefore are not described further. Frame members 5008 and 5010 are straight frame members while frame member 5012 is curved longitudinally to extend through 90° of an arc of a circle having a radius 5014 of 5 feet to match the radius of curvature of the curved foundation member 4000 shown in Figure 65.

30

Referring back to Figure 66, frame member 5012 has first and second end faces 5016 and 5018 disposed at right angles to each other. Each end portion has a respective radially extending opening 5020 and 5022, respectively for receiving co-operating pins 5024 and 5026 on adjacent frame members 5008 and 5010. The adjacent frame members also have

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respective flat end faces **5028** and **5030** which abut the first and second end faces **5016** and **5018**, respectively when the frame members are assembled together.

Adjacent frame member **5008** has first, second, third and fourth connecting flanges **5032**,
5 **5034**, **5036** and **5038** which are used to connect the finished panel to the foundation shown
in Figure 65. The first connecting flange **5032** is similar to the connecting flange **172** of
Figures 5, 6 and 7 and projects outwardly of the panel, along the longitudinal axis **5040** of
frame member **5008**. The second, third and fourth connecting flanges **3034**, **3036** and **3038**
have structure similar to the first connecting flange but extend transversely to the longitudinal
10 axis **5040**. The second connecting flange is disposed adjacent the first connecting flange
while the third and fourth connecting flanges are disposed adjacent each other and adjacent
the third frame member **5006**.

The fifth frame member **5010** also has connecting flanges **5044** and **5046** extending
15 transversely thereto and has an inside face with a plurality of spaced apart chair bolster hooks
5048, similar to those indicated at **204** in Figure 4.

Frame members **5002**, **5008** and **5012** also have a plurality of spaced part tension cable hooks
20 **5050** similar to those indicated at **196** in Figure 4.

Figure 67

Referring now to Figure 67, the frame members **5002** - **5012** are assembled together to form
first and second interior portions **5052** and **5054**, respectively. The interior portions include
respective slabs of preformed styrofoam **5056** and **5058** similar to the slabs on the interior
25 portion of the panel shown at **270** and **272** in Figure 11. Slab **5056** is virtually identical to
the slab shown on interior portion **270** and therefore will not be described further. Slab **5058**
is similar to the slab on interior portion **272** with the exception of a rounded corner portion
5060. Slab **5058** has longitudinal, transverse and curved recess portions, the longitudinal
portions being indicated at **5062**, the transverse portions being indicated at **5064** and the
30 curved recess portion being indicated at **5066**. The slab also has first and second intersecting
diagonal recess portions **5068** and **5070**, respectively. The first diagonal recess portion
extends between the curved recess portion and an opposite corner, the second diagonal recess
portion extends between opposite corners, transversely to the first diagonal recessed portion.

Figure 68

Referring to Figure 68, a first resiliently extendable flexible tension cable 5072 is routed in the recessed portions of the first slab 5056 in a manner similar to that shown in Figure 11 and serves to bias the frame portions inwardly. A second resiliently extendable flexible tension cable 5074 is routed in recessed portions 5062, 5064, 5066, 5068 and 5070 and serves to hold frame members 5002, 5008, 5010 and 5012 together. As with the floor panel described in Figure 14, the portions of the tension cable which are routed in a longitudinal and transverse recesses lie in a first plane whereas the portions which are routed in the diagonal recesses lie in a second plane, spaced apart from the first plane, similar to the routing of cables described with respect to Figure 11.

Figure 69

Referring to Figure 69, first and second layers of mesh material 5076 and 5078 are tensioned and connected to the bolster hooks 5048 facing respective first and second inner portions of the panel. The first layer of mesh material is similar to wire mesh 330 shown in Figure 16. The second layer is also similar to wire mesh 330 of Figure 16 with the exception that it has a rounded corner portion 5080 to match the curvature of frame member 5012. The first and second layers of mesh material lie in a third plane, above the second plane in which the diagonally extending portions of tension cable are routed. Concrete (not shown) is then poured over the mesh material such that the transverse, longitudinal and diagonal recesses are filled and the concrete is finished to have a smooth planar surface. The reverse side of the panel is finished in a similar manner and includes third and fourth tension cables, third and fourth layers of mesh and a second finished side of concrete.

Figure 70

Referring to Figure 70, a finished panel according to the invention is shown generally at 5082 and has a finished interior surface 5084 and protruding connecting flanges 5032, 5034, 5036, 5038, 5042, 5044, 5046 and 5086 which mate with corresponding connecting flanges 124, 124, 4012, 4014, 80, 4032, 4030, 80 and 134, respectively, shown in Figure 65, the connecting flanges protruding from the panel and the flanges protruding from the foundation act as co-operating connecting means which are operable to deform elastically under seismic forces imposed on the foundation or panel.

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Curved Exterior Wall PanelFigure 71

Referring to Figure 71 a plurality of frame members for forming a curved exterior wall panel is shown generally at 5088. The plurality of frame members includes first and second curved
5 frame members 5090 and 5092, first and second end members 5094 and 5096 and first, second, third and fourth intermediate frame members 5098, 5100, 5102 and 5104.

The end members 5094 and 5096 are similar to members 420 and 432 of Figure 22 while the intermediate frame members 5098, 5100, 5102 and 5104 are similar to member 5006 shown
10 in Figure 66. These members therefore require no further description. The first and second curved frame members 5090 and 5092 are mirror images of each other and therefore only the first curved frame member 5090 will be described.

Figure 72

Referring to Figure 72, the first curved frame member 5090 has an interior facing face 5106
15 having first, second, third, fourth and fifth panel portions 5108, 5110, 5112, 5114 and 5116, respectively which are spaced apart by first, second, third and fourth intermediate portions 5118, 5120, 5122 and 5124, respectively. The frame member 5090 also has first and second opposite end portions 5126 and 5128, respectively.

20

Each end portion 5126 and 5128 has an opening 5130 and 5132, respectively for receiving
respective pins 5134 and 5136 on mating end portions of corresponding end members 5094 and 5096, respectively (of Figure 71). Similarly, each intermediate portion 5118, 5120, 5122 and 5124 has a respective pair of openings 5138, 5140, 5142 and 5144 for mating with
25 respective pairs of pins 5146, 5148, 5150 and 5152 on the end portions of the corresponding intermediate members 5098, 5100, 5102 and 5104, respectively (of Figure 71). The pins are permitted to move axially in the openings thereby permitting the curved end member to move in a direction parallel to the intermediate members and end members.

The panel portions 5108, 5110, 5112, 5114 and 5116 are similar and therefore only panel
30 portion 5108 will be described. Panel portion 5108 includes first and second spaced apart tension cable hooks 5154 and 5156, respectively, the hooks being similar to those shown at 5050 in Figure 66. Between the tension cable hooks 5154 and 5156 are located three spaced apart chair bolster hooks 5158, 5160 and 5162, arranged in a line.

35

Figure 73

Referring to Figure 73, a curved slab of styrofoam **5164** is formed with the same curvature as the curved frame members **5090** and **5092** of Figure 71 and has a web portion **5166**, a plurality of longitudinally extending recessed portions **5170** and a plurality of rib portions **5168**.

Figure 74

Referring to Figure 74, the manufacture of the curved panel is begun with a sheet of mesh material **5172** which is laid flat on the manufacturing floor. A water impermeable membrane such as tar paper **5174** is laid flat on the mesh material **5172** and the curved styrofoam slab **5164** is laid on the tar paper **5174**.

Figure 75

Referring to Figure 75, the end and intermediate frame members **5094**, **5096**, **5098**, **5100**, **5102** and **5104** are laid in the recessed portions **5170** and the curved frame members **5090** and **5092** are placed against them such that the pins of respective members (such as **5134** and **5136**) are received in corresponding openings (such as **5130** and **5132**) in the curved end frame members. The tar paper **5174** and mesh material **5172** are then bent upwards to follow the shape of the curved styrofoam and the edges of the membrane and mesh are bent over the end members to embrace the end members **5094** and **5096** and the curved frame members **5090** and **5092**.

Figures 76 and 77

Referring to Figures 71, 72 and 76, a single resiliently extendable flexible tension cable **5176** is routed between the tension cable hooks **5154** and **5156** of each panel portion and is tensioned using a turnbuckle **5157** such that the curved frame members **5090** and **5092** are held snugly against the end members **5094** and **5096** and the intermediate members **5098** - **5104**.

A further layer of mesh material **5178** is then connected between the end members **5094** and **5096** and the curved frame members **5090** and **5092** such that a curved inner plane **5180** is defined by the mesh material, as best seen in Figure 77. A concrete retaining edge **5182**, shown best in Figure 76, is preformed to conform to the curved inner plane **5180** and is riveted, welded or screwed to adjacent frame members to form an edge defining a perimeter of an inner surface of the panel.

Figure 78

Concrete is then poured over the mesh material **5178** such that it flows into the recessed portions **5170** of the styrofoam slab to form concrete ribs **5184** therein with concrete web portions **5186** extending between the ribs **5184**. The concrete of the ribs thus extends about
5 the intermediate members **5098**, **5100**, **5102** and **5104** and the tension cable **5176** while the web portions **5186** extend about the mesh material **5178**. The concrete is left undisturbed to cure, whereupon a smoothly curved inner surface **5188** is formed. A smoothly curved outer surface **5190** is formed by the first mesh material **5172** and may be smoothly finished using any conventional finish such as stucco or the like.

10

Figure 79

Referring to Figure 79, a finished curved panel according to the invention is shown generally at **5192**. The panel has projecting connecting portions **5194**, **5196**, **5198**, **5200** which extend outwards from respective corners thereof. The connecting portions are similar to connecting
15 portions **642**, **646**, **648** and **650** shown in Figure 31, and thus each has a respective opening for routing of utility service conduits and each has a threaded opening **5201** for securing the panel to an adjacent panel or foundation member.

Figure 80

20 Referring to Figure 80, a floor panel is shown immediately prior to assembly on the curved foundation member **4000**, end foundation adapter portion **4002** and side foundation adapter **4004**.

The floor panel is lowered onto the foundation members such that flanges **5032**, **5034**, **5036**,
25 **5038**, **5046**, **5044**, **5042** and **5086** mate with corresponding connecting flanges **124**, **4012**, **4014**, **4030**, **4032**, **80** and **134**, respectively. The curved corner portion **4052** is located adjacent the curved foundation member **4000**.

Next, first, second, third and fourth adapter connecting flanges **5202**, **5204**, **5206** and **5208**
30 are laid upon connecting flanges **5034**, **5036/5038** **5046/5044** and **5042**, respectively. The curved wall panel **5000** is then placed upon the foundation such that connecting portions **5200** and **5198** mate with connecting flanges **5204** and **5206**, respectively. First and second adjacent wall panels **5203** and **5205**, each having a length of 3 feet are then installed on the connecting flanges **5202**, **5204**, **5206** and **5208** in a similar manner to complete the corner
35 portion of the structure.

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The wall panel connecting portions 5198 and 5200, flanges 5202, 5204, 5206, 5208, floor panel connecting flanges 5034, 5036, 5038, 5042, 5044, 5046, 5086 and corresponding foundation connecting flanges 124, 124, 4012, 4014, 80, 4032, 4030, 80 and 134, respectively, are then connected together using bolts to rigidly secure the panels to the foundation. The connection of the panels and foundation in this manner creates a three dimensional space frame wherein the individual frame members of each panel act as structural members in the space frame. The connectors projecting from the foundation and panel members respectively act as elastically deformable connections which are capable of absorbing and distributing dynamic forces.

10

Finally, it will be appreciated that the wall, floor or roof panels may be made in virtually any geometric shape and are not limited to flat planar or curved planar forms.

While specific embodiments of the invention have been described and illustrated such
15 embodiments are not considered to limit the invention as construed in accordance with the accompanying claims.

What is claimed is:

1. A building panel comprising:
 - 5 a) a plurality of frame members;
 - b) frame member connecting means for connecting together said frame members to form a frame lying in a frame plane, the frame defining a perimeter of the panel, the perimeter bounding an interior portion of the panel;
 - 10 c) biasing means for biasing at least one of said frame members inwardly, generally in said frame plane, towards said interior portion of the panel;
 - d) a first solidified castable substance cast in said interior portion of the frame, between said frame members and about said biasing means such that loads
15 imposed on said solidified castable substance are transferred by said biasing means to said frame members.
2. A building panel as claimed in claim 1 wherein the biasing means includes a
20 resiliently extendible tension link extending between at least two of said frame members.
3. A building panel as claimed in claim 2 wherein the biasing means includes tensioning means for tensioning said flexible tension link.
- 25 4. A building panel as claimed in claim 3 wherein the tensioning means includes a turnbuckle.
5. A building panel as claimed in claim 1 wherein the biasing means includes a first
30 tensioned wire mesh extending between at least two frame members.
6. A building panel as claimed in claim 1 wherein the biasing means includes a
35 resiliently extendable tension link extending between the frame members, said flexible tension link having a first portion lying in a first plane and a second portion lying in a second plane, the second plane being spaced apart from said first plane.

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7. A building panel as claimed in claim 6 wherein said first portion extends generally perpendicular to two opposing frame members and wherein said second portion extends at an angle to said two opposing frame members.
- 5 8. A building panel as claimed in claim 7 wherein said biasing means further includes a first tensioned flexible mesh member extending between at least two frame members, said mesh member lying in a third plane spaced apart from said first and second planes.
- 10 9. A building panel as claimed in claim 1 wherein at least two of said frame members form a first pair of opposite sides of said frame and wherein at least two of said frame members form a pair of adjacent sides of said frame, said first pair of opposite sides extending between said pair of adjacent sides.
- 15 10. A building panel as claimed in claim 9 wherein said frame member connecting means permits movement of said frame members forming said pair of opposite sides relative to and in a direction parallel to the longitudinal axis of said frame members forming said pair of adjacent sides.
- 20 11. A building panel as claimed in claim 9 wherein said each frame member of said pair of adjacent sides has a respective pin projecting in a direction parallel with the longitudinal axis of the member and wherein each frame member of said pair of opposite sides has a respective pin receptacle for receiving a respective said pin therein.
- 25 12. A building panel as claimed in claim 1 wherein the castable substance is formed to include a generally planar portion parallel to said frame plane and a plurality of ribs projecting perpendicularly to said planar portion, the ribs extending substantially between said frame members.
- 30 13. A building panel as claimed in claim 2 wherein the castable substance is formed to include a generally planar portion parallel to said frame plane and a plurality of ribs projecting perpendicularly to said planar portion, the ribs extending substantially between said frame members, said resiliently extendable tension link being disposed
- 35 in said ribs.

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14. A building panel as claimed in claim 8 wherein the castable substance is formed to include a generally planar portion parallel to said frame plane and a plurality of ribs projecting perpendicularly to said planar portion, the ribs extending substantially between said frame members, said first and second planes intersecting said ribs and said third plane intersecting said planar portions such that said first and second portions of said resiliently extendable tension link are disposed within said ribs and said tensioned mesh is disposed within said planar portion.
15. A building panel as claimed in claim 12 wherein the panel further includes an insulating material in said interior portion, said insulating material having recessed portions therein for forming said ribs when said castable substance is cast.
16. A building panel as claimed in claim 13 wherein the panel further includes an insulating material in said interior portion, said insulating material having recessed portions therein for forming said ribs when said castable substance is cast.
17. A building panel as claimed in claim 14 wherein the panel further includes an insulating material in said interior portion, said insulating material having recessed portions therein for forming said ribs when said castable substance is cast.
18. A building panel as claimed in claim 2 wherein said frame members have hooks thereon and wherein said resiliently extendable tension link is looped around said hooks.
19. A building panel as claimed in claim 1 further including cooperating connecting means for connecting the panel to a cooperating connecting means of an adjacent building panel, the connecting means being operable to deform elastically under forces imposed on said panel.
20. A building panel as claimed in claim 19 wherein the cooperating connecting means includes a projecting portion extending from said panel.
21. A building panel as claimed in claim 20 wherein the projecting portion extends in a direction parallel to an edge portion of the frame and is integral with a frame member of said panel.

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22. A building panel as claimed in claim 20 wherein the frame portions have hollow portions disposed longitudinally therein and wherein the projecting portion has an opening for permitting utility service conduits to be routed in said hollow portions.
- 5 23. A building panel as claimed in claim 20 wherein the projecting portion has an end portion and a plate secured to the end portion for securing the panel to an adjacent panel, the plate having an opening therein for passage of utility service conduits therethrough.
- 10 24. A building panel as claimed in claim 8 further including a second resiliently extendable wire mesh material extending between the frame portions, said second wire mesh being spaced apart from said first wire mesh.
- 15 25. A building panel as claimed in claim 24 further including a second solidified castable substance cast about said second layer of mesh material.
- 20 26. A building panel as claimed in claim 2 wherein the biasing means includes a second resiliently extendable tension link extending between at least two of said frame members.
27. A building panel as claimed in claim 26 wherein the biasing means includes second tensioning means for tensioning said second tension link.
- 25 28. A building panel as claimed in claim 27 wherein the second tensioning means includes a second turnbuckle.
- 30 29. A building panel as claimed in claim 8 wherein the biasing means includes a second resiliently extendable tension link extending between the frame members, said second tension link having a third portion lying in a fourth plane and a fourth portion lying in a fifth plane, the fifth plane being spaced apart from said fourth plane, the fourth plane being spaced apart from the first and second planes.
- 35 30. A building panel as claimed in claim 29 wherein said fourth portion extends generally perpendicular to two opposing frame members and wherein said fifth portion extends at an angle to said two opposing frame members.

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31. A building panel as claimed in Claim 1 wherein at least one of the frame members is curved and the building panel generally lies in a flat plane.
32. A building panel as claimed in Claim 1 wherein at least two parallel frame members
5 are similarly curved to form a curved panel lying in a curved plane.
33. A method of making a building panel, the method comprising the steps of:
- a) connecting together frame members to form a frame lying in a frame plane;
10
- b) biasing at least some of said frame members inwardly generally in said frame plane towards an interior portion bounded by the frame members;
- c) casting a first curable substance in said interior portion of the frame, between
15 said frame members such that loads imposed on said first curable substance, when cured, are transferred to said frame members.
34. A method as claimed in claim 33 further including the step of laying a first wire mesh over the frame prior to the step of casting.
20
35. A method as claimed in claim 34 wherein the step of laying includes the step of connecting the first mesh material to members on opposite sides of the panel frame.
36. A method as claimed in claim 35 wherein the step of connecting is preceded by the
25 step of securing mesh-fastening hooks to the frame members.
37. A method as claimed in claim 34 wherein the step of laying comprises the step of tensioning the first layer of mesh material between frame members on opposite sides of the panel.
30
38. A method as claimed in claim 33 further including the step of placing insulating material in said interior portion.

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39. A method as claimed in claim 38 further including the step of preforming the insulating material with recesses, the recesses being in a first planar side of said insulating material.
- 5 40. A method as claimed in claim 39 wherein the step of preforming the insulating material comprises the step of preforming vertical, horizontal and diagonal recesses in a side of said panel, the recesses extending between the frame members.
- 10 41. A method as claimed in claim 33 wherein the step of biasing includes the step of connecting a first resiliently extendable tension link between two frame members on opposite sides of the panel and tensioning the first link prior to the step of casting.
42. A method as claimed in claim 41 wherein the step of casting includes casting the first curable substance about said first tension link.
- 15 43. A method as claimed in claim 42 wherein the step of biasing includes the step of connecting a second resiliently extendable tension link between frame members on opposite sides of the frame.
- 20 44. A method as claimed in claim 43 further including the step of securing to the frame concrete form edge retaining members in corners of the frame prior to the step of casting.
- 25 45. A method as claimed in claim 34 including the step of laying a second layer of mesh material over the frame.
46. A method as claimed in claim 45 wherein the step of laying includes the step of connecting the second layer of mesh material to frame members on opposite sides of the panel.
- 30 47. A method as claimed in claim 46 wherein the step of connecting is preceded by the step of securing mesh-fastening hooks to the frame portions.
- 35 48. A method as claimed in claim 45 wherein the step of laying comprises the step of tensioning the second layer of mesh material.

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49. A method as claimed in claim 45 further including the step of casting a second curable substance about said second layer of mesh material.
50. A building structure foundation member, the member comprising:
- 5
- a) a solidified castable material formed to include a footing portion for resting on the ground and a support portion for supporting a building structure;
 - b) a hollow conduit extending lengthwise in at least one of said footing portion and said support portion for holding utility service provisions;
 - 10 c) openings in said support portion for permitting access to said hollow conduit and said utility service provisions; and
 - 15 d) connecting means for connecting said member to an adjacent similar member, the connecting means being operable to deform elastically when seismic forces are imposed on said member.
51. A building structure foundation member as claimed in Claim 50 wherein the member has engaging faces for mating with similar engaging faces of respective adjacent members.
- 20
52. A building structure foundation member as claimed in Claim 51 wherein the hollow conduit includes a unitary length of structural tubing having first and second end openings accessible at said engaging faces respectively.
- 25
53. A building structure foundation member as claimed in Claim 52 wherein said connecting means includes at least one elastically deformable flange rigidly connected to said structural tubing and protruding from said solidified castable material, for engaging with a co-operating flange on an adjacent member.
- 30
54. A building structure foundation member as claimed in Claim 53 wherein said flange is bolted to said flange on said adjacent member.

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55. A building structure foundation member as claimed in Claim 50 wherein said openings are formed in upstanding lengths of structural tubing secured generally at right angles to and in communication with said hollow conduit, said upstanding lengths projecting from said support portion of said member and being operable to be secured to a building member mounted thereon.

56. A building structure foundation member as claimed in Claim 50 wherein said footing portion includes a hollow conduit containing insulating material to provide insulating properties to the foundation member.

10

57. A foundation for a building structure, the foundation including:

a) a plurality of foundation members each comprising:

15

i) a hollow conduit extending lengthwise in at least one of said footing portion and said support portion for holding utility service provisions;

ii) openings in said support portion for permitting access to said hollow conduit and said utility service provisions;

20

iii) connecting means for connecting said member to an adjacent similar member, the connecting means being operable to deform elastically when forces are imposed on said member; and

25

b) a plurality of connectors for co-operating with respective connecting means on each member to secure adjacent members together.

58. A foundation for a building structure as claimed in Claim 57 wherein the hollow conduits in each of said foundation members are in communication with each other.

30

59. A foundation for a building structure as claimed in Claim 57 wherein the connecting means on each of the foundation members is rigidly connected to a respective hollow conduit in its respective member and wherein the connecting together of the

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foundation members forms a space frame with the hollow conduits of each of the foundation members acting as the space frame members.

60. A foundation for a building structure as claimed in Claim 59 wherein the space frame
5 lies in a flat plane.

61. A method of securing an architectural finish element to a surface ultimately formed
by a castable material cast about a mesh material, the method including the steps of:

10 a) securing at least one projection to a backing surface of said architectural
finish element such that said projection extends generally away from said
backing surface;

15 b) inserting said at least one projection into said castable material before said
castable material has set, until said backing surface rests on a surface of said
castable material, said at least one projection co-operating with said mesh
material to engage therewith; and

20 c) permitting said castable material to set about said at least one projection,
thereby firmly securing said projection in said castable material and securing
said architectural finish element thereto.

62. A method of securing an architectural finish element as claimed in Claim 61 wherein
the step of inserting is preceded by the step of securing.

25 63. A method of securing an architectural finish as claimed in Claim 61 wherein the step
of securing is preceded by the step of forming said at least one projection with a
portion for engaging and hooking on to the mesh during the step of inserting.

30 64. A three dimensional building structure comprising:

a) a plurality of building panels, each panel including:

i) a plurality of frame members;

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- 5 ii) frame member connecting means for connecting together said frame members to form a frame lying in a frame plane, the frame defining a perimeter of the panel, the perimeter bounding an interior portion of the panel;
- iii) biasing means for biasing at least one of said frame members inwardly, generally in said frame plane, towards said interior portion of the panel;
- 10 iv) a first solidified castable substance cast in said interior portion of the frame, between said frame members;
- b) panel connecting means for connecting said building panels together, the panel connecting means being operable to deform elastically under forces
- 15 c) a plurality of connectors for co-operating with respective connecting means on each panel to secure adjacent panels together.
- 20 65. A three dimensional building structure as claimed in Claim 64 wherein the co-operating connecting means on each panel includes a projecting portion extending from each panel, the projecting portion extending in a direction parallel to an edge portion of the frame of the panel and being integral with at least one frame member of the panel.
- 25 66. A three dimensional building structure as claimed in Claim 64 wherein the frame members of adjacent panels form a rigid space frame defining the shape of said three dimensional structure.
- 30 67. A hi-rise building comprising:
- a) a plurality of spaced apart vertical members aligned to lie in spaced apart vertical planes;

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- b) a plurality of horizontal members connected to and extending between said vertical members to define a plurality of spaced apart horizontal planes intersecting said vertical members;
- 5 c) a plurality of building panels disposed between said spaced apart horizontal planes, each of said panels including:
- i) a plurality of frame members;
- 10 ii) frame member connecting means for connecting together said frame members to form a frame lying in a frame plane, the frame defining a perimeter of the panel, the perimeter bounding an interior portion of the panel;
- 15 iii) biasing means for biasing at least one of said frame members inwardly, generally in said frame plane, towards said interior portion of the panel;
- 20 iv) a first solidified castable substance cast in said interior portion of the frame, between said frame members and about said biasing means such that loads imposed on said solidified castable substance are transferred by said biasing means to said frame members; and
- 25 v) connecting means for connecting said each panel to an adjacent panel, the connecting means being operable to deform elastically under force;
- 30 the panels being connected together to form a space frame defining an array of units between said spaced apart horizontal planes and said spaced apart vertical planes, the connecting means on panels adjacent the vertical and horizontal members connecting the space frame to the vertical members and horizontal members.

68. A hi-rise building as claimed in Claim 67 wherein the connecting means for
35 connecting adjacent panels together and the connecting means for connecting the

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space frame to the vertical members and horizontal members include respective projecting portions extending from panels adjacent the vertical columns and horizontal beams.

5 69. A hi-rise building as claimed in Claim 68 wherein said projecting portions extend in a direction parallel to an edge portion of a frame member of the panel and wherein the projecting portions are integral with respective frame members of said panel.

10 70. A plurality of building panels for forming a three dimensional structure, the panels including;

i) a plurality of frame members;

15 ii) frame member connecting means for connecting together said frame members to form a frame lying in a frame plane, the frame defining a perimeter of the panel, the perimeter bounding an interior portion of the panel;

20 iii) biasing means for biasing at least one of said frame members inwardly, generally in said frame plane, towards said interior portion of the panel;

25 iv) a first solidified castable substance cast in said interior portion of the frame, between said frame members and about said biasing means such that loads imposed on said solidified castable substance are transferred by said biasing means to said frame members;

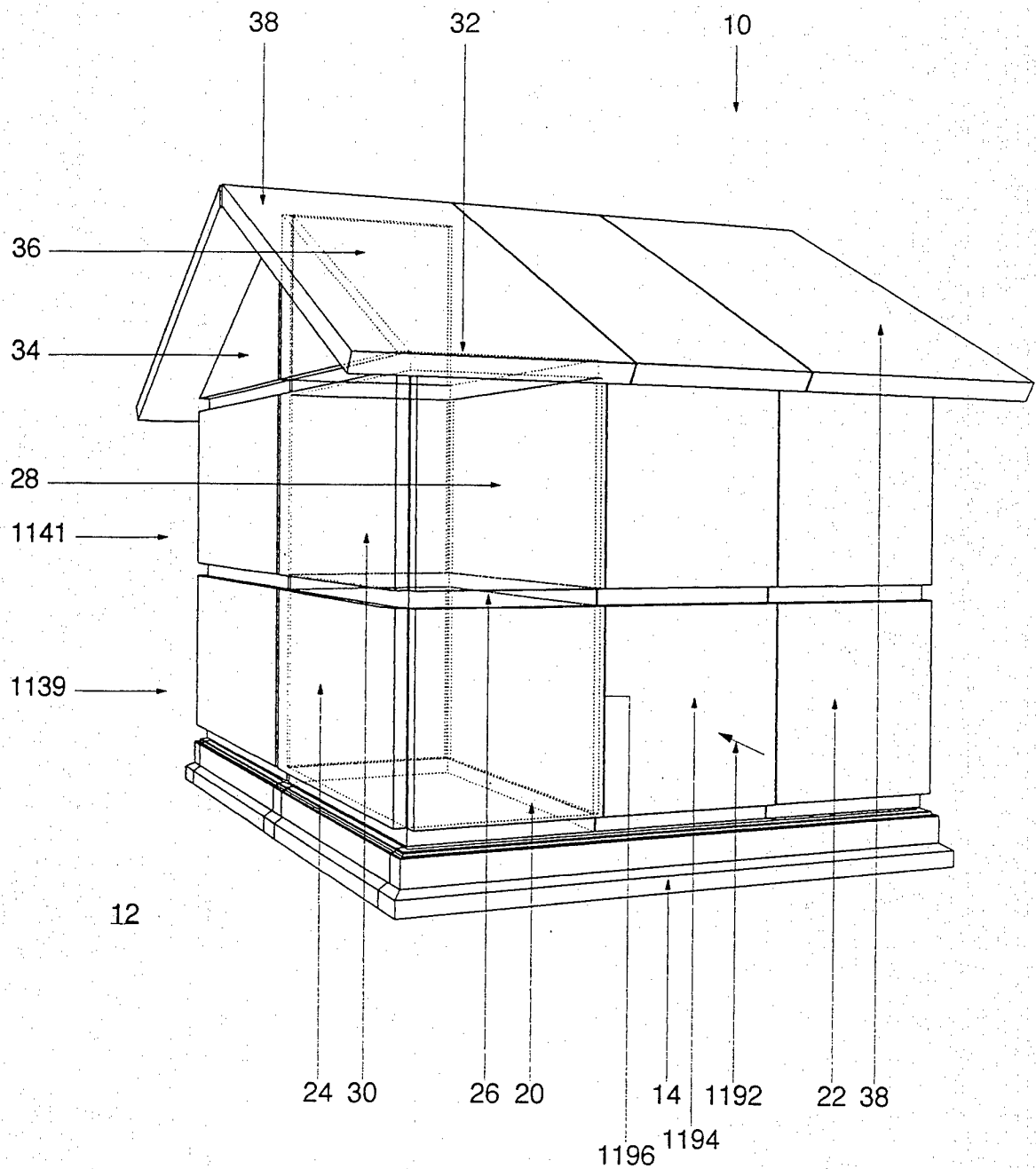
30 v) connecting means for connecting each of said panels to a co-operating connecting means of an adjacent said panel, the connecting means being operable to deform elastically under forces imposed on said panel, and

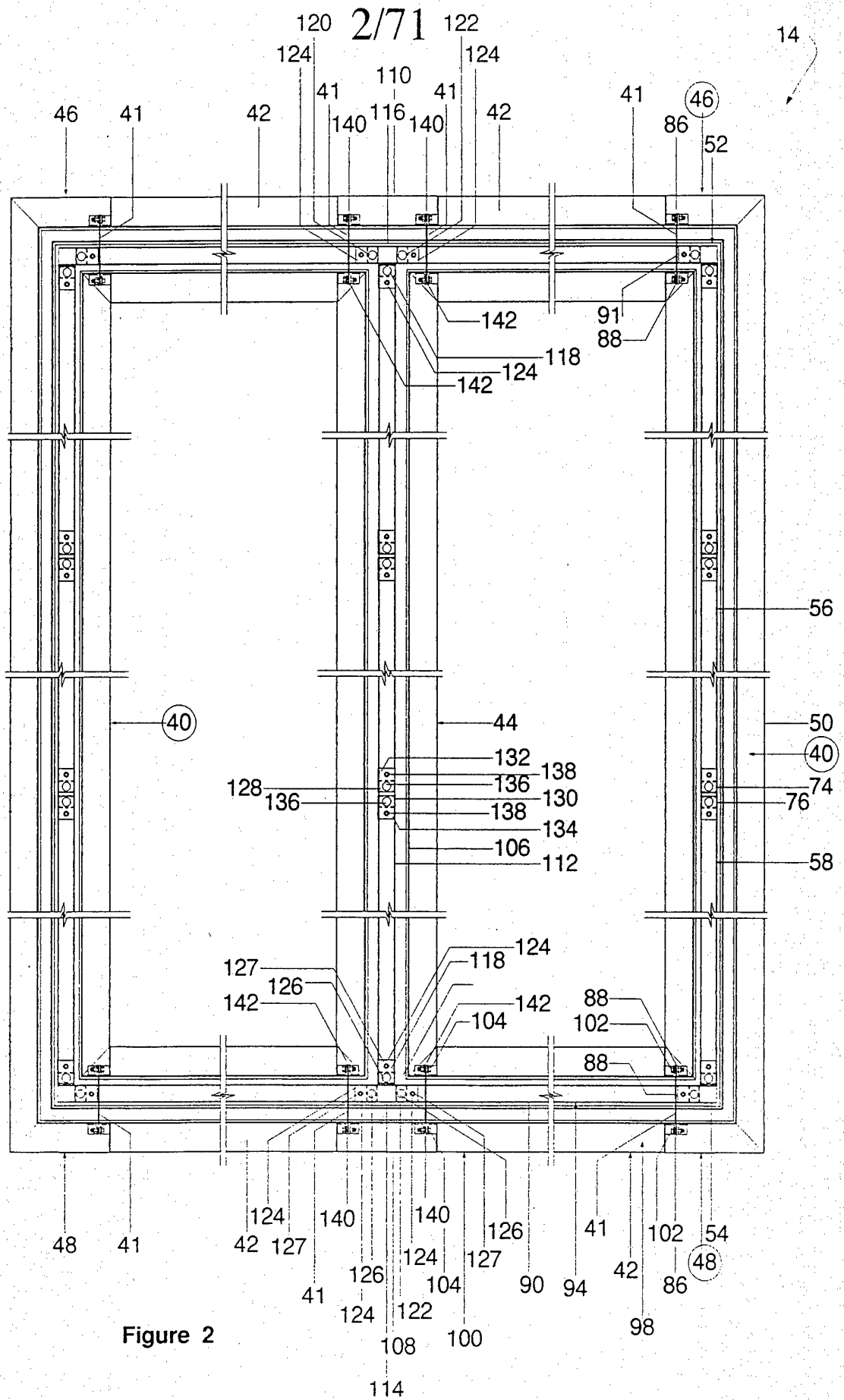
35 vi) a plurality of connectors co-operating with said panel connecting means for connecting at least some of said panels together to form a transportation container capable of holding a sufficient number of panels and connectors to form a dwelling from said sufficient number of panels and said panels used to form said transportation container.

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71. A three dimensional structure as claimed in Claim 70 wherein the plurality of connectors co-operating with said panel connecting means includes cooperating means for co-operating with a handling crane for lifting said transportation container.
- 5 72. A three dimensional structure as claimed in claim 71 wherein said cooperating means includes a crane adapter operable to be engaged by said handling crane.

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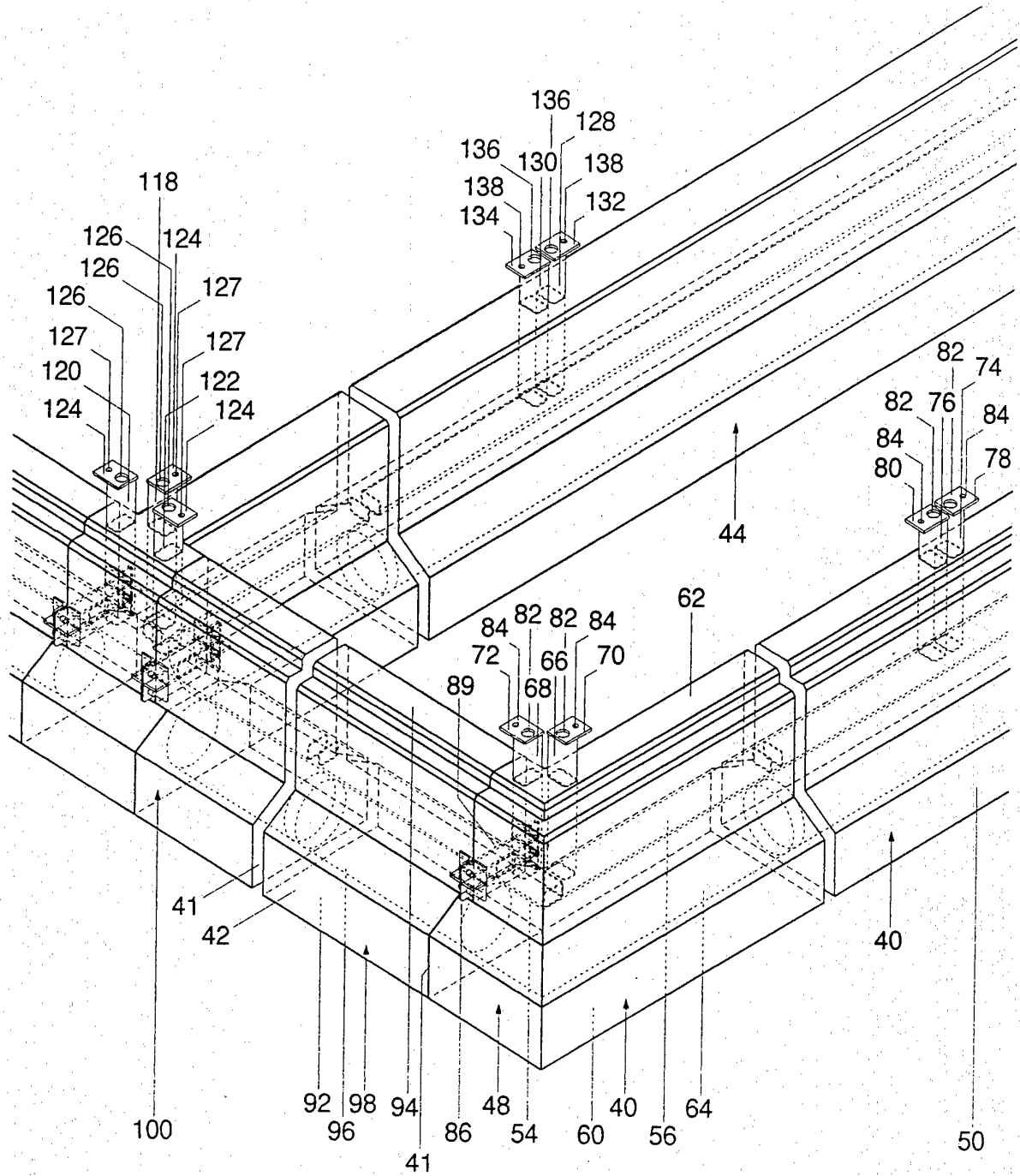


Figure 3

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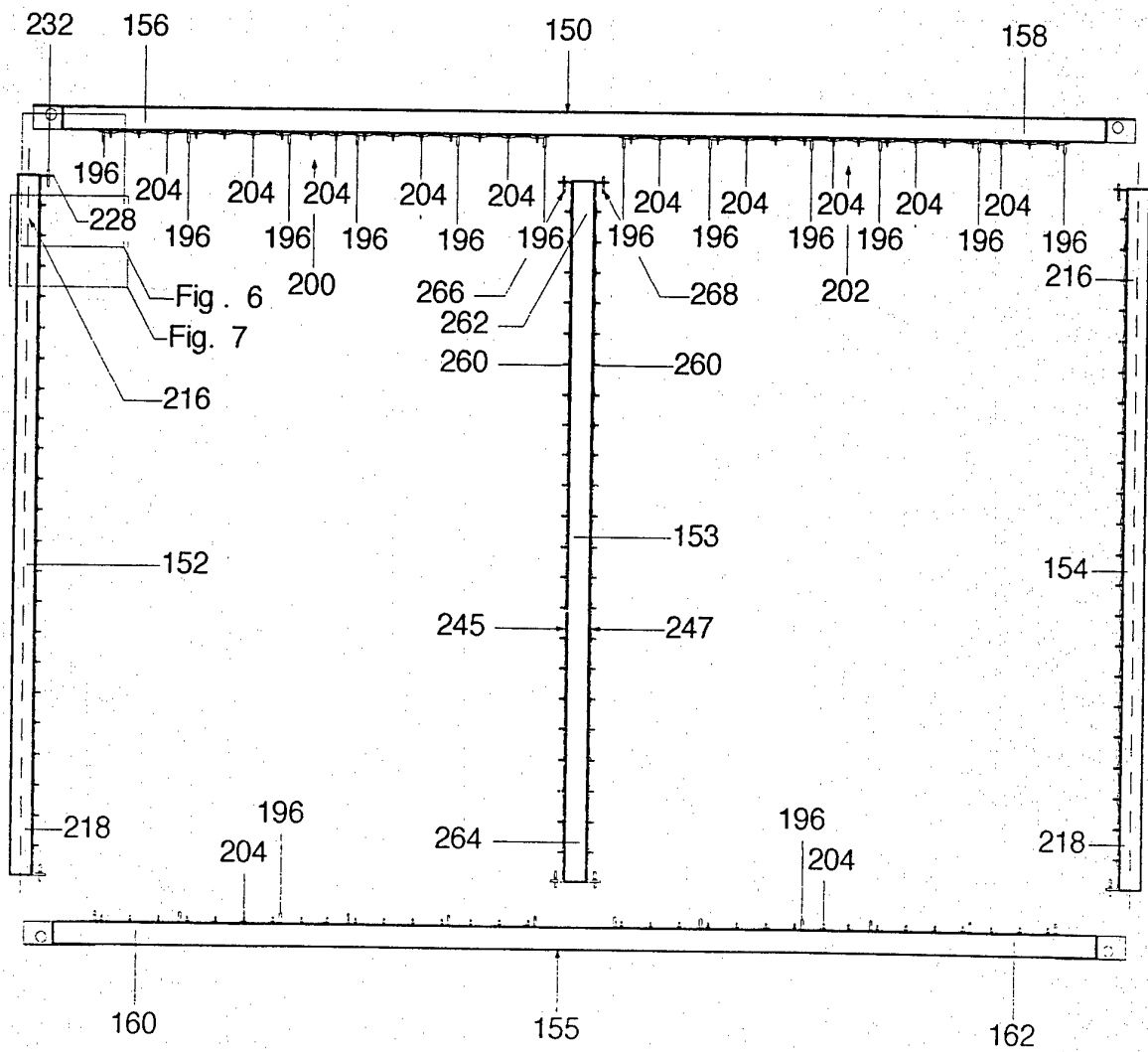


Figure 4

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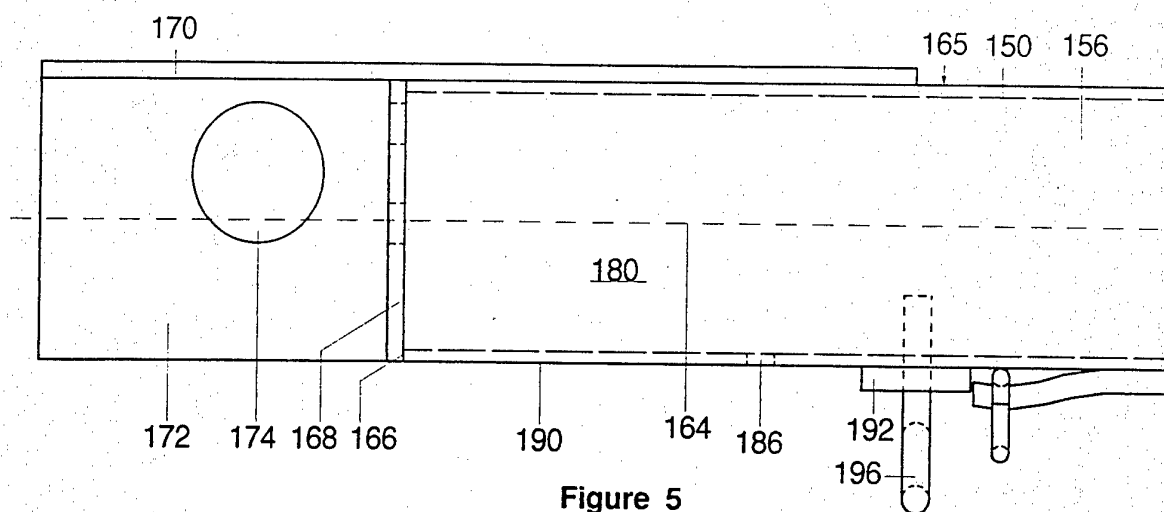


Figure 5

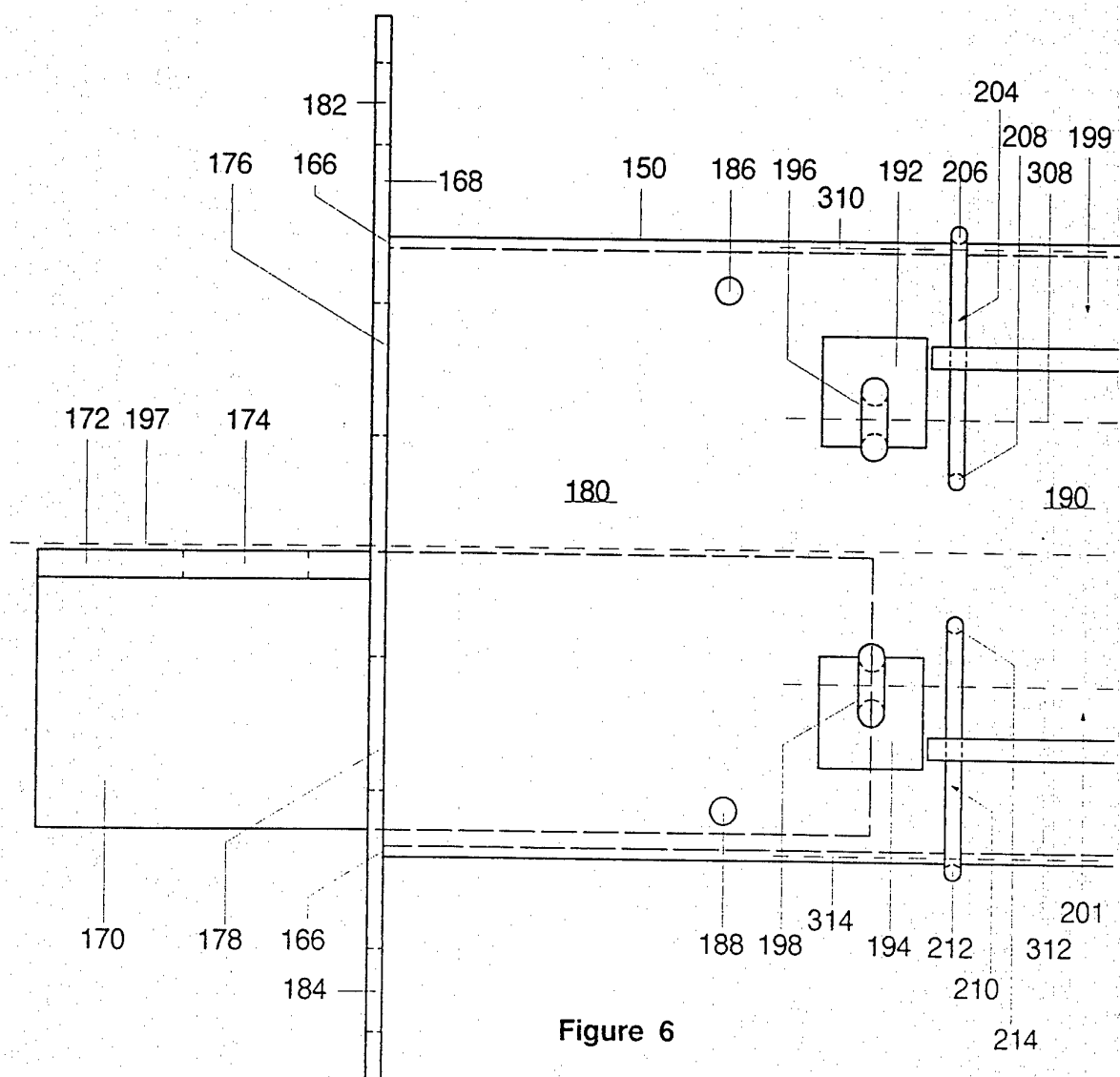


Figure 6

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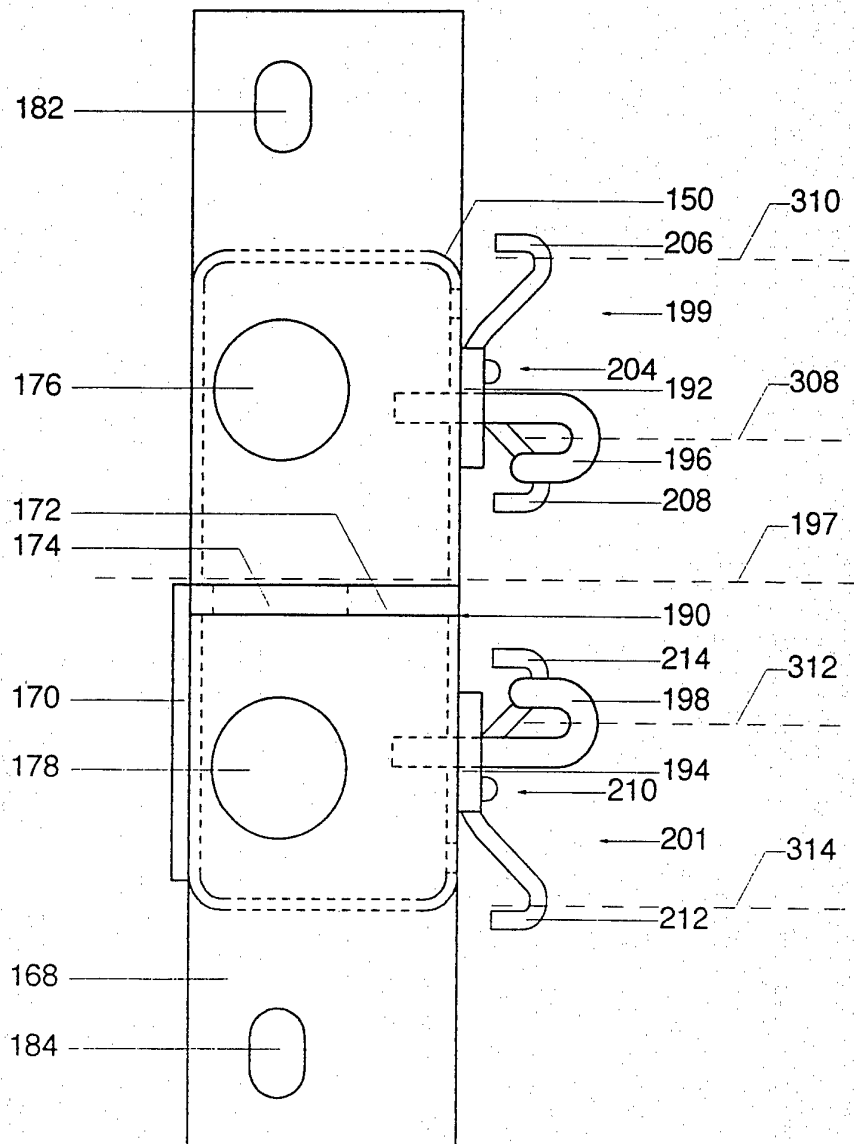


Figure 7

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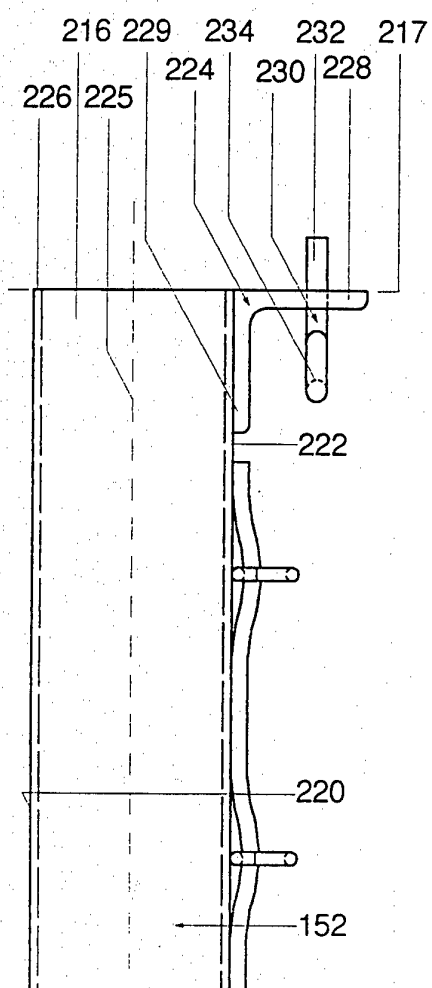


Figure 8

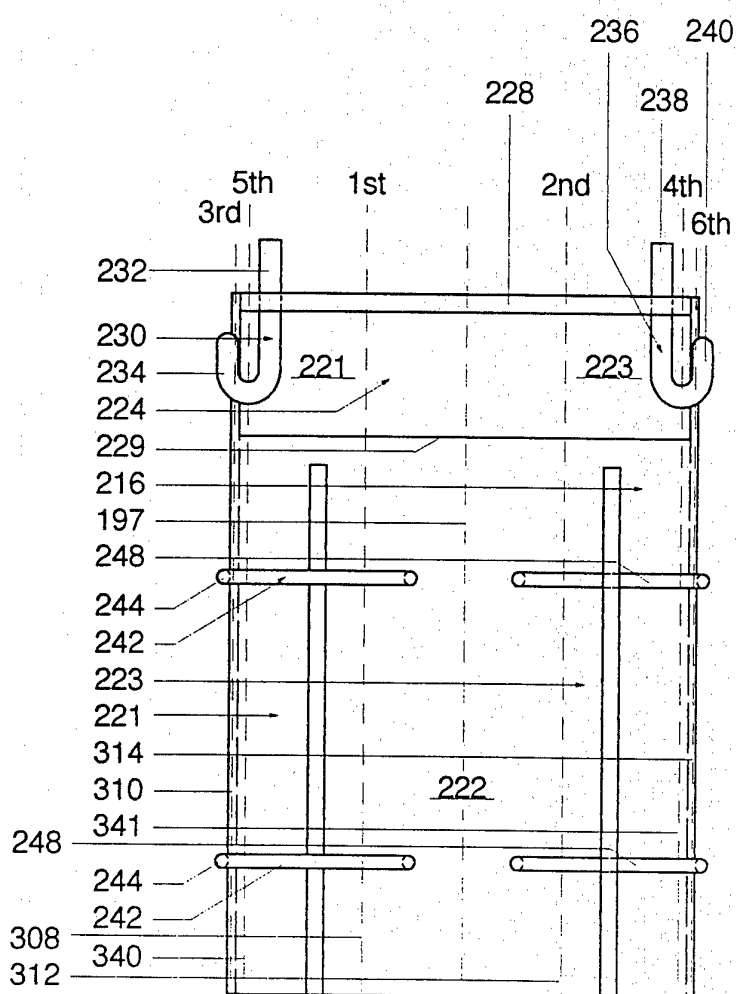


Figure 9

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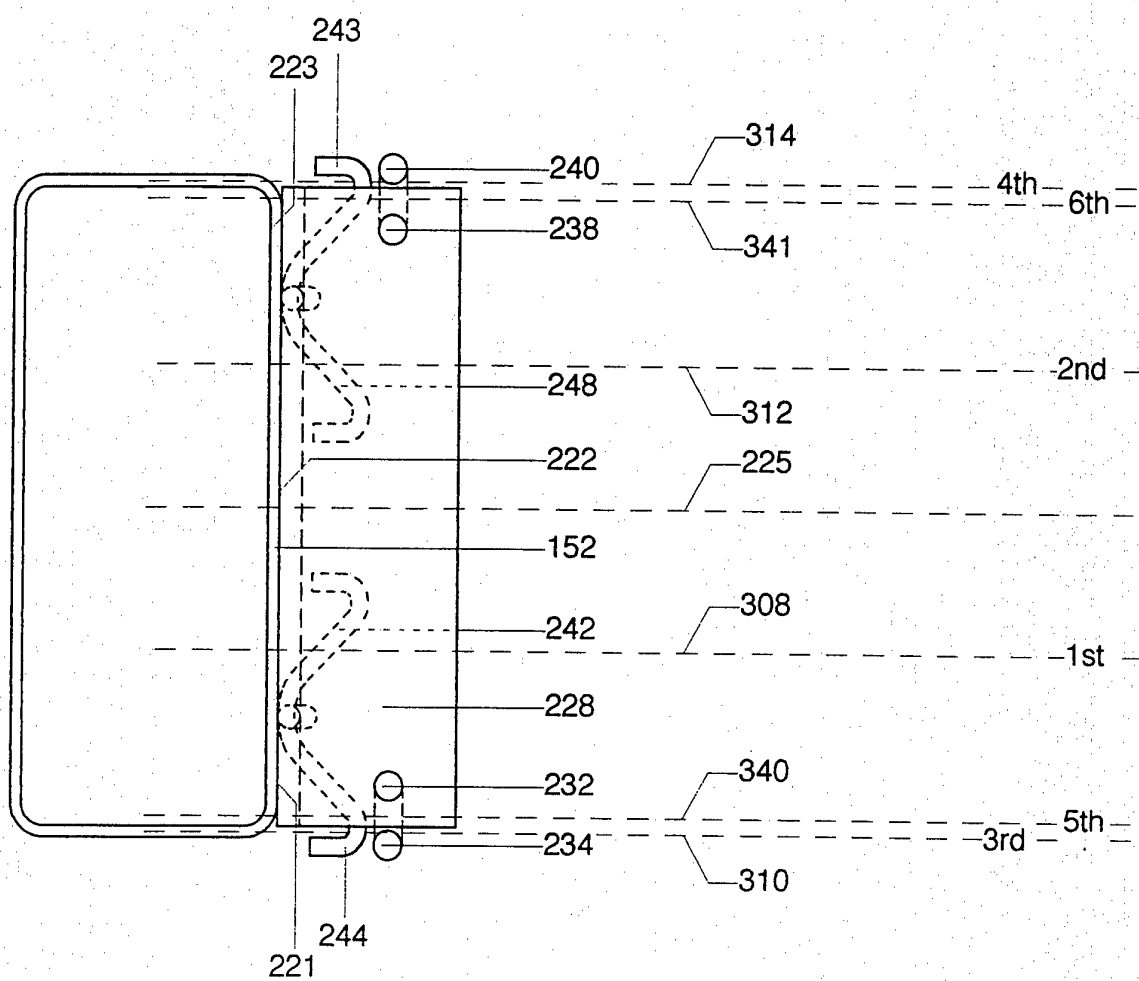


Figure 10

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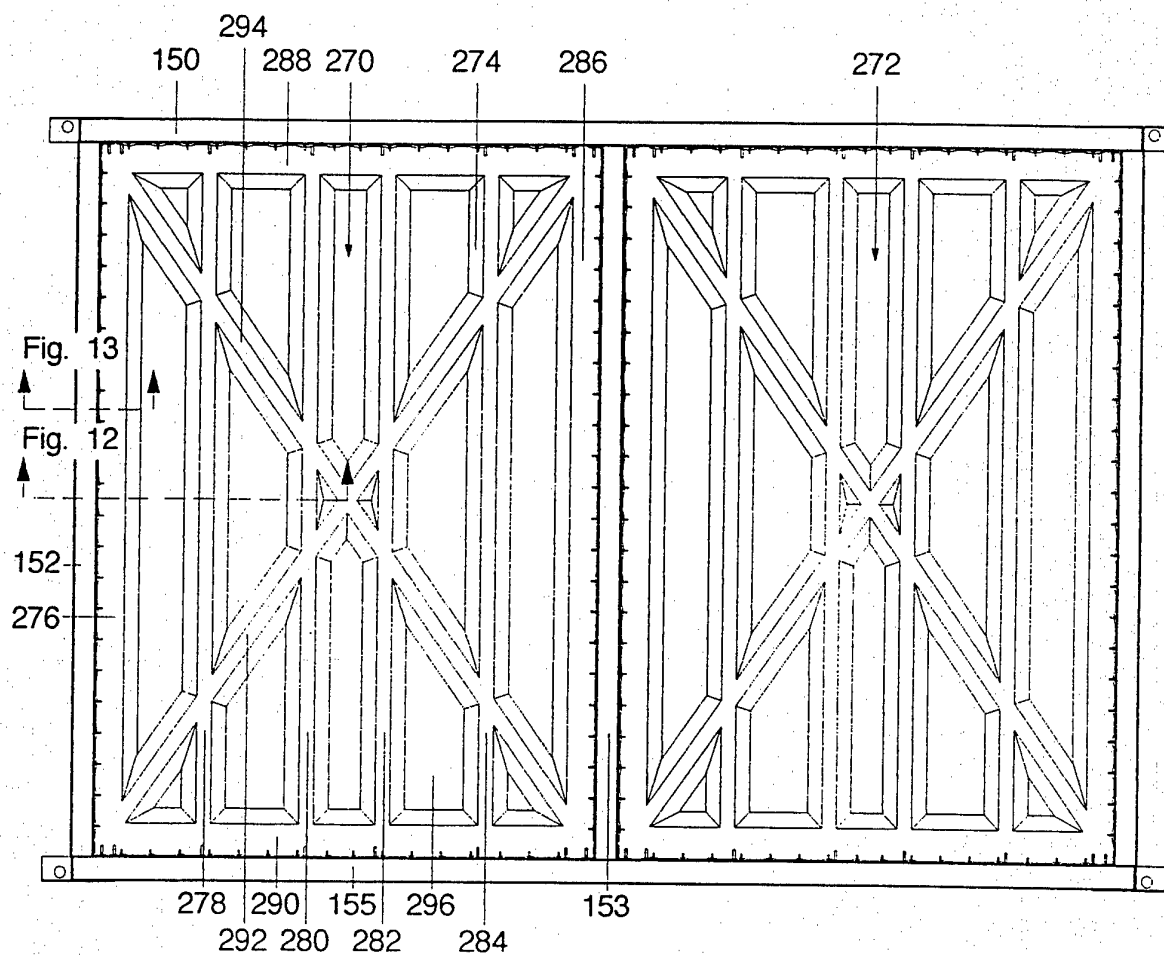


Figure 11

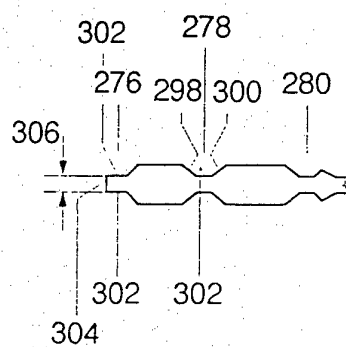


Figure 12

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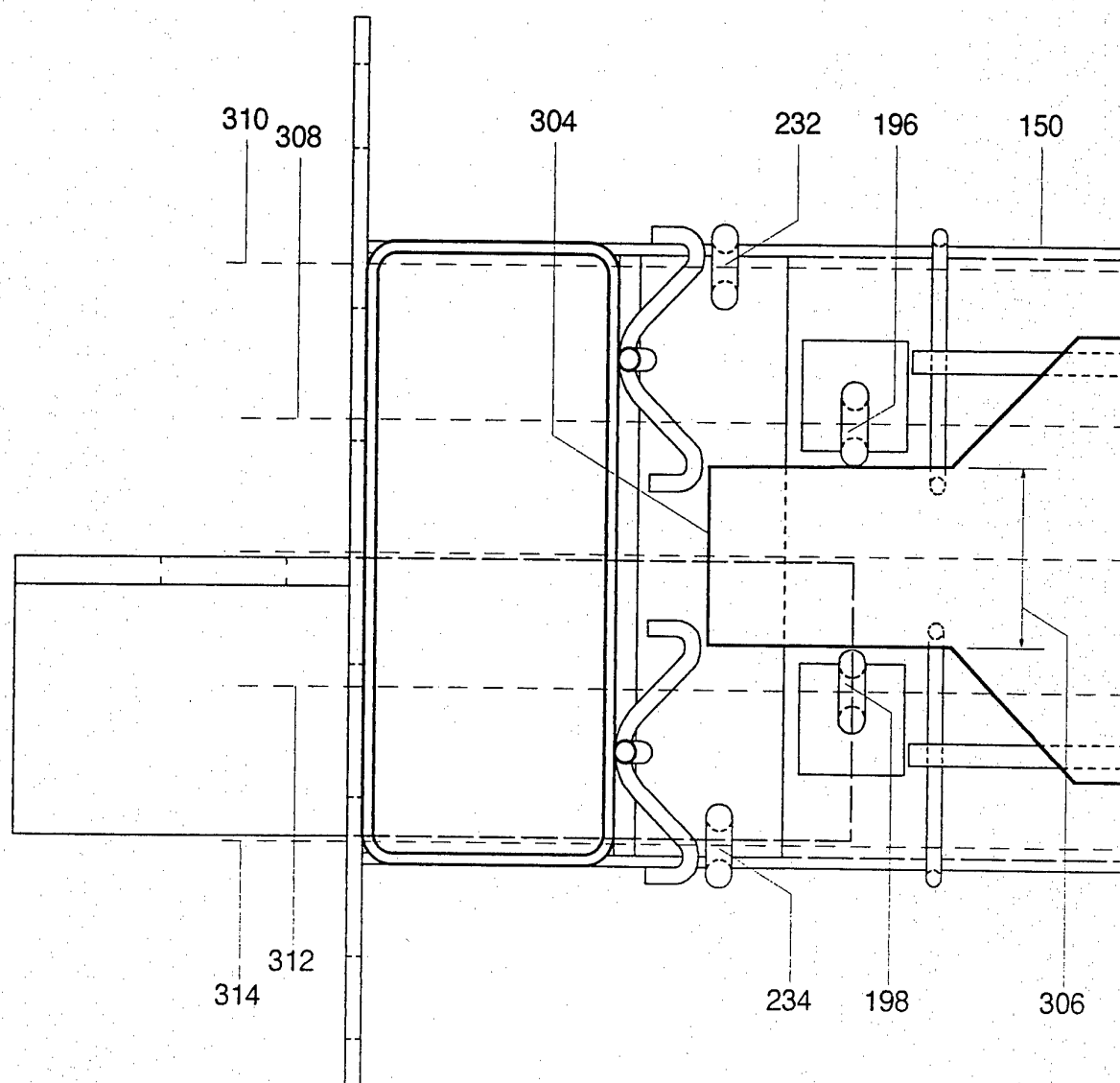


Figure 13

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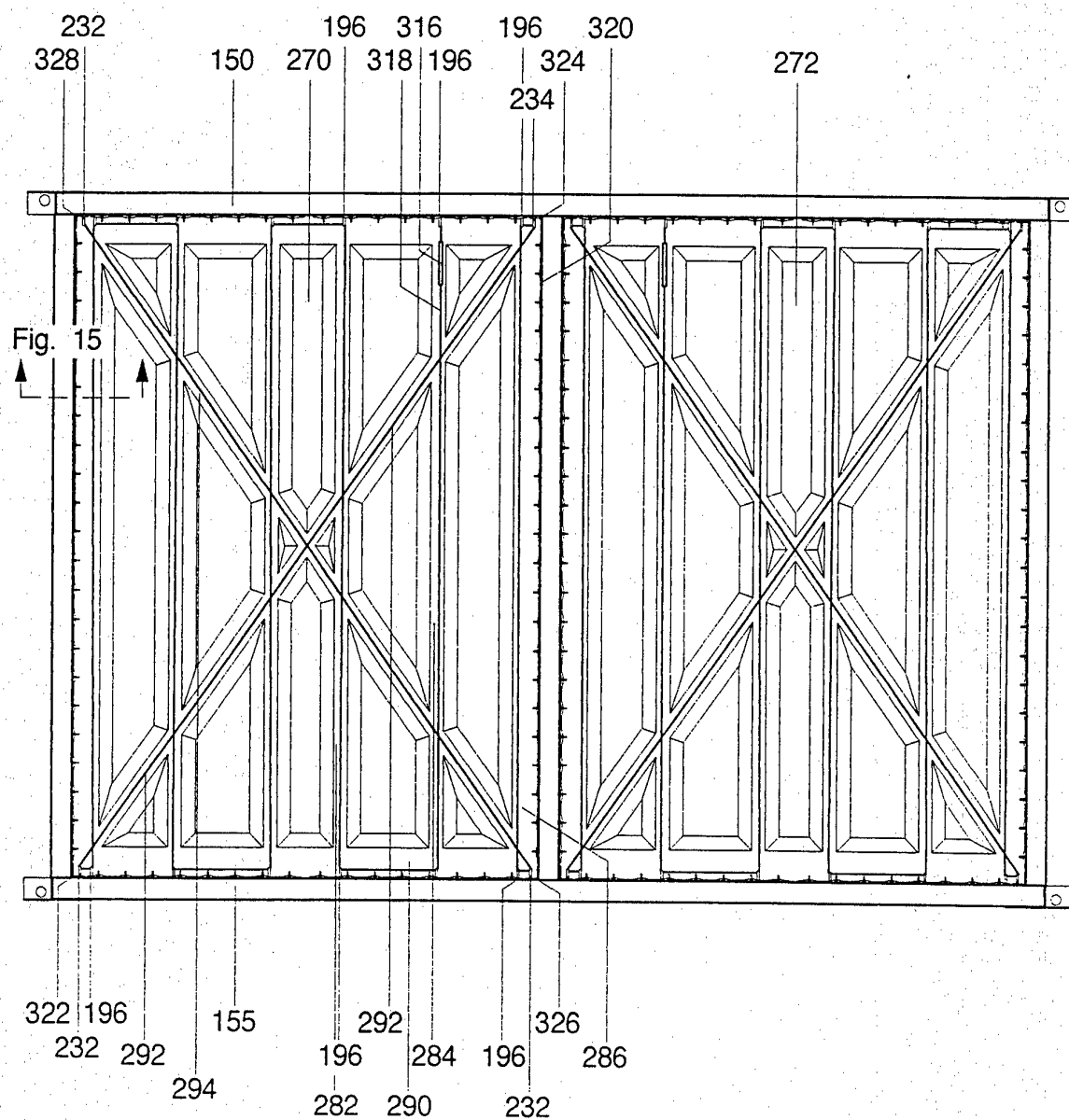


Figure 14

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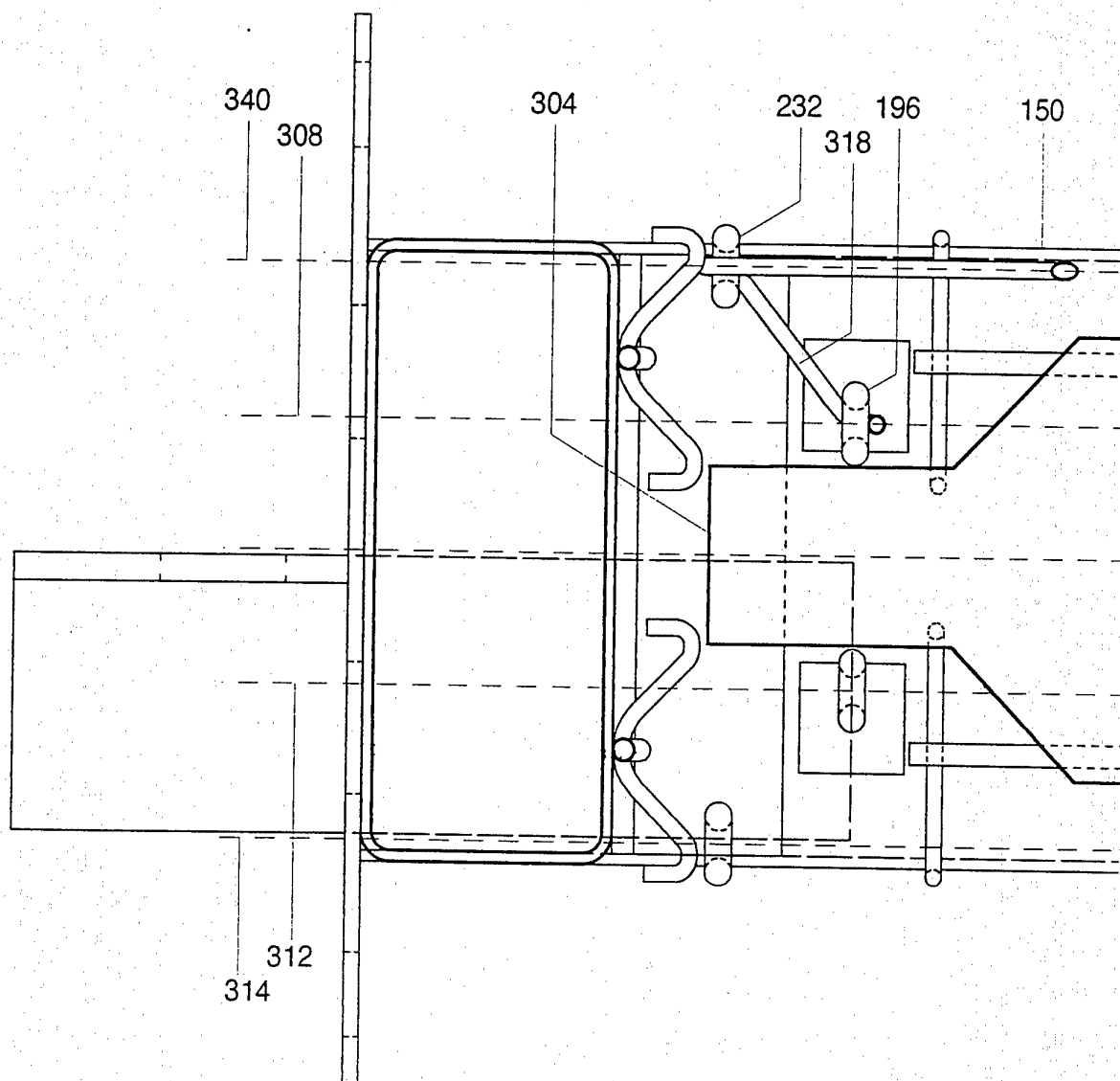


Figure 15

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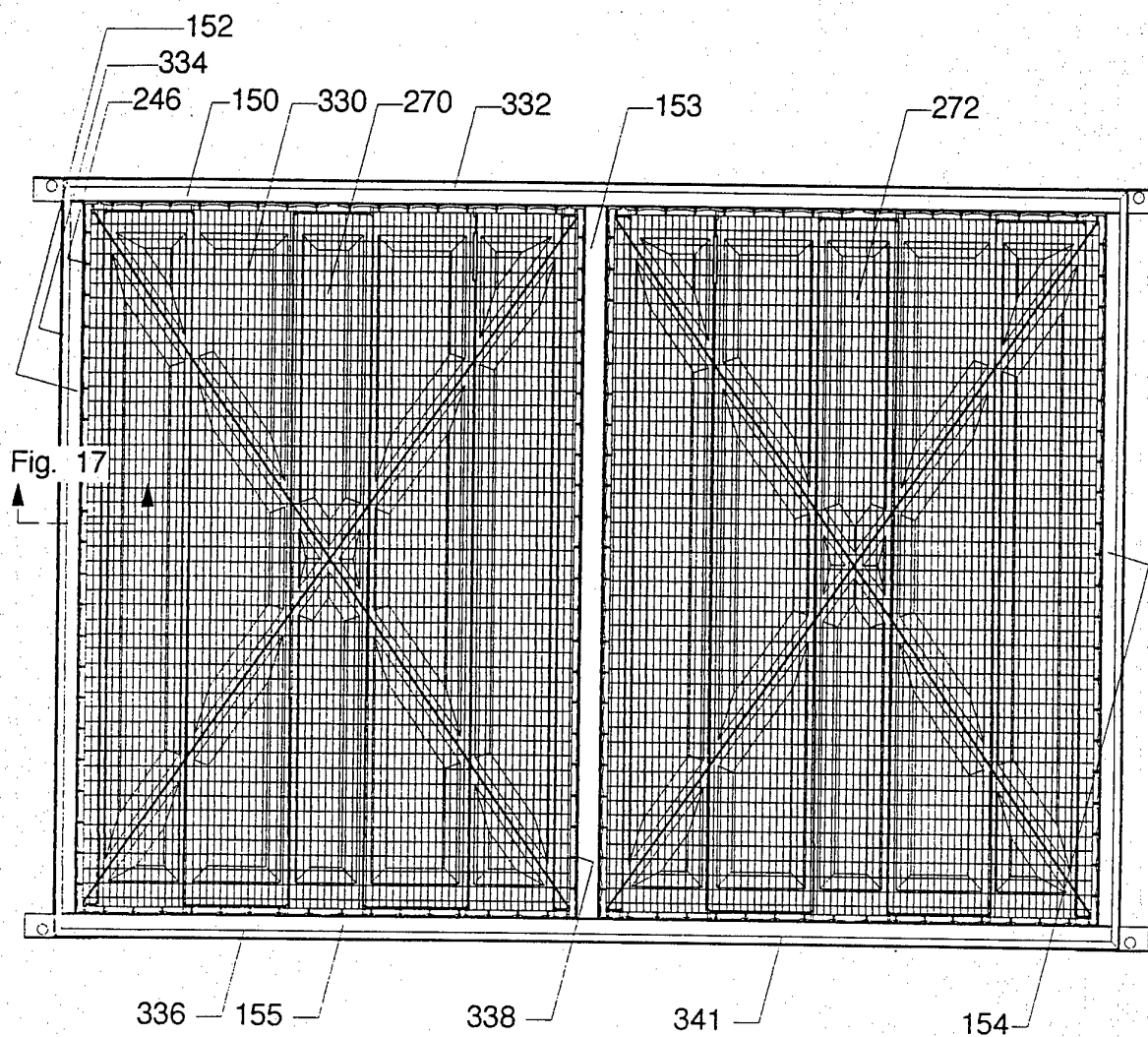


Figure 16

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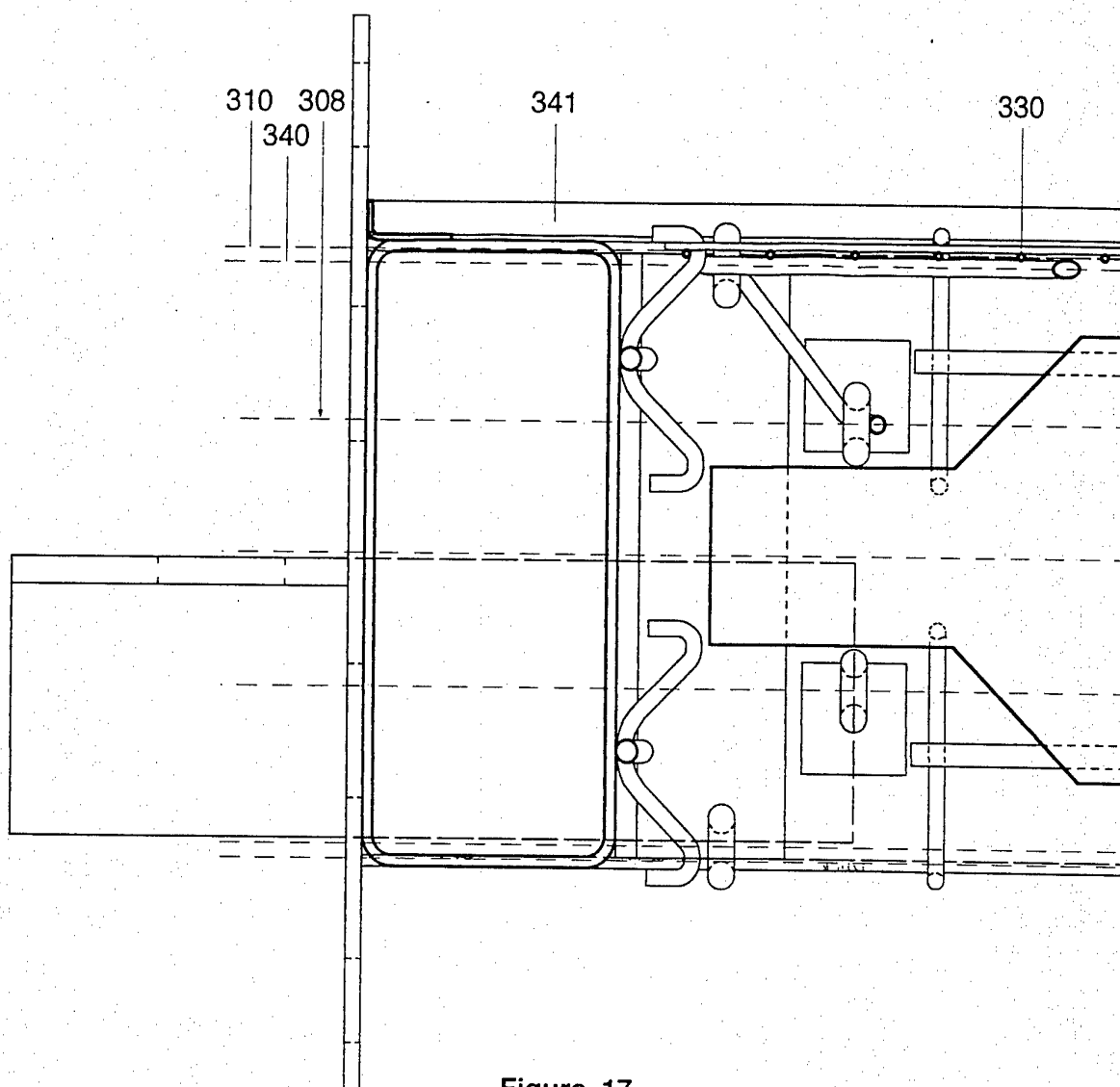


Figure 17

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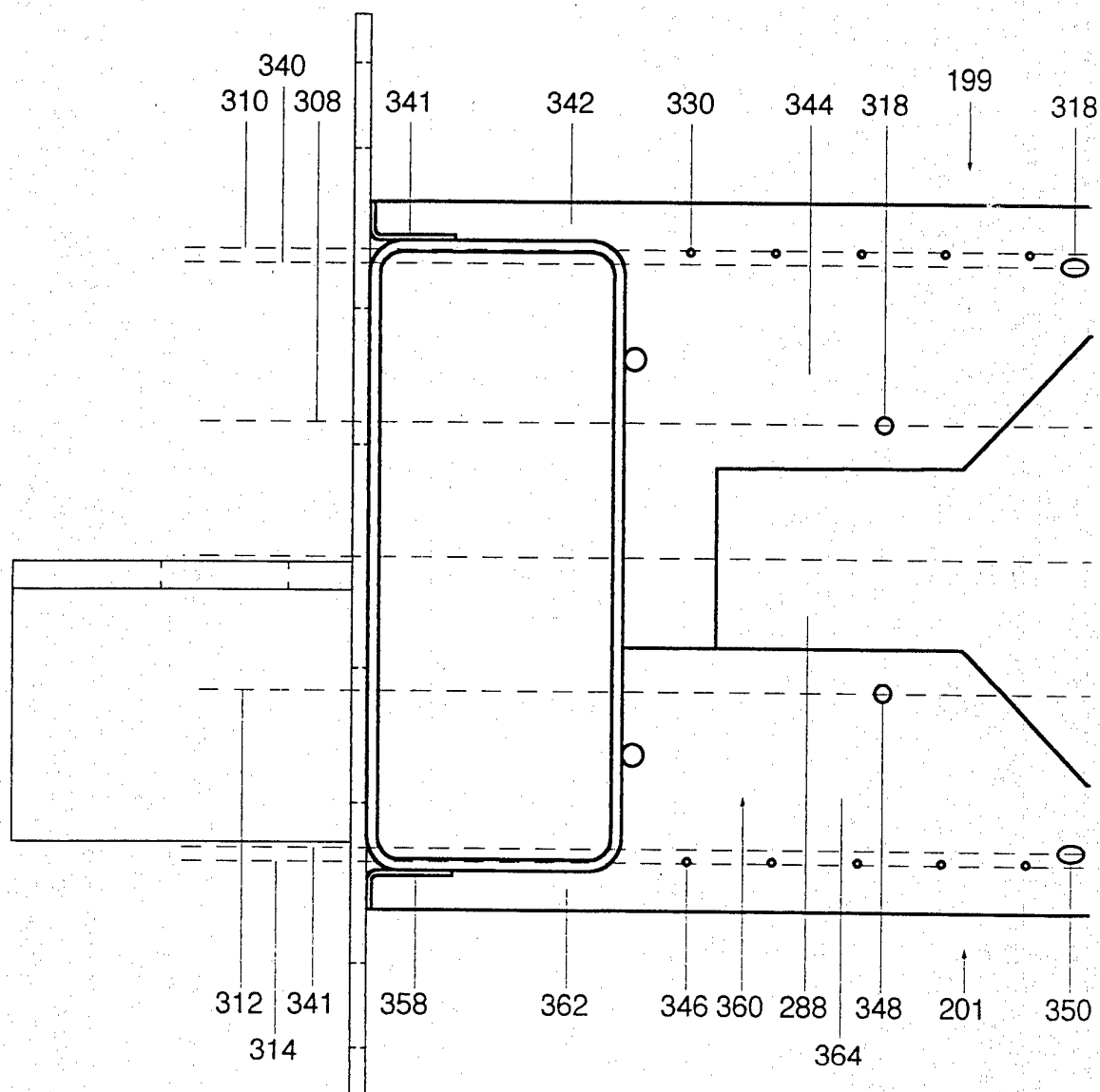


Figure 19

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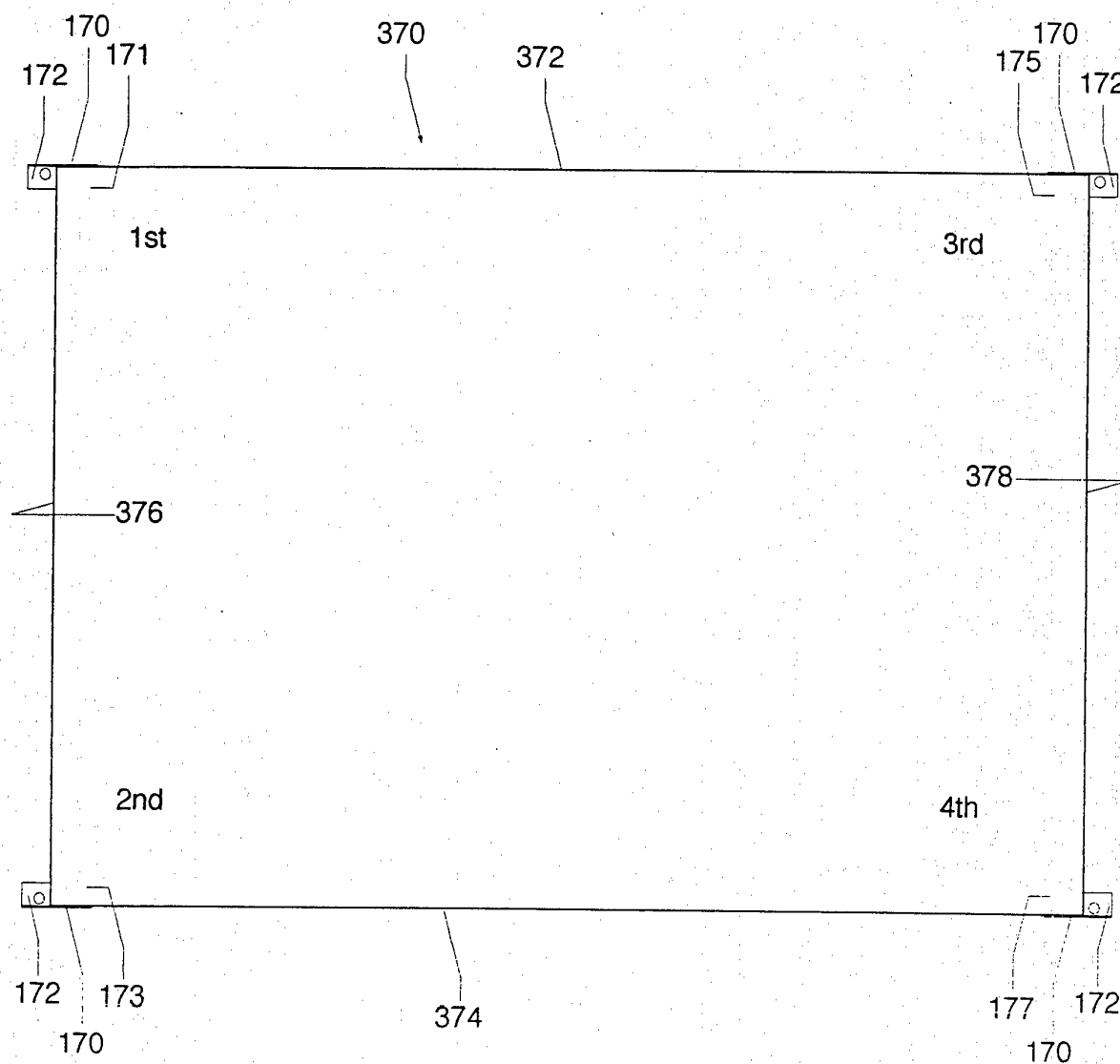


Figure 20

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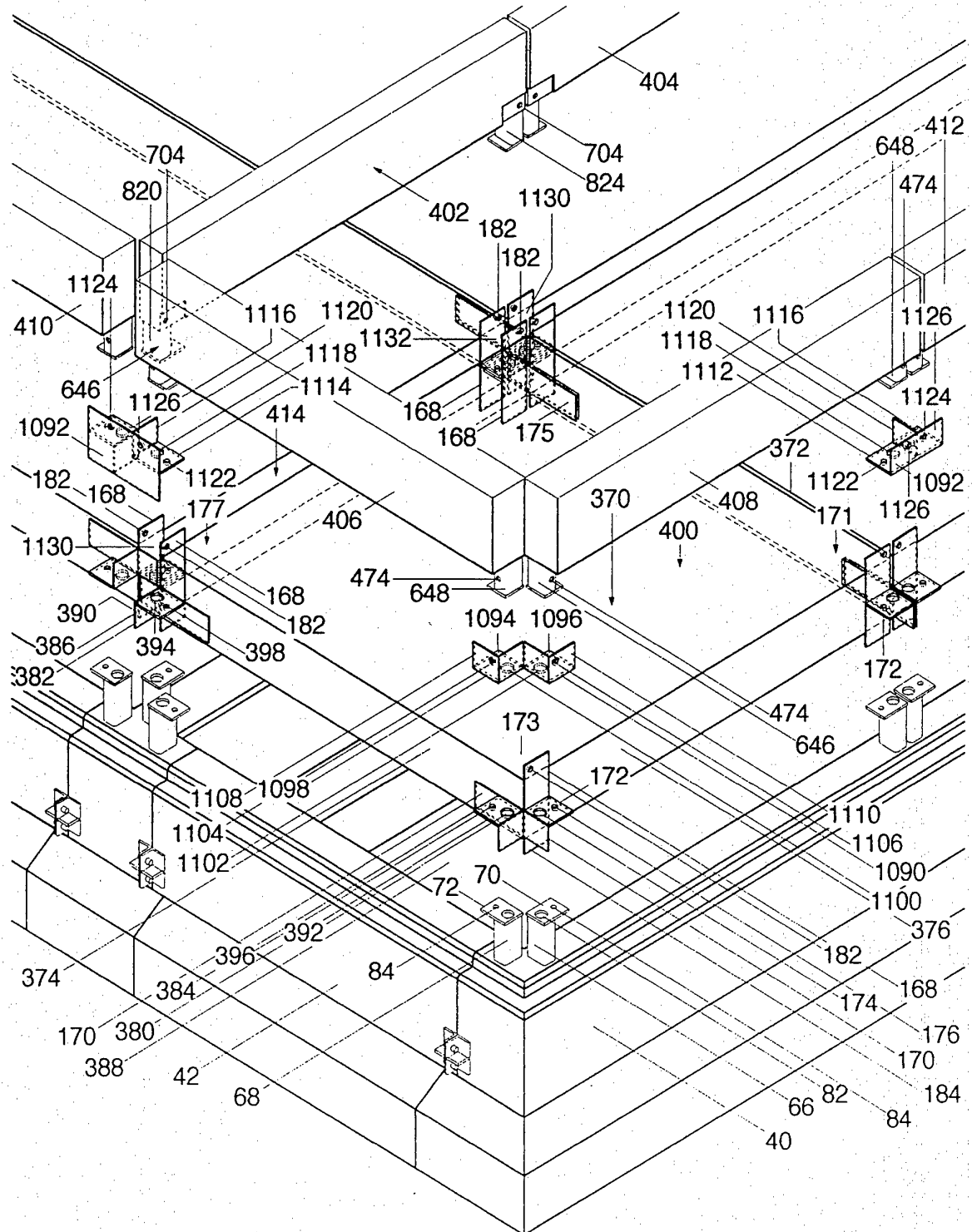


Figure 21

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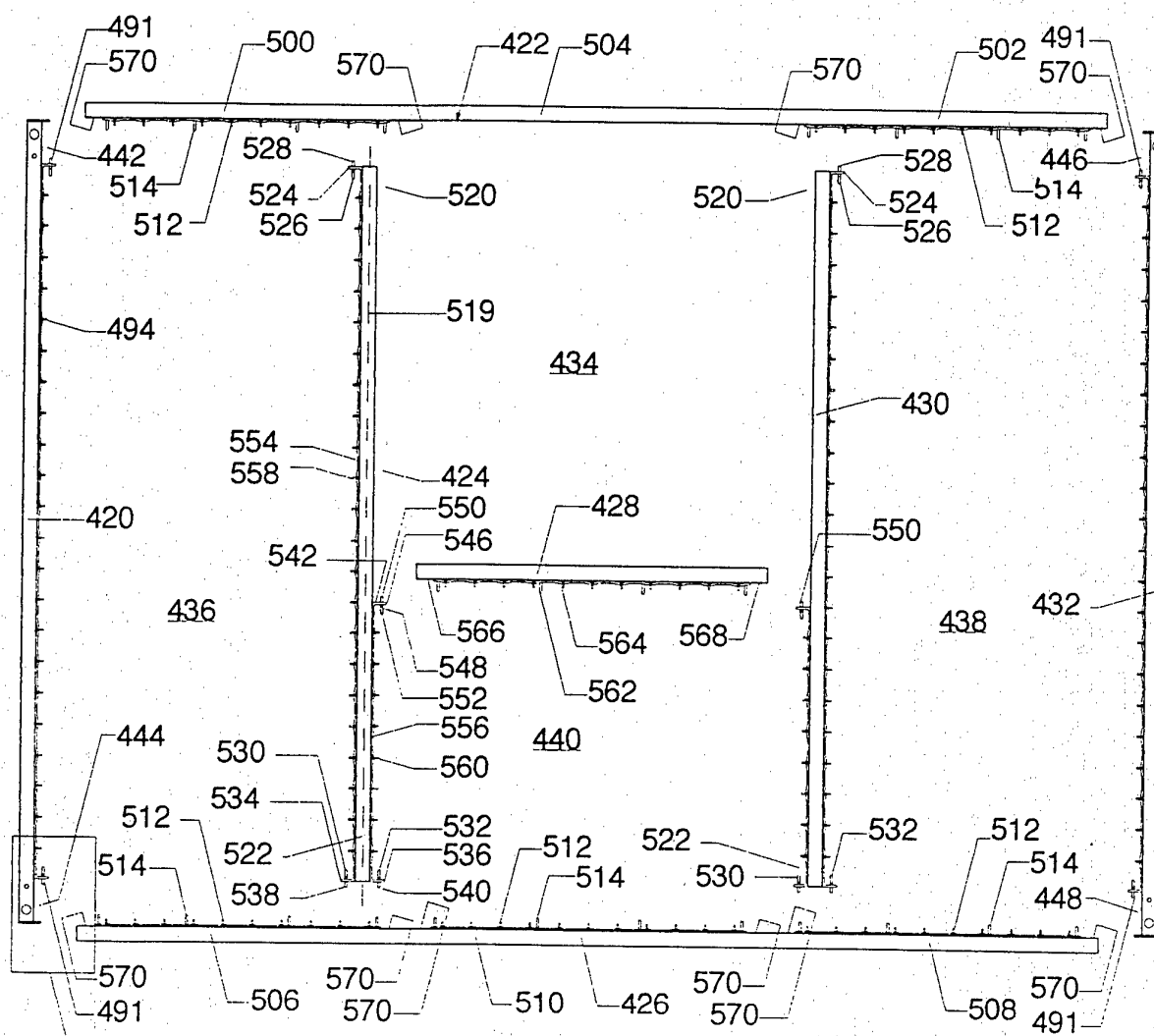


Figure 23

Figure 22

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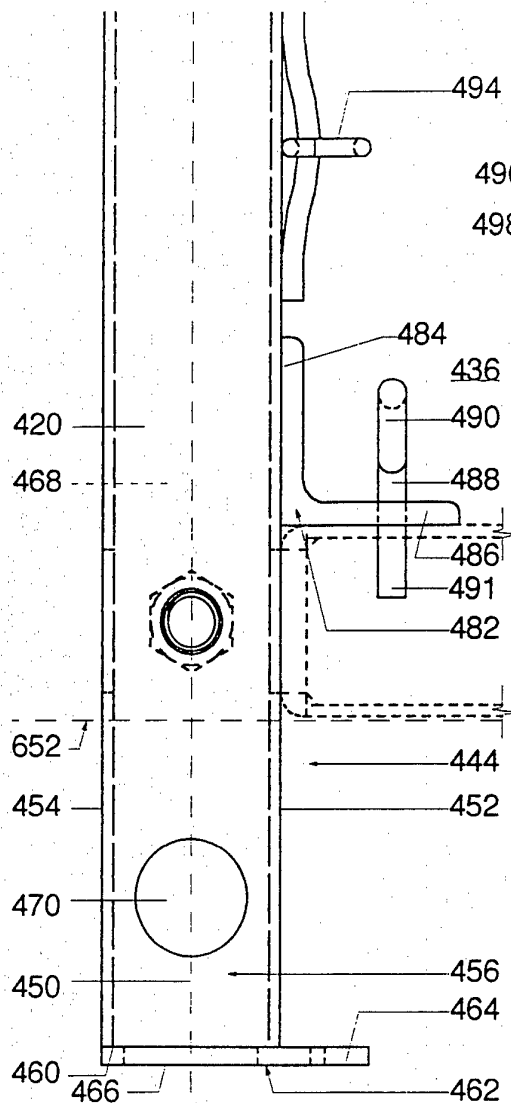


Figure 23

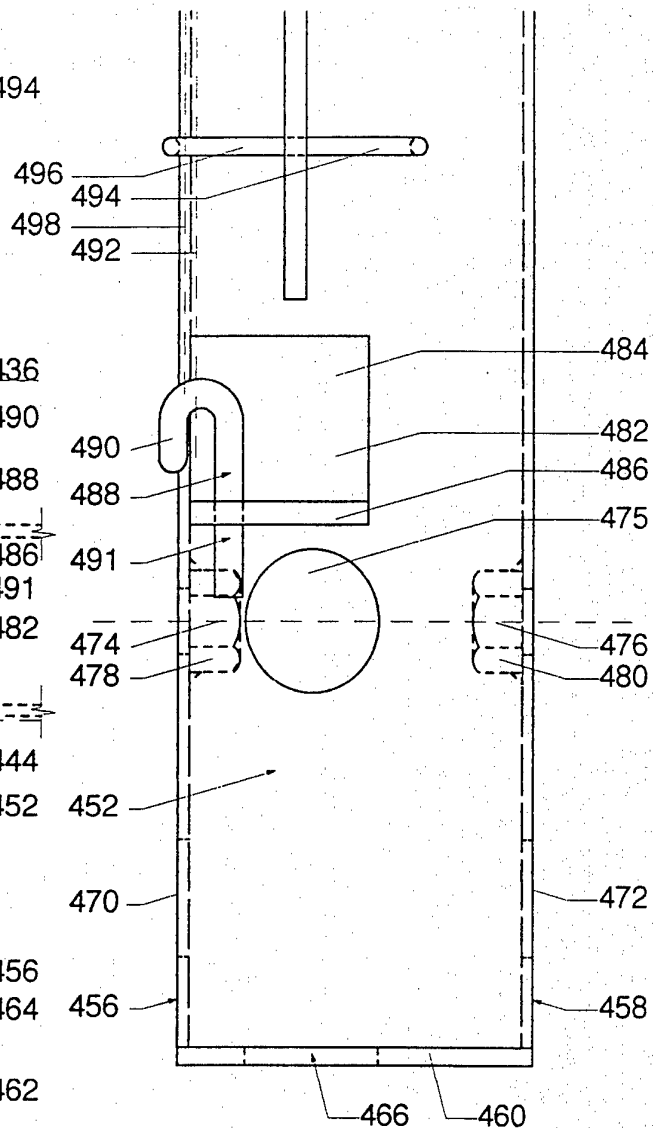


Figure 24

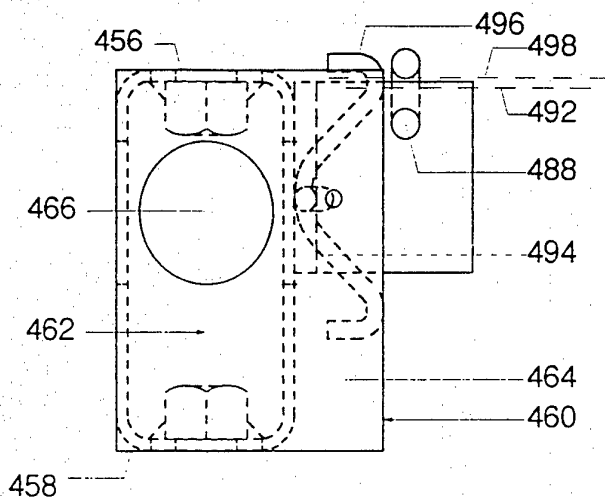


Figure 25

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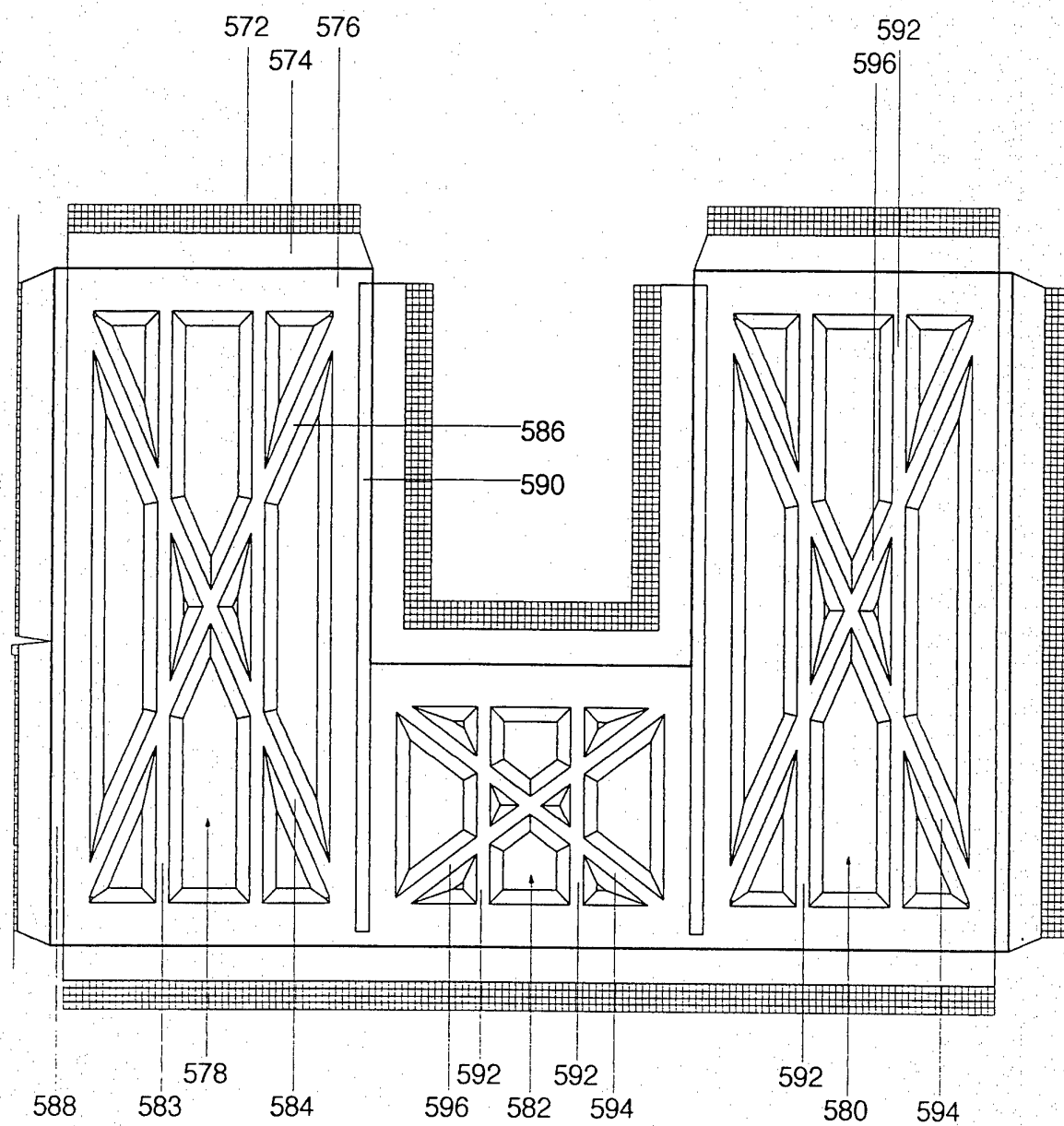


Figure 27

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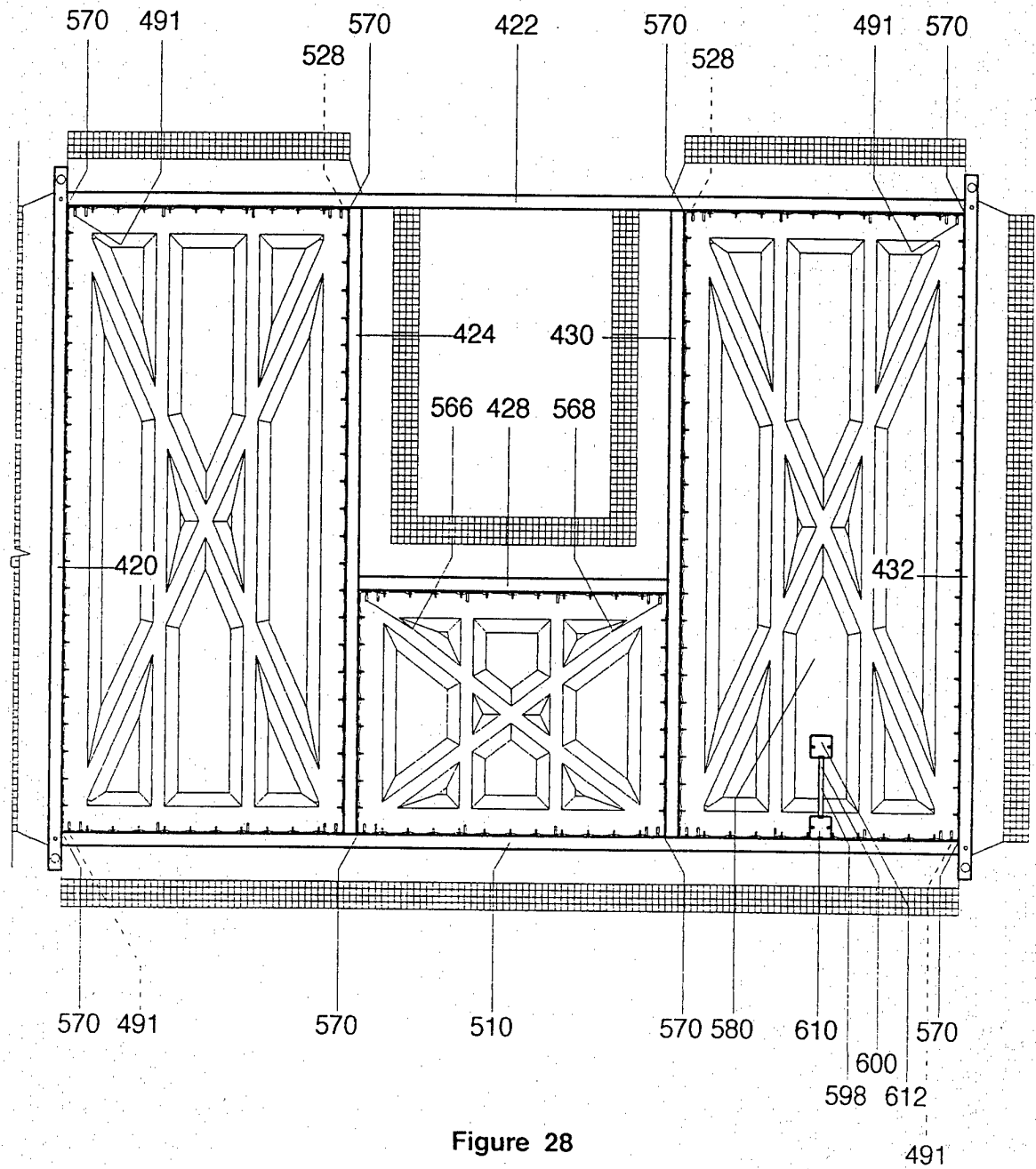


Figure 28

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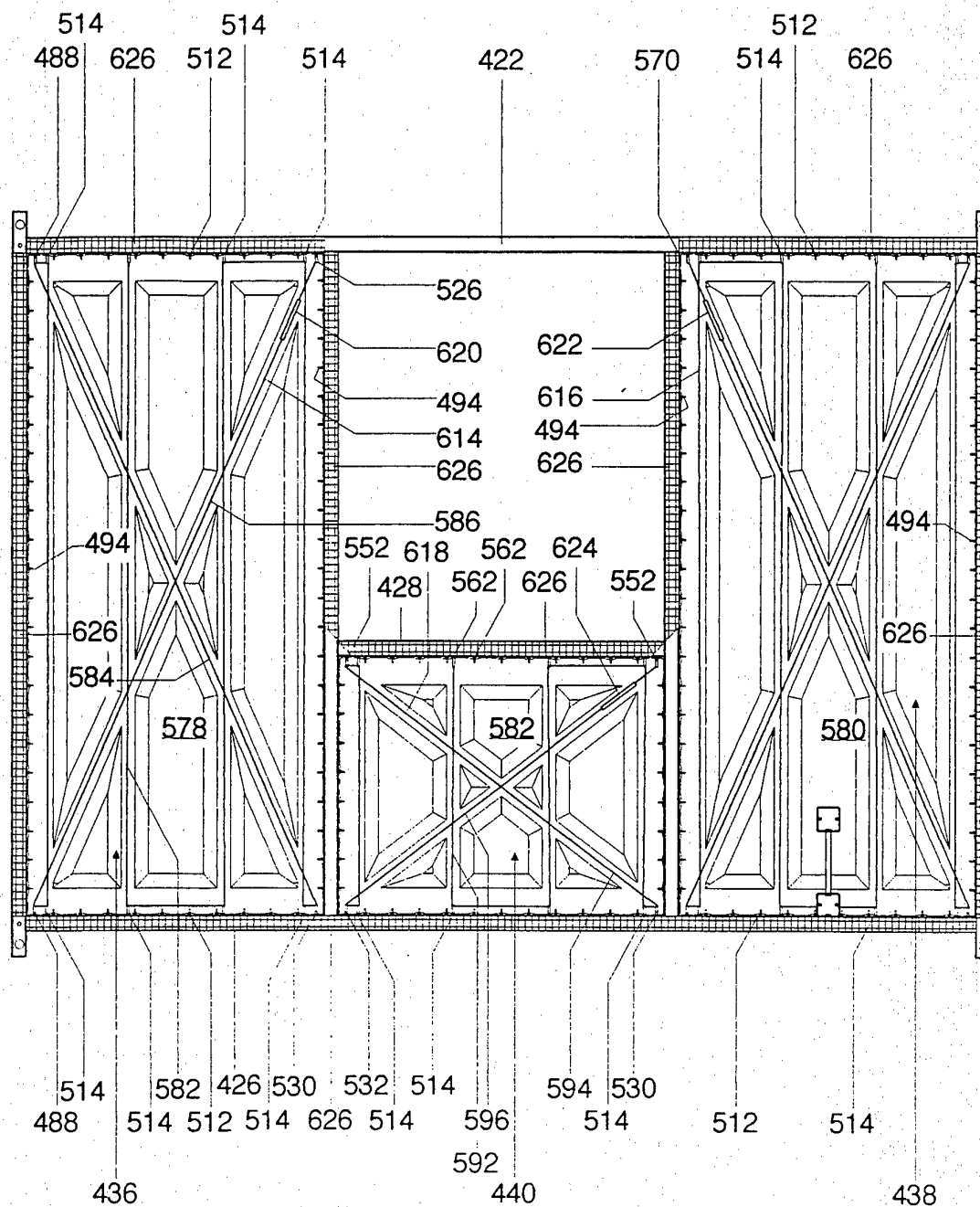
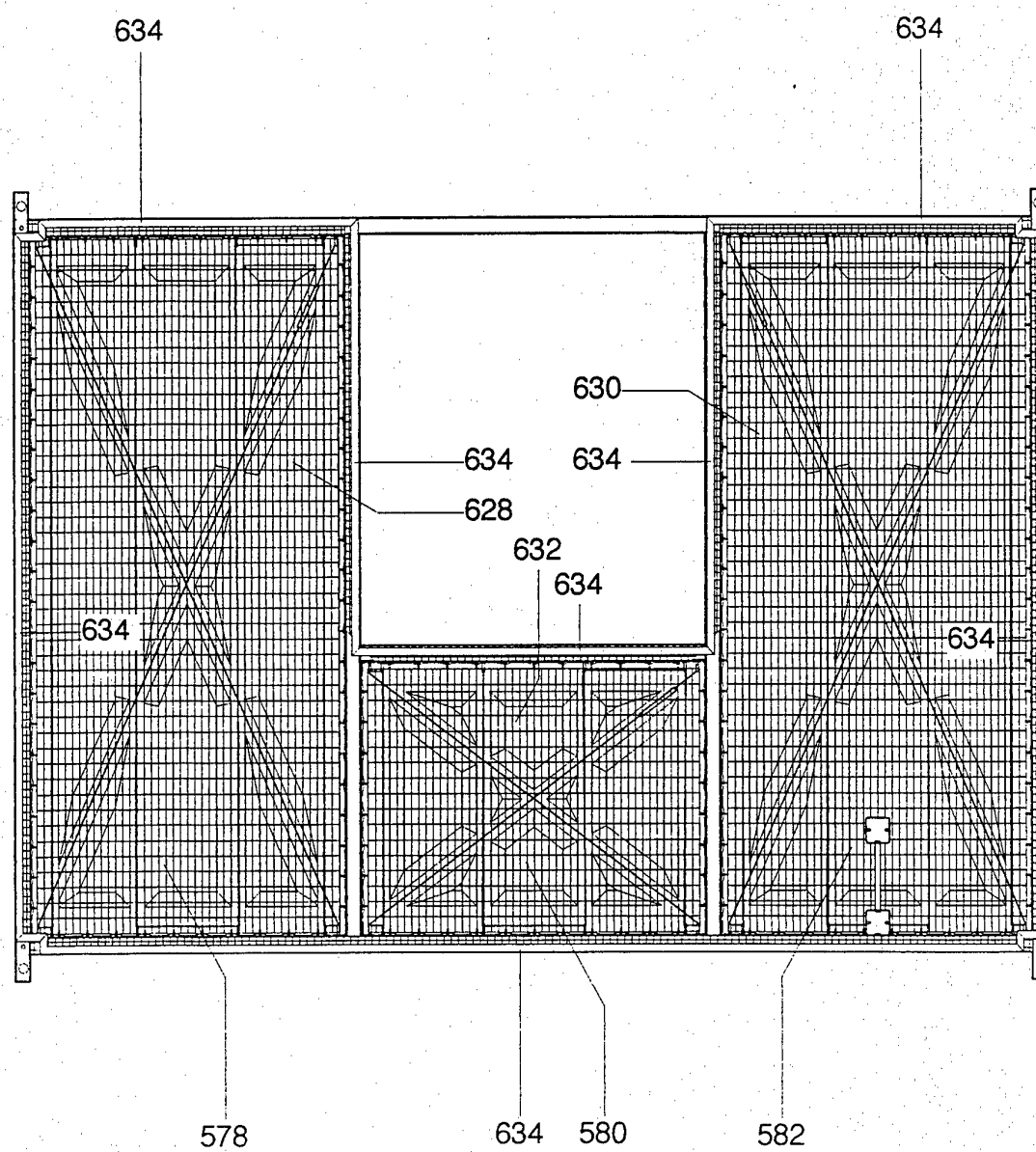


Figure 29

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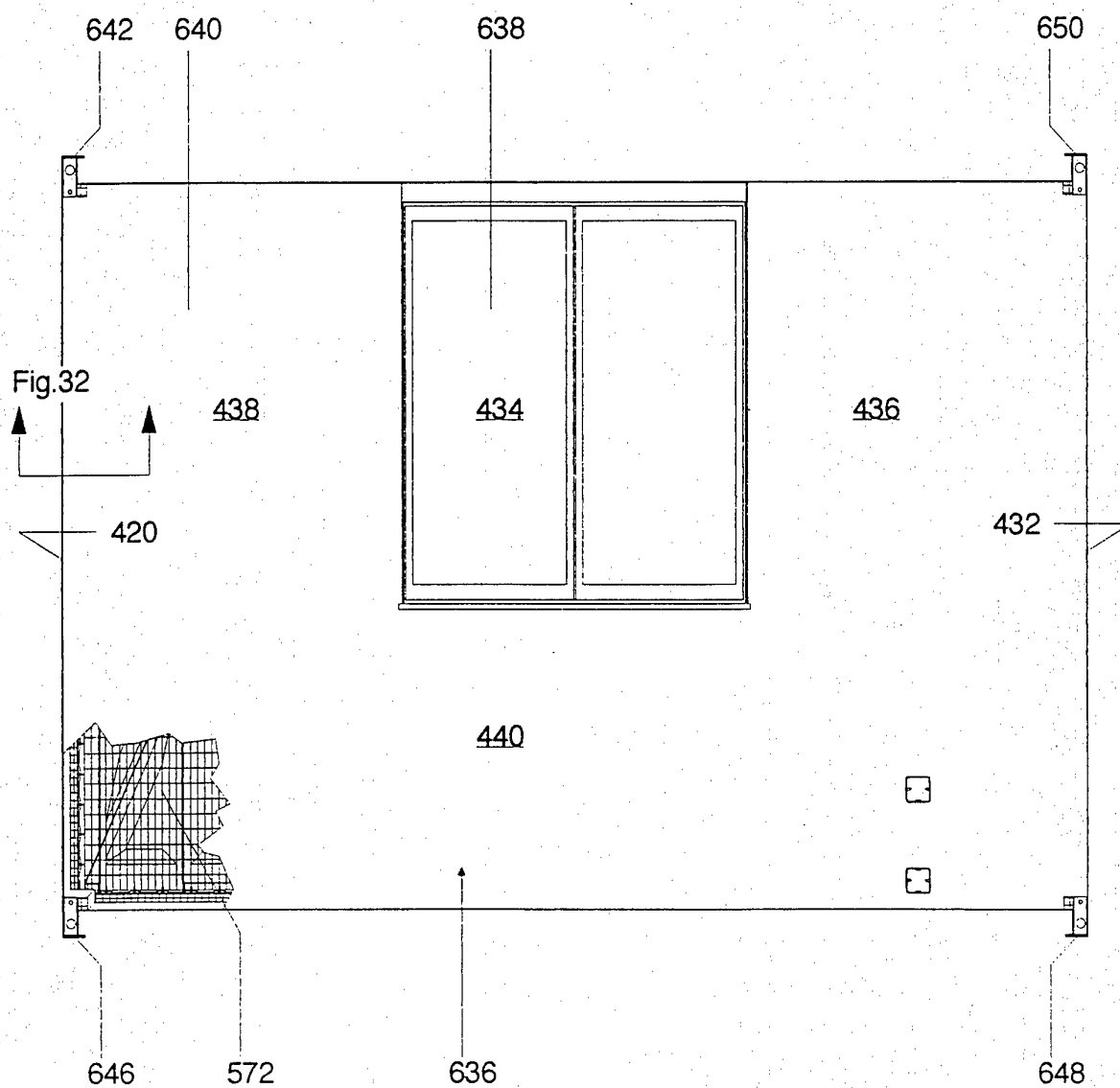


Figure 31

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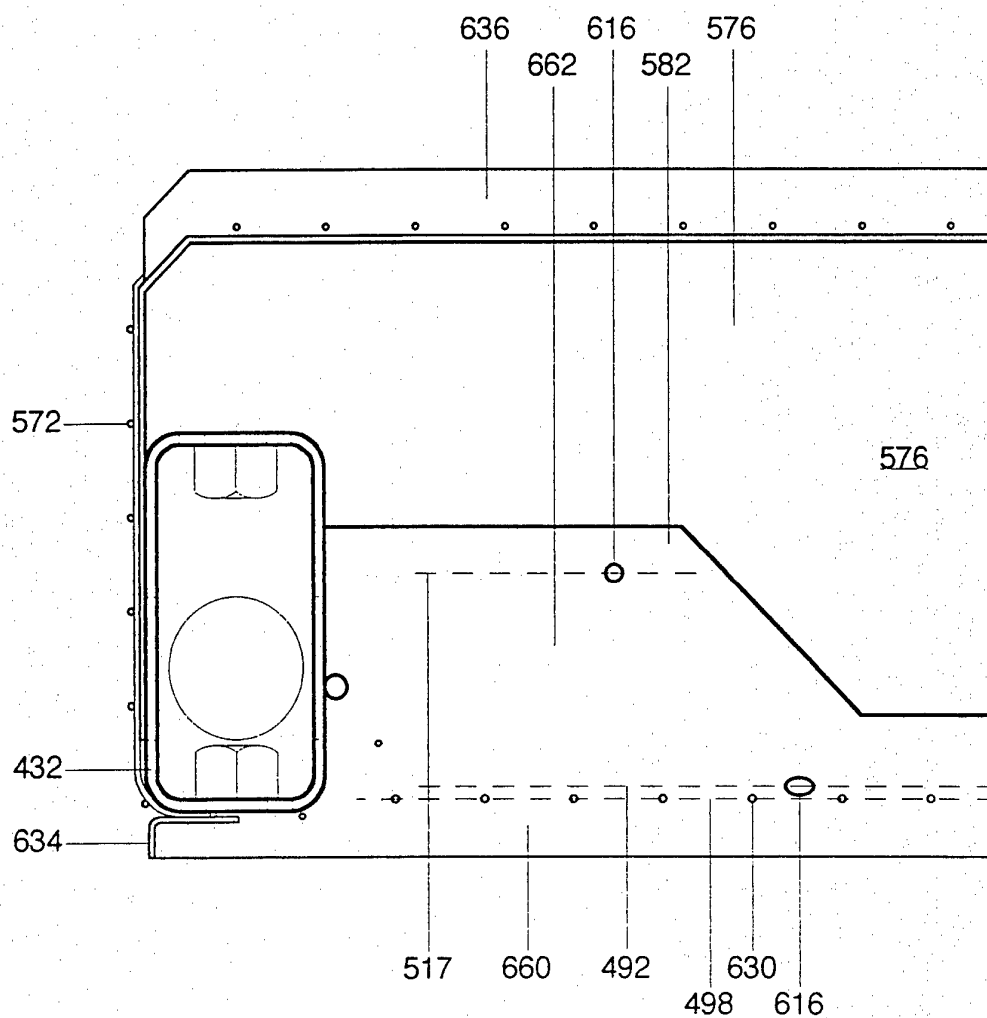


Figure 32

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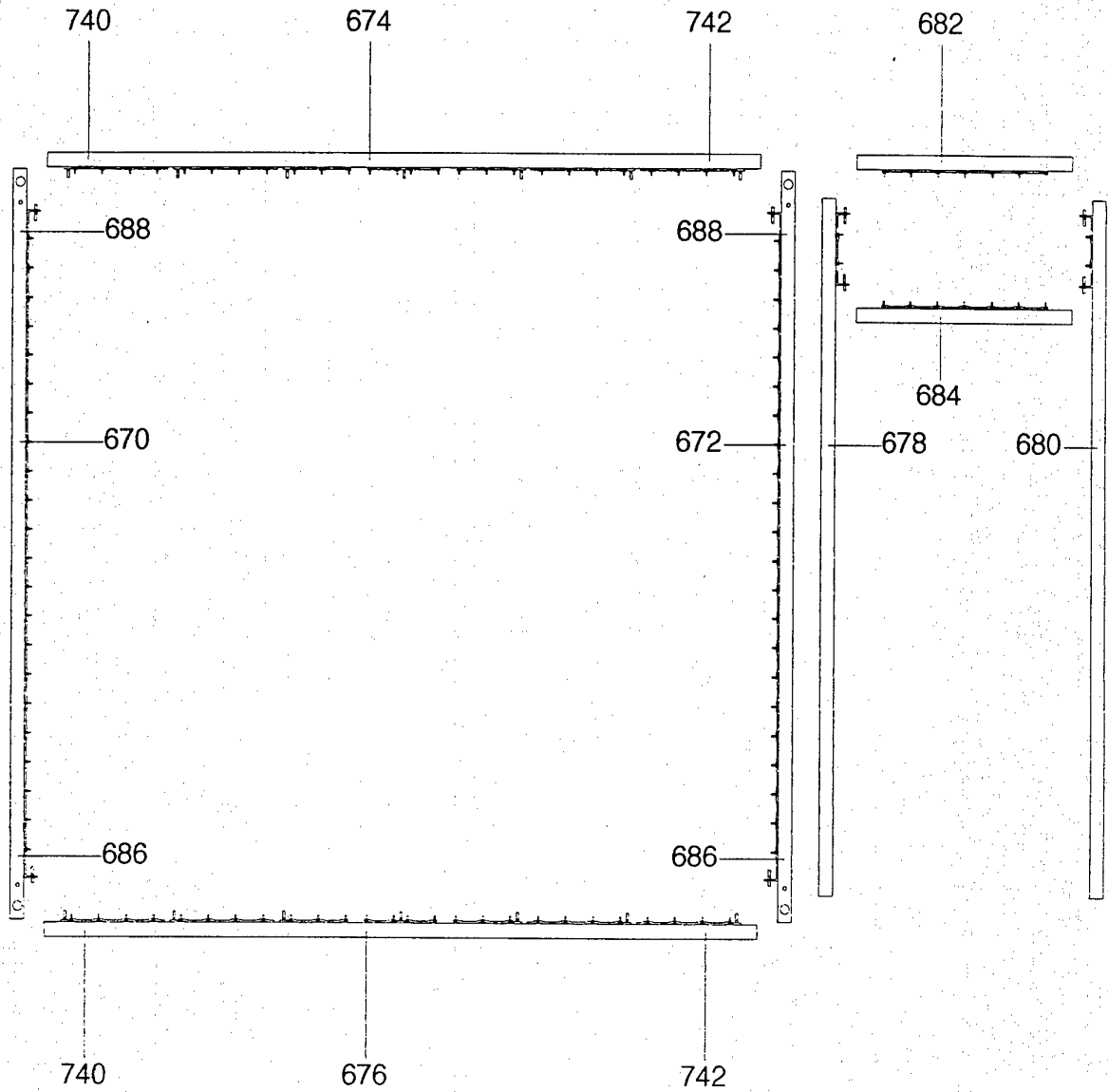


Figure 33

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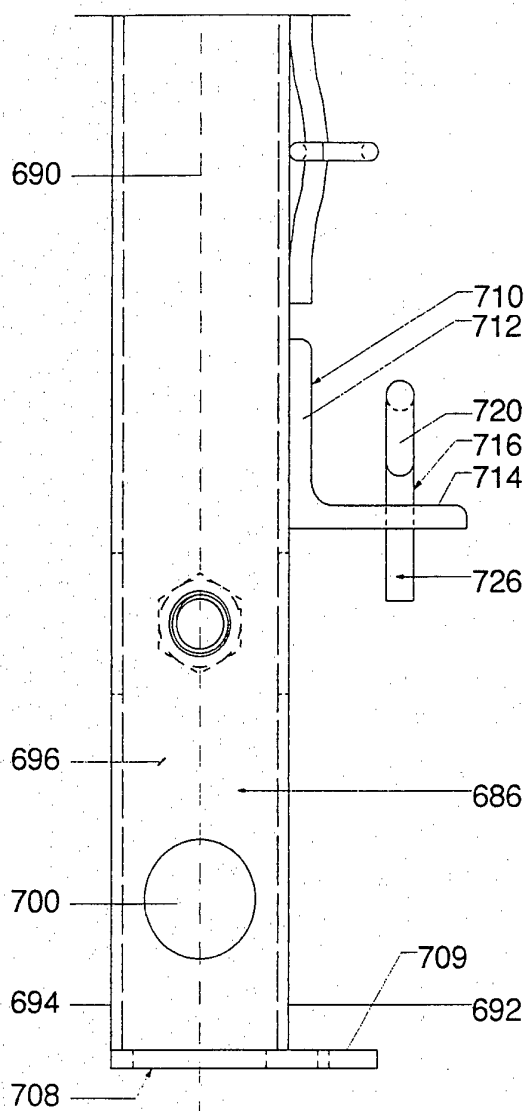


Figure 34

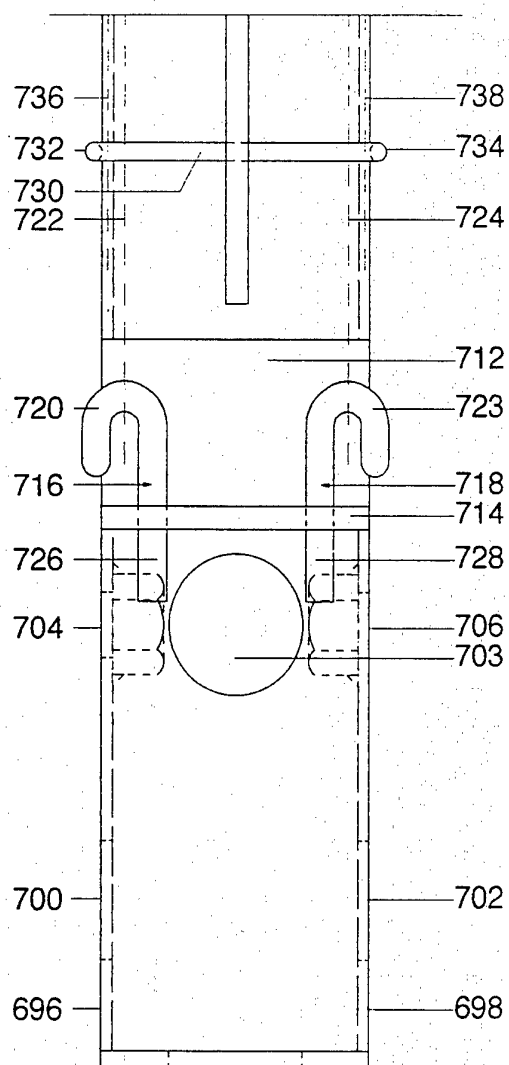


Figure 35

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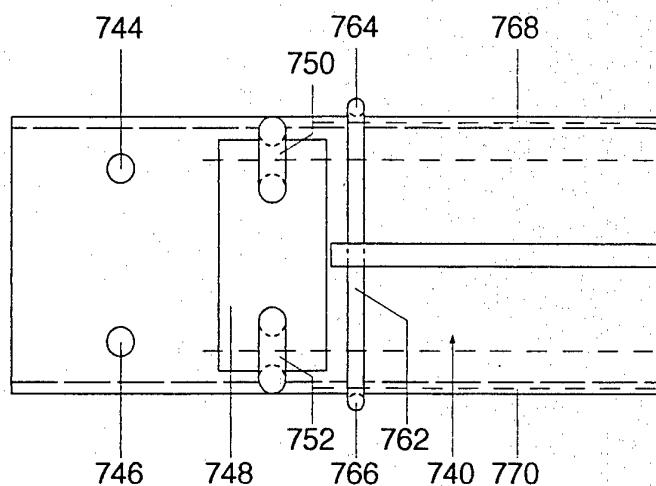


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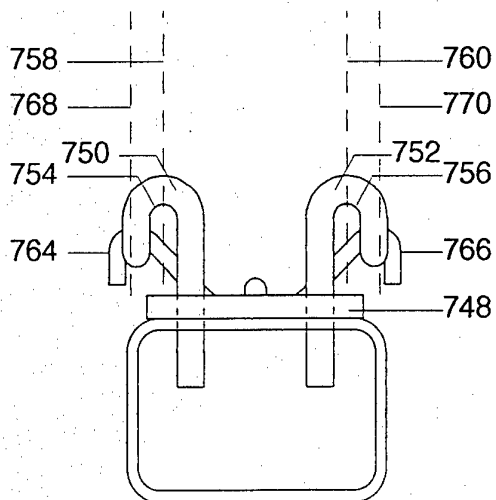


Figure 37

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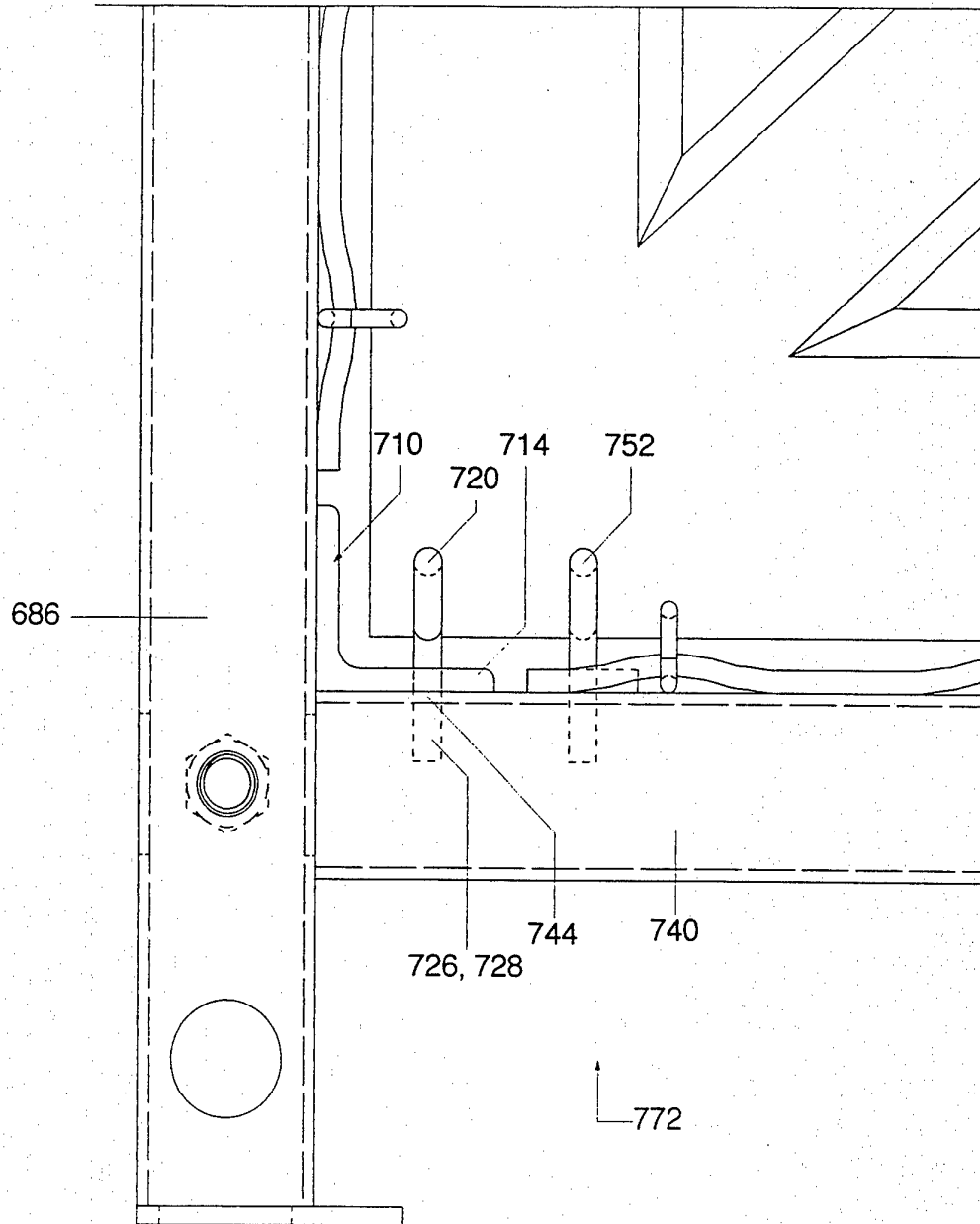


Figure 38

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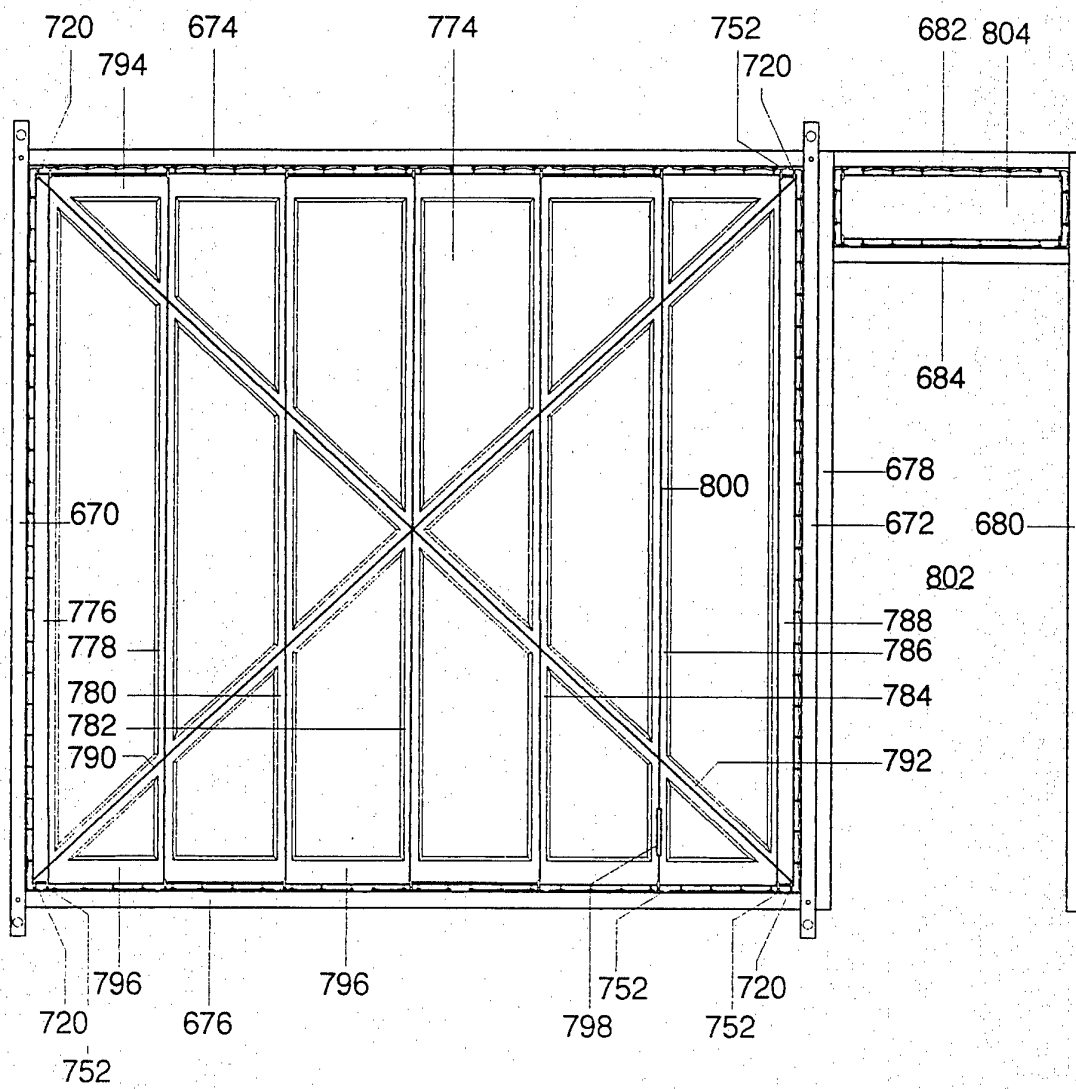


Figure 39

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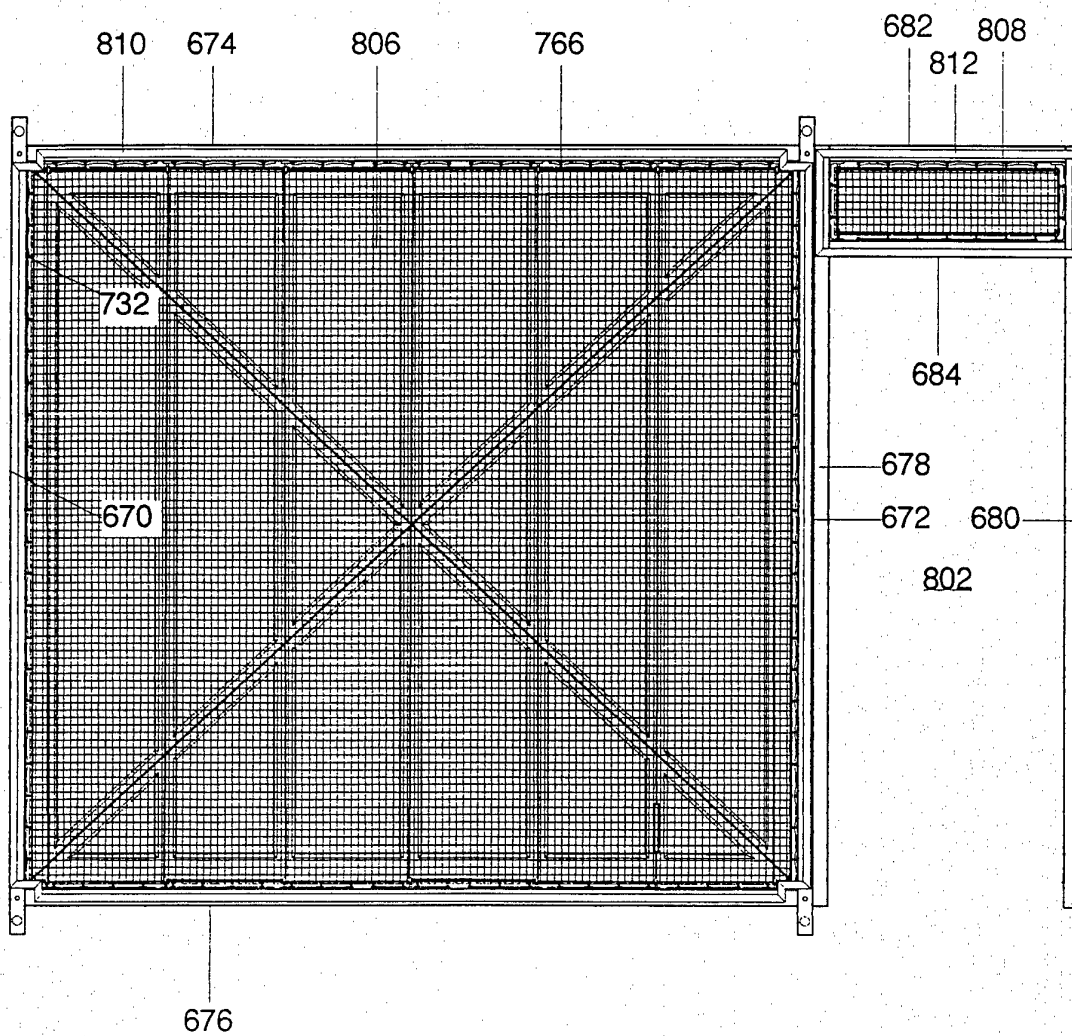


Figure 40

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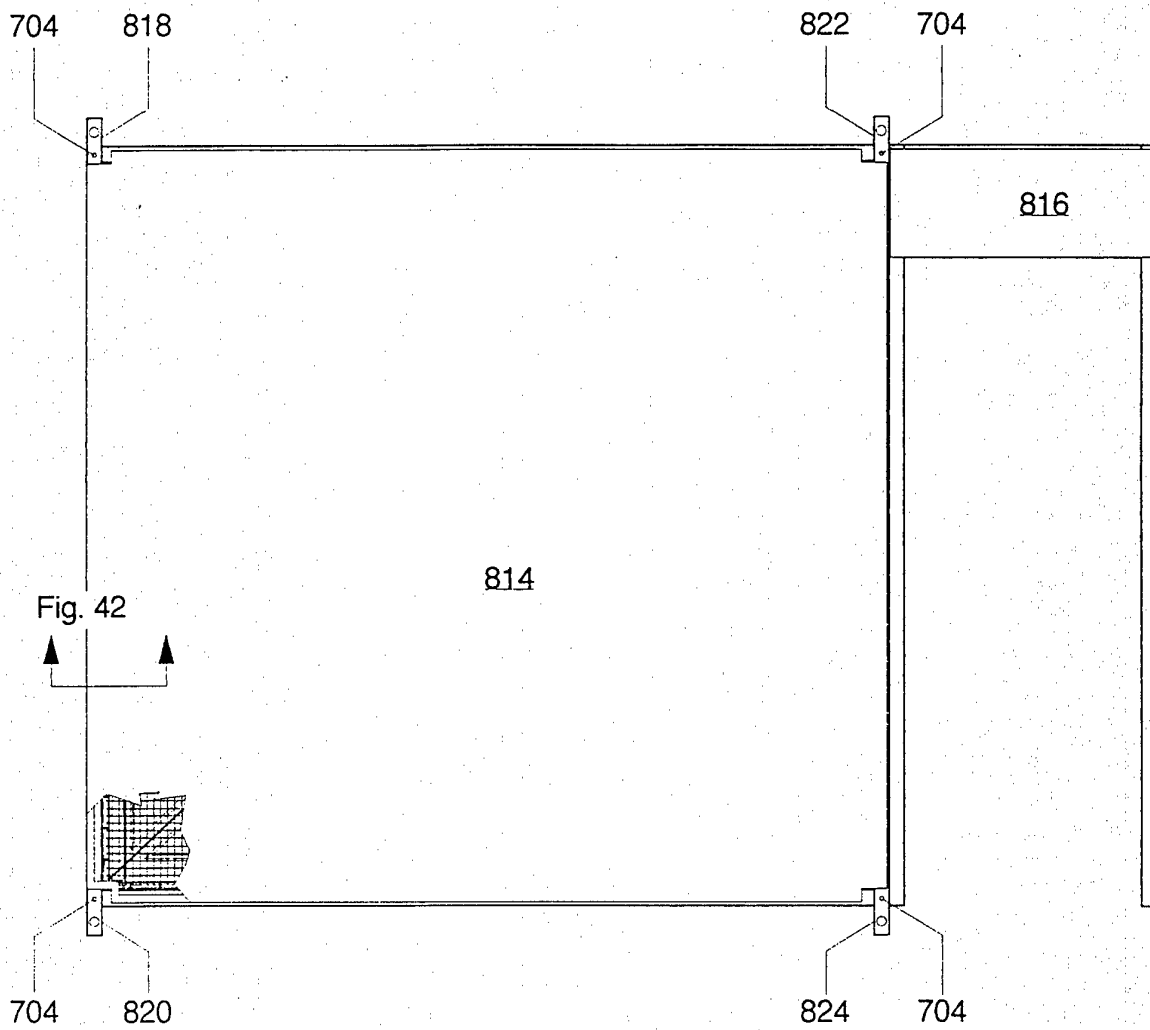


Figure 41

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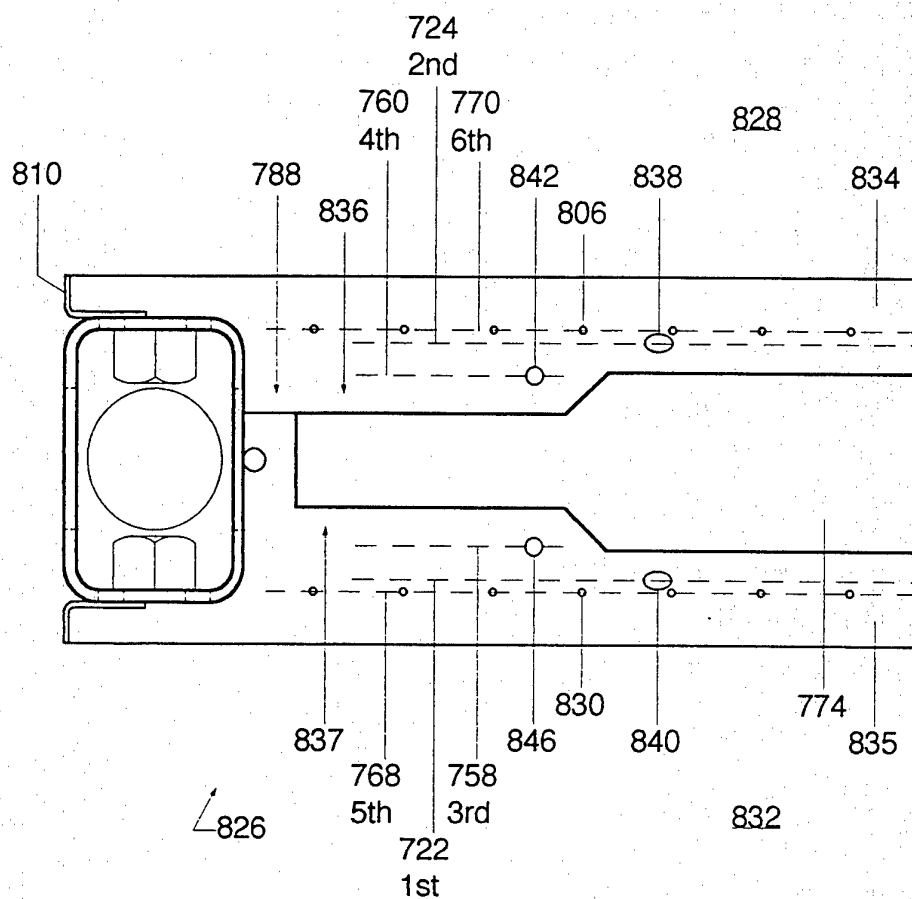


Figure 42

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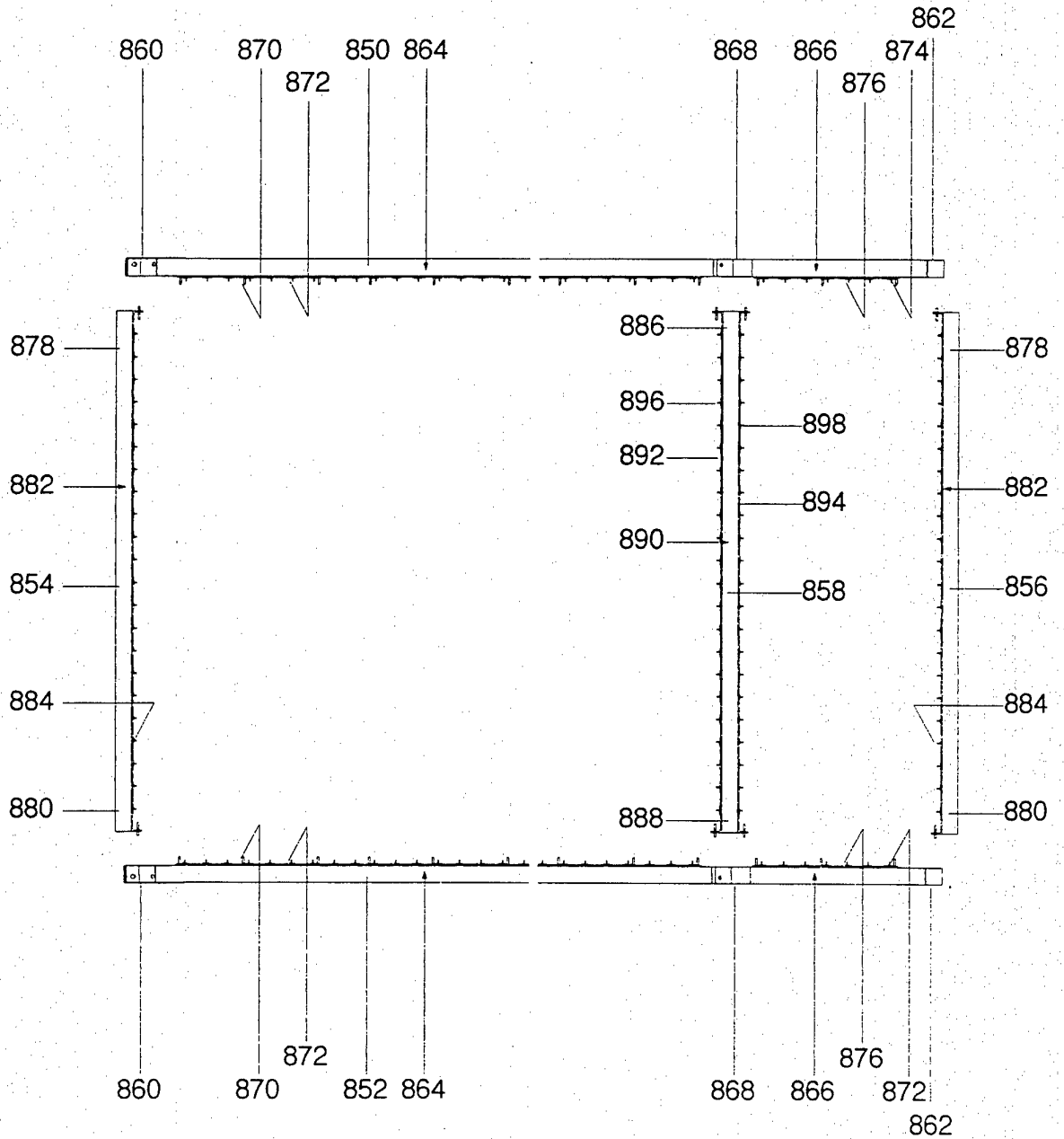
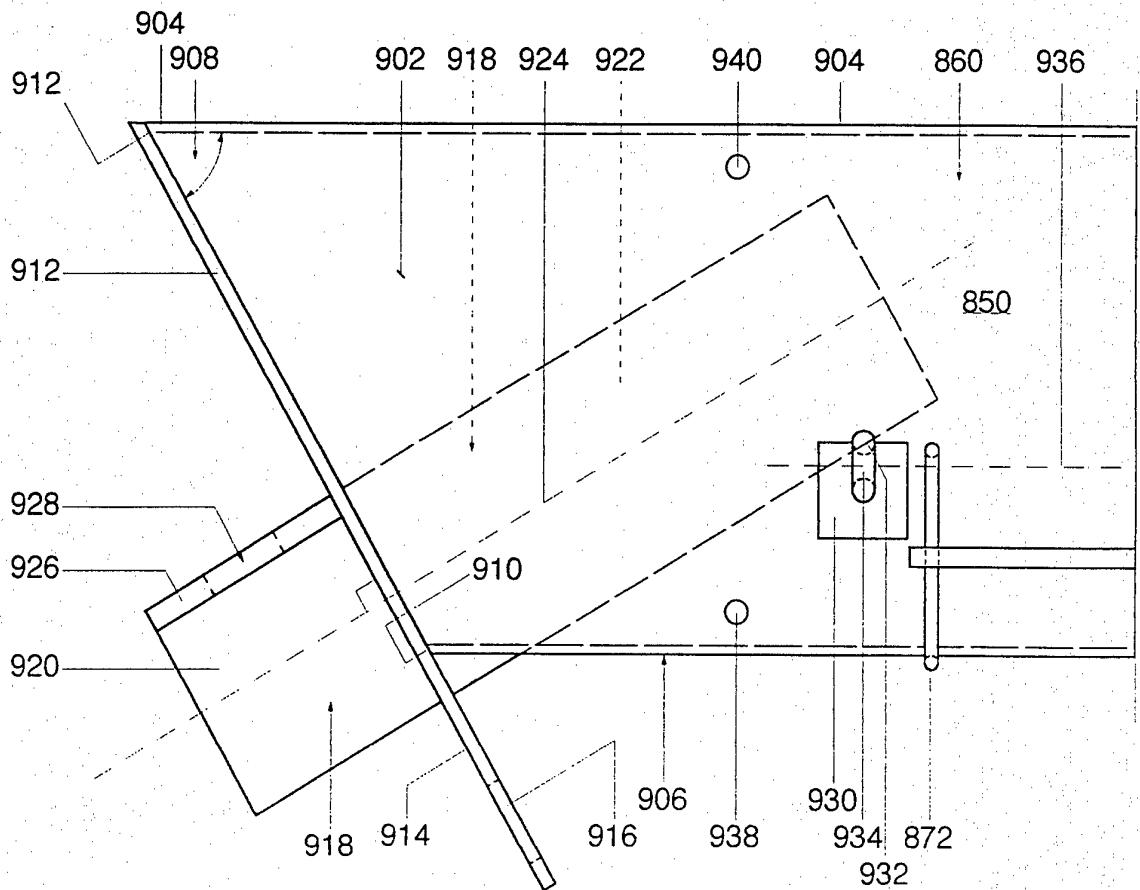
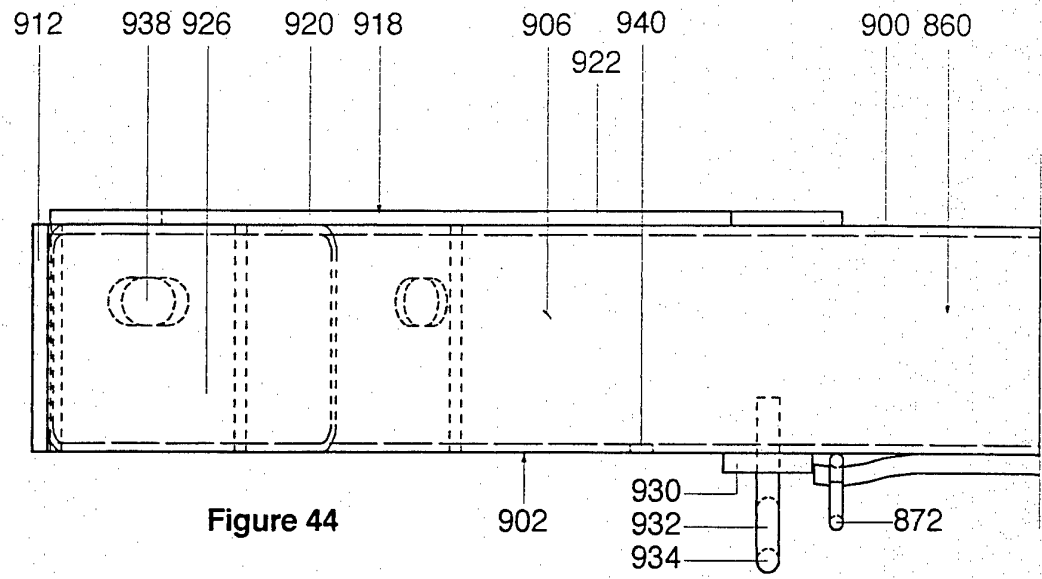


Figure 43

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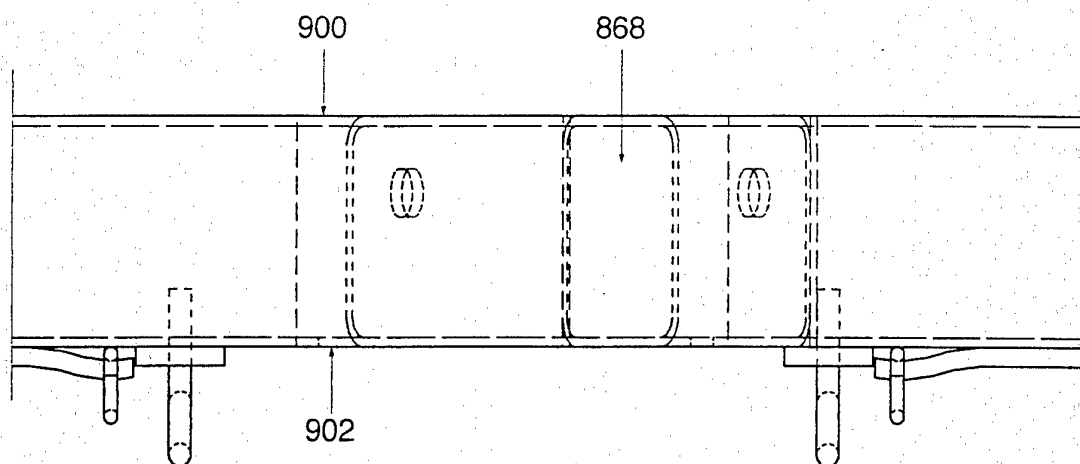


Figure 46

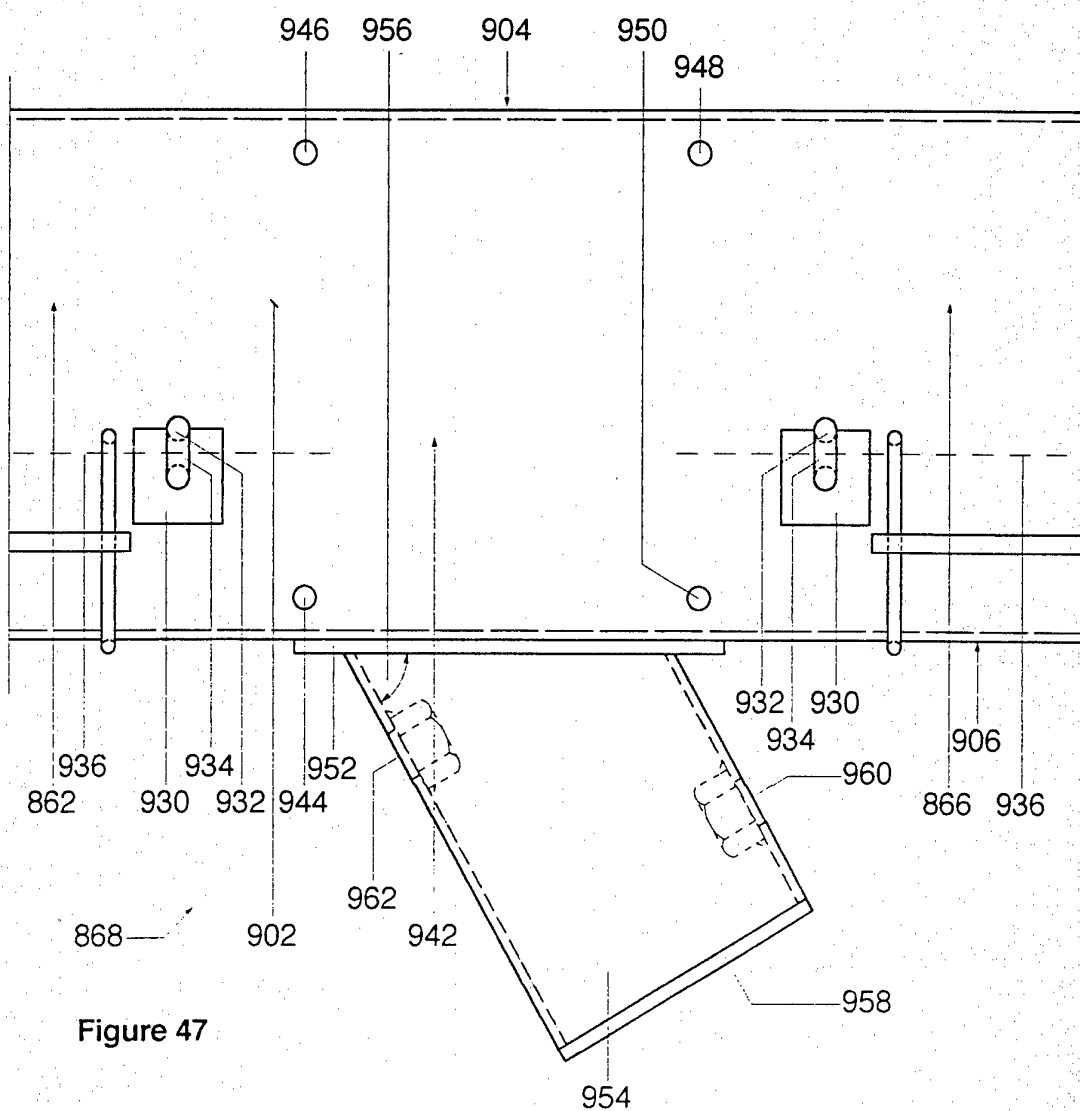
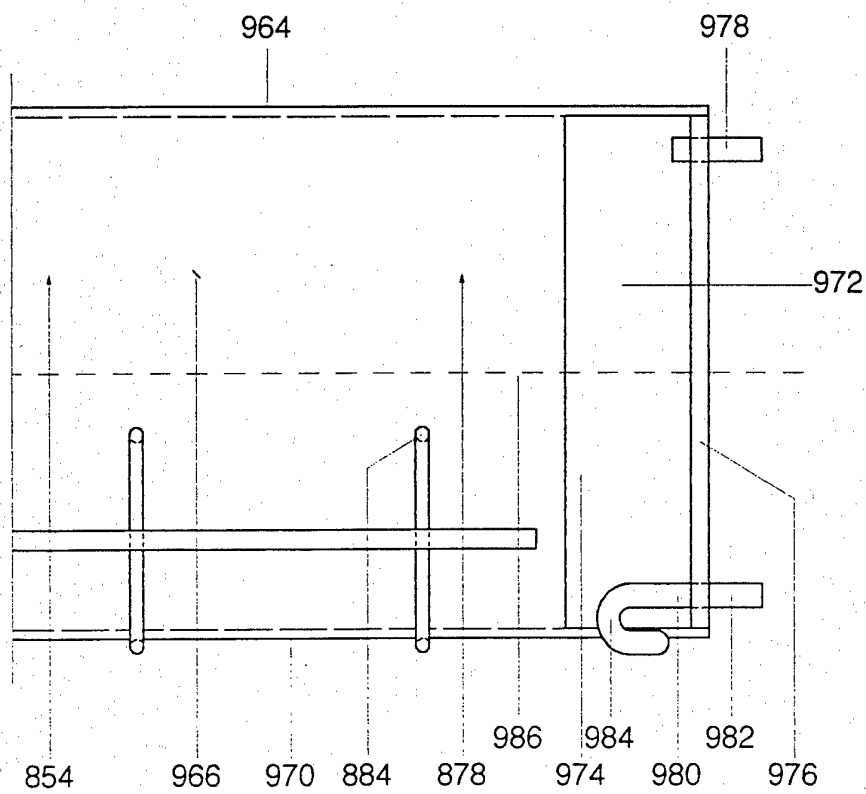
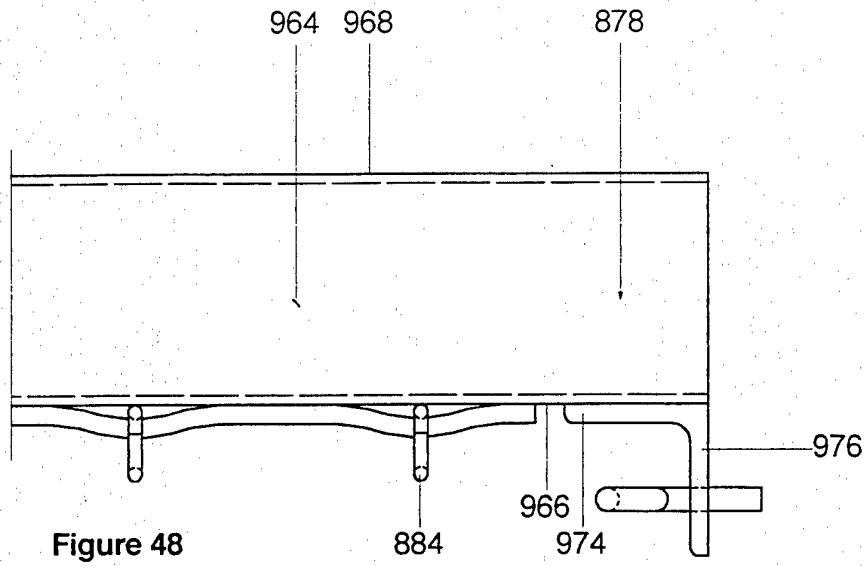


Figure 47

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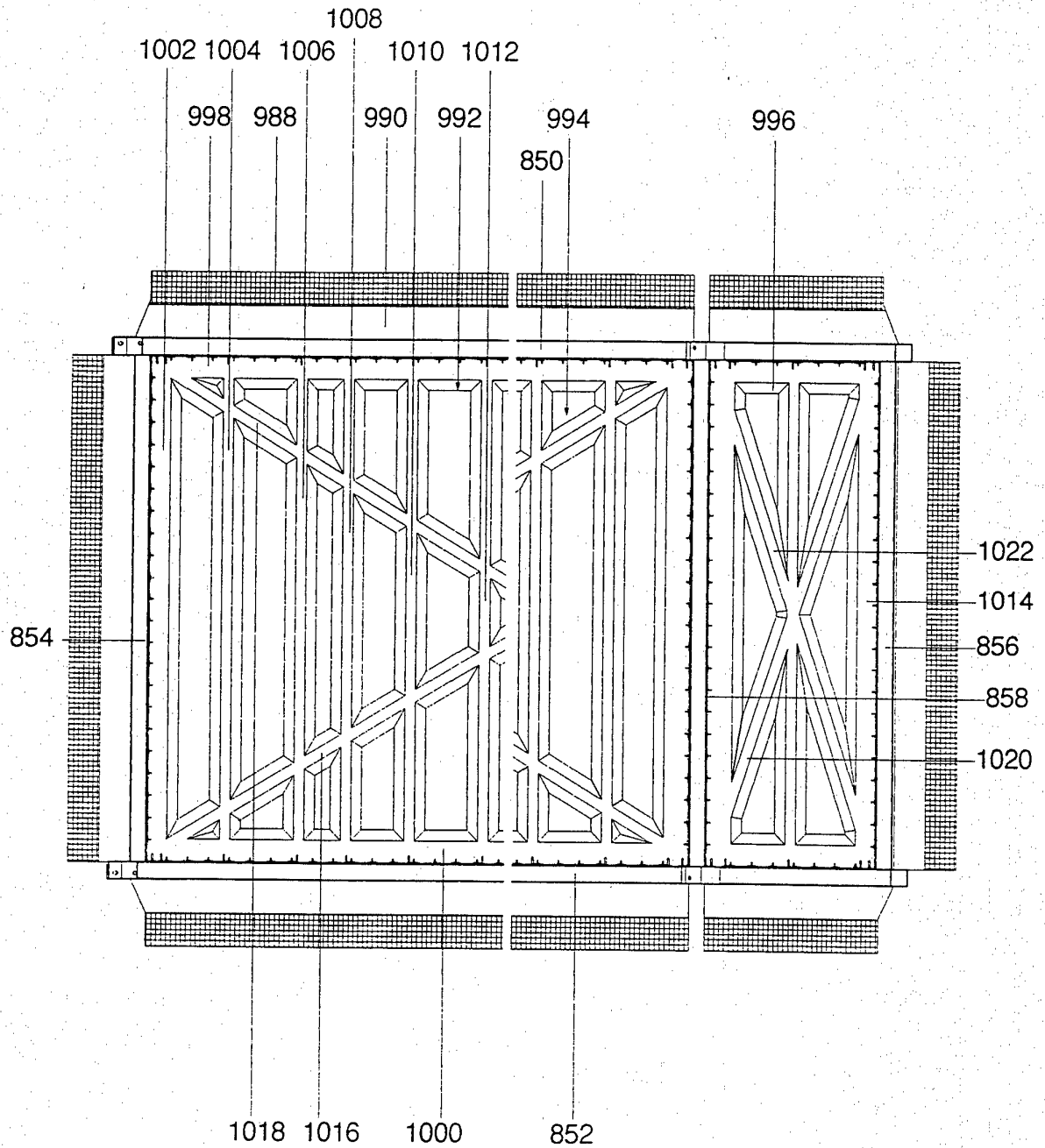


Figure 50

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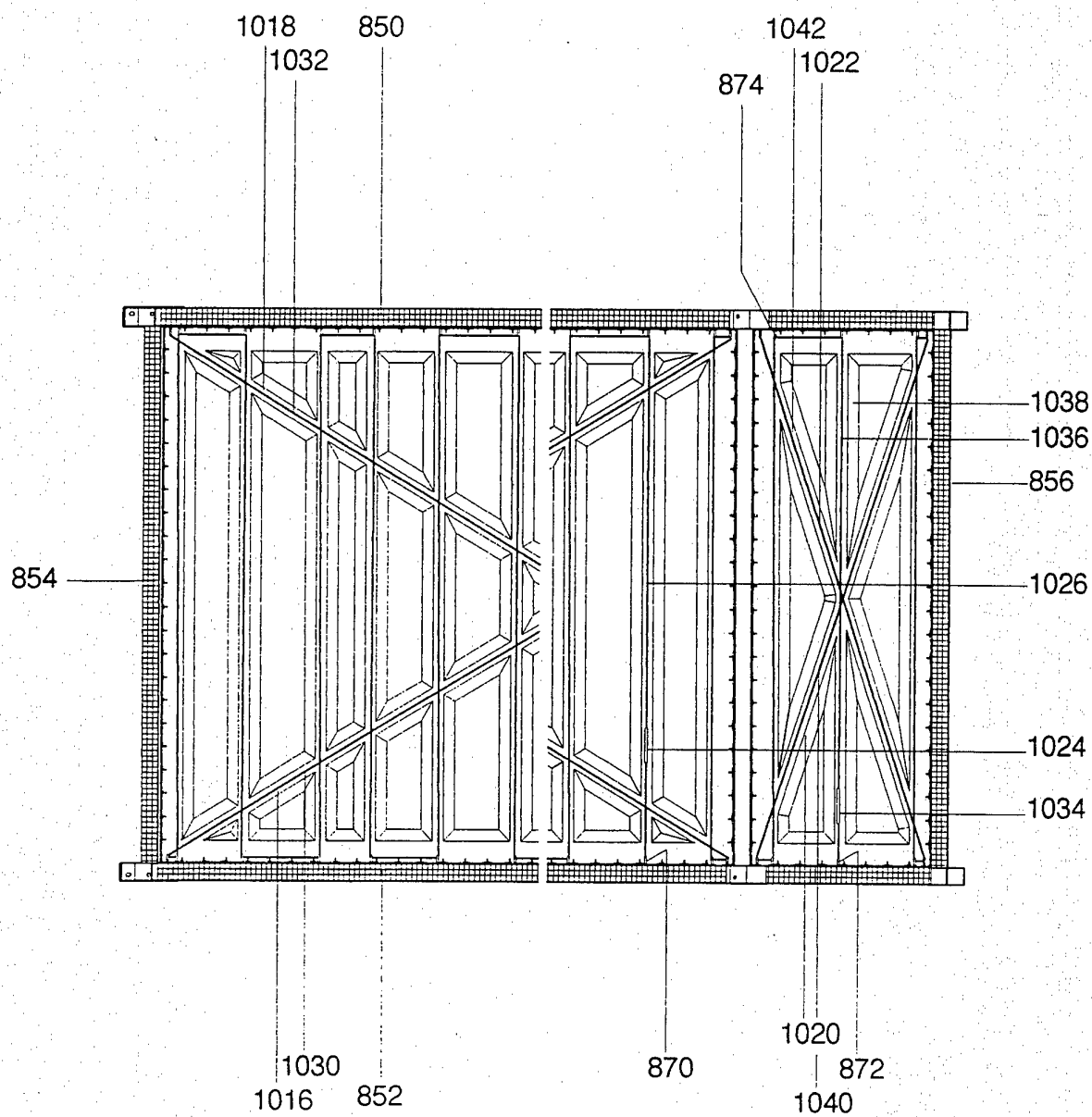


Figure 51

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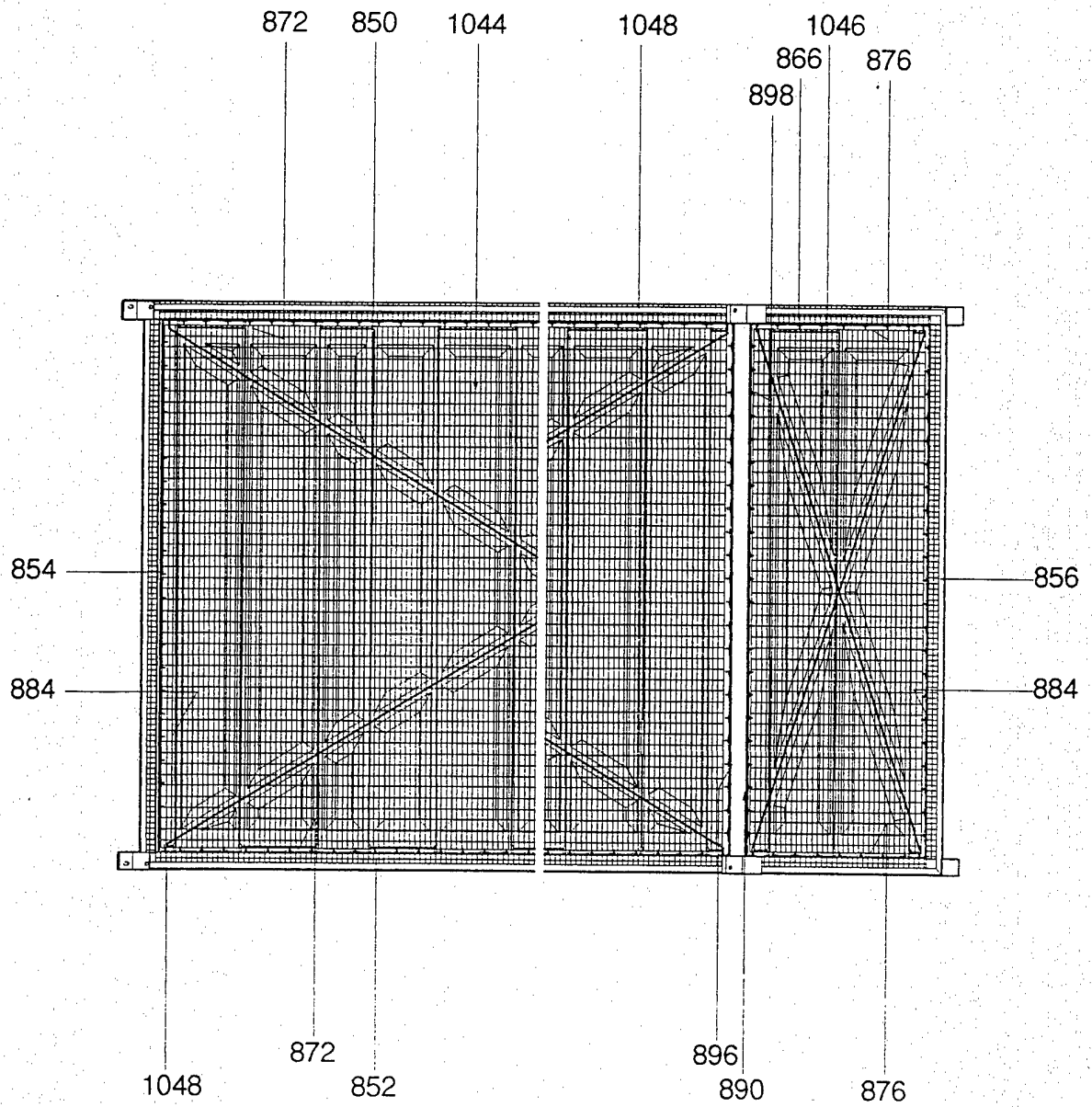


Figure 52

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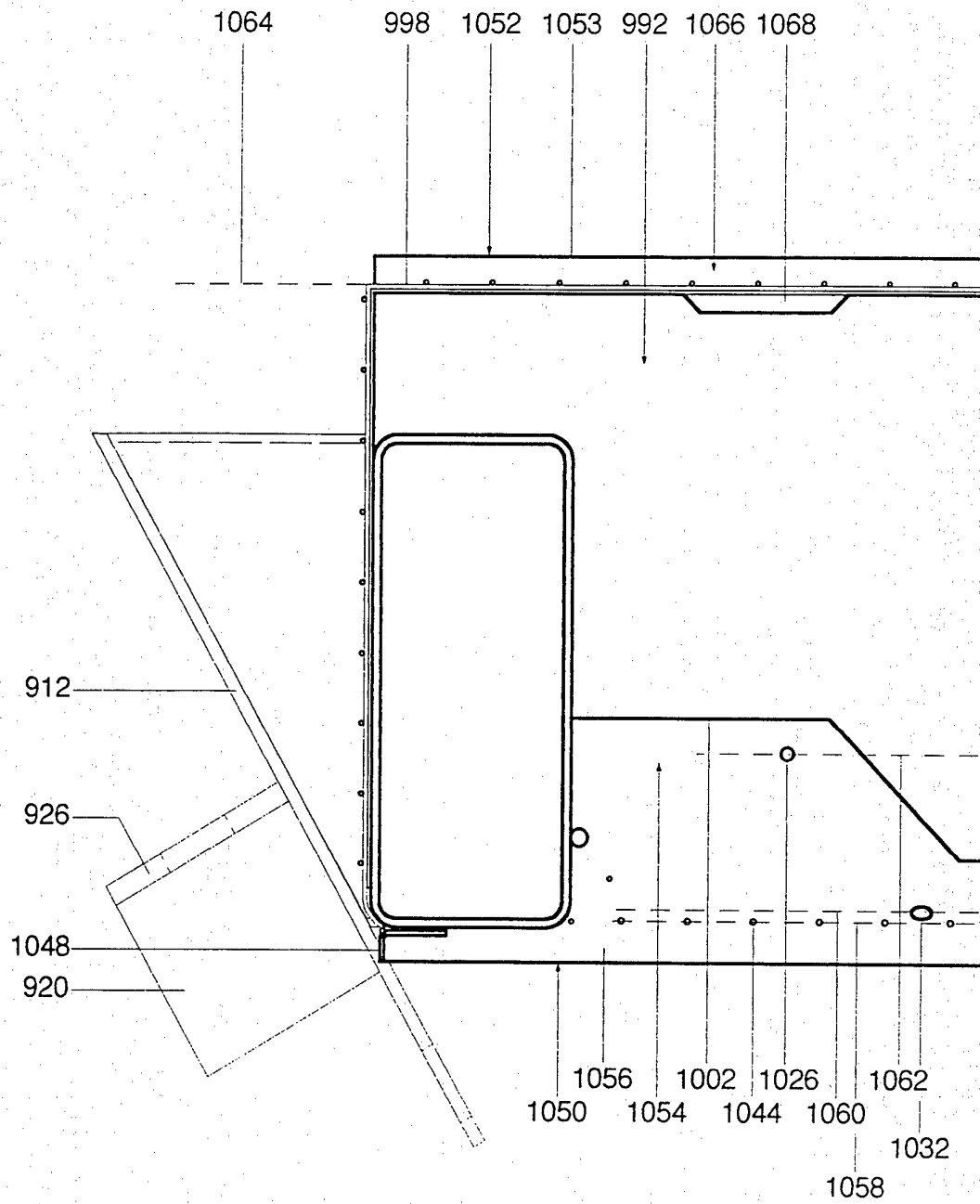


Figure 53

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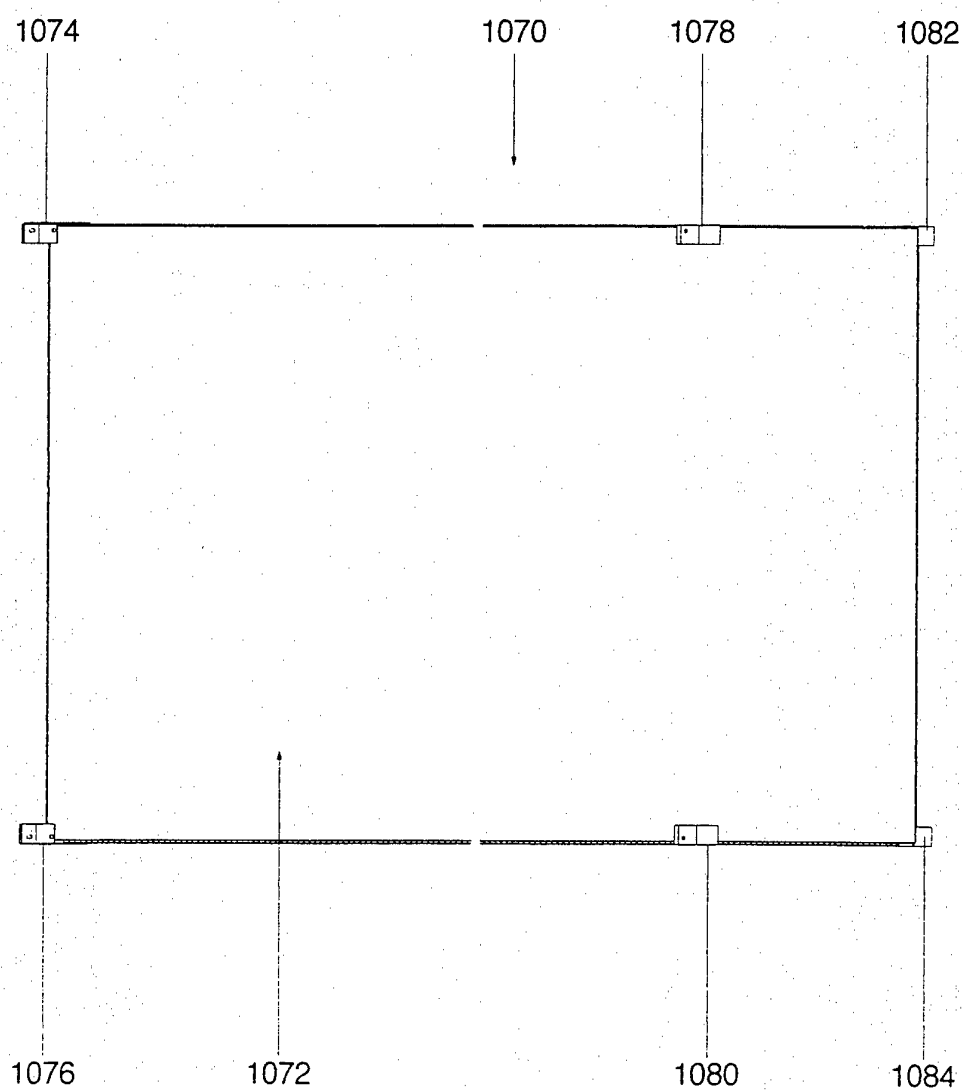
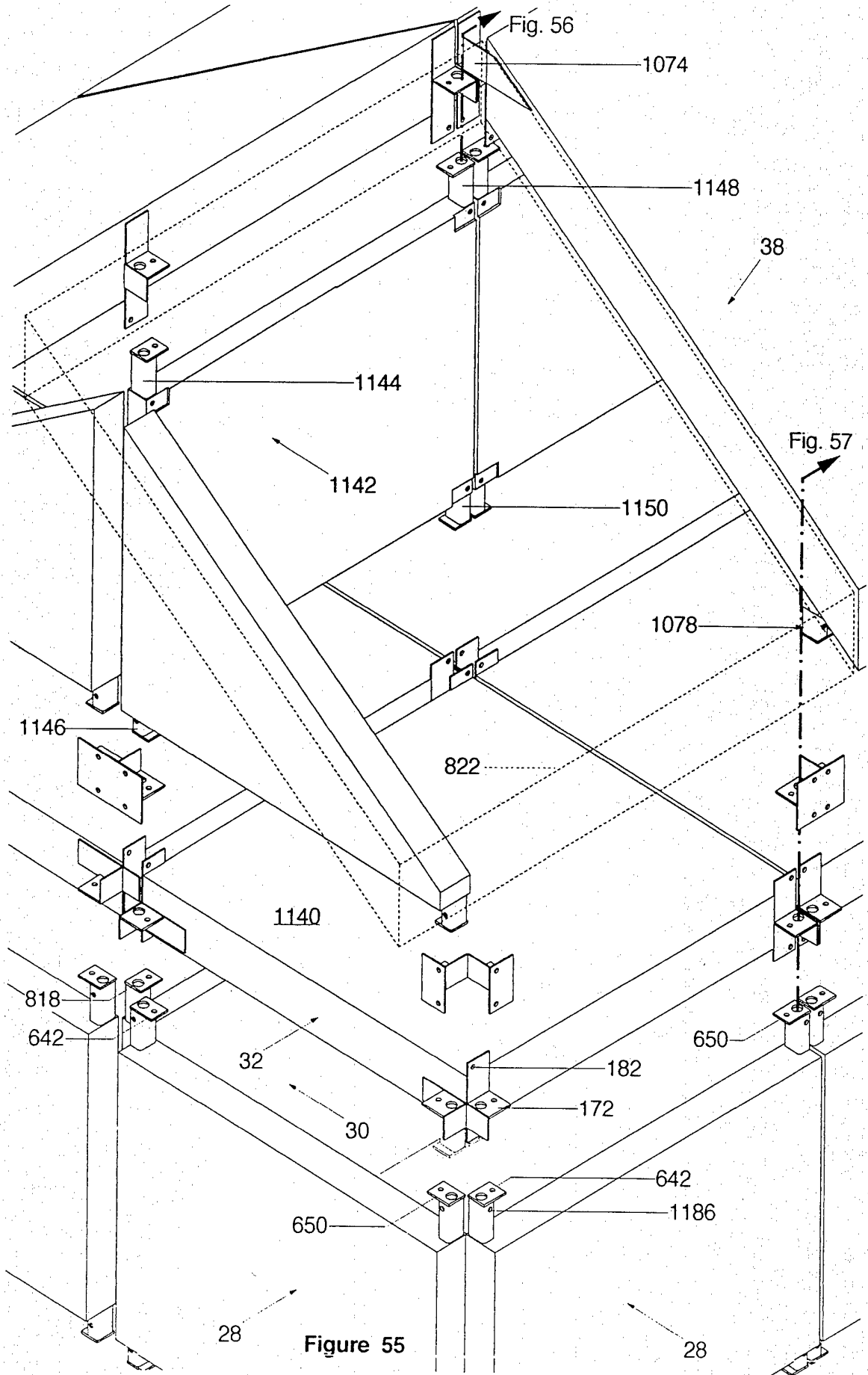


Figure 54

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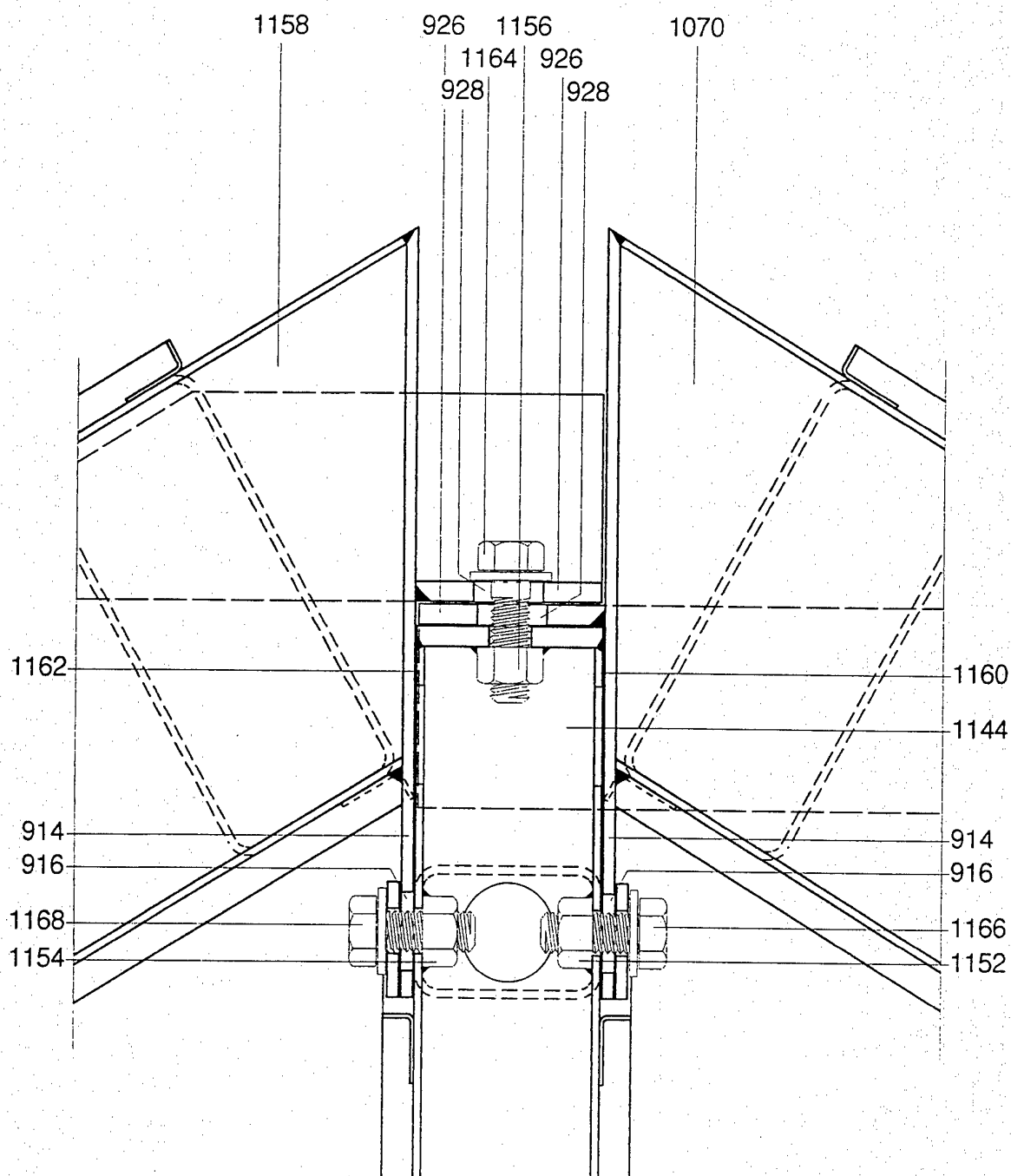


Figure 56

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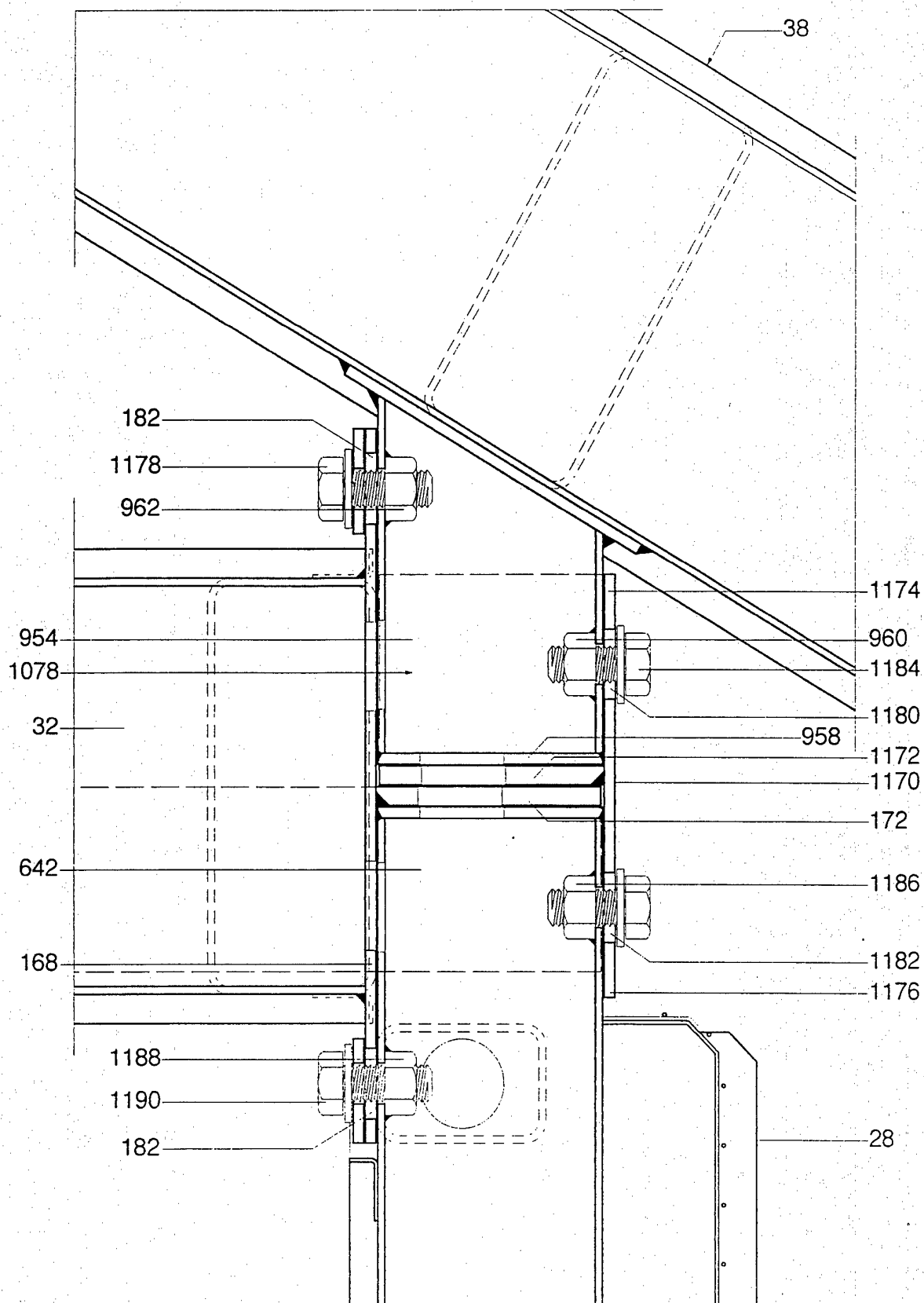


Figure 57

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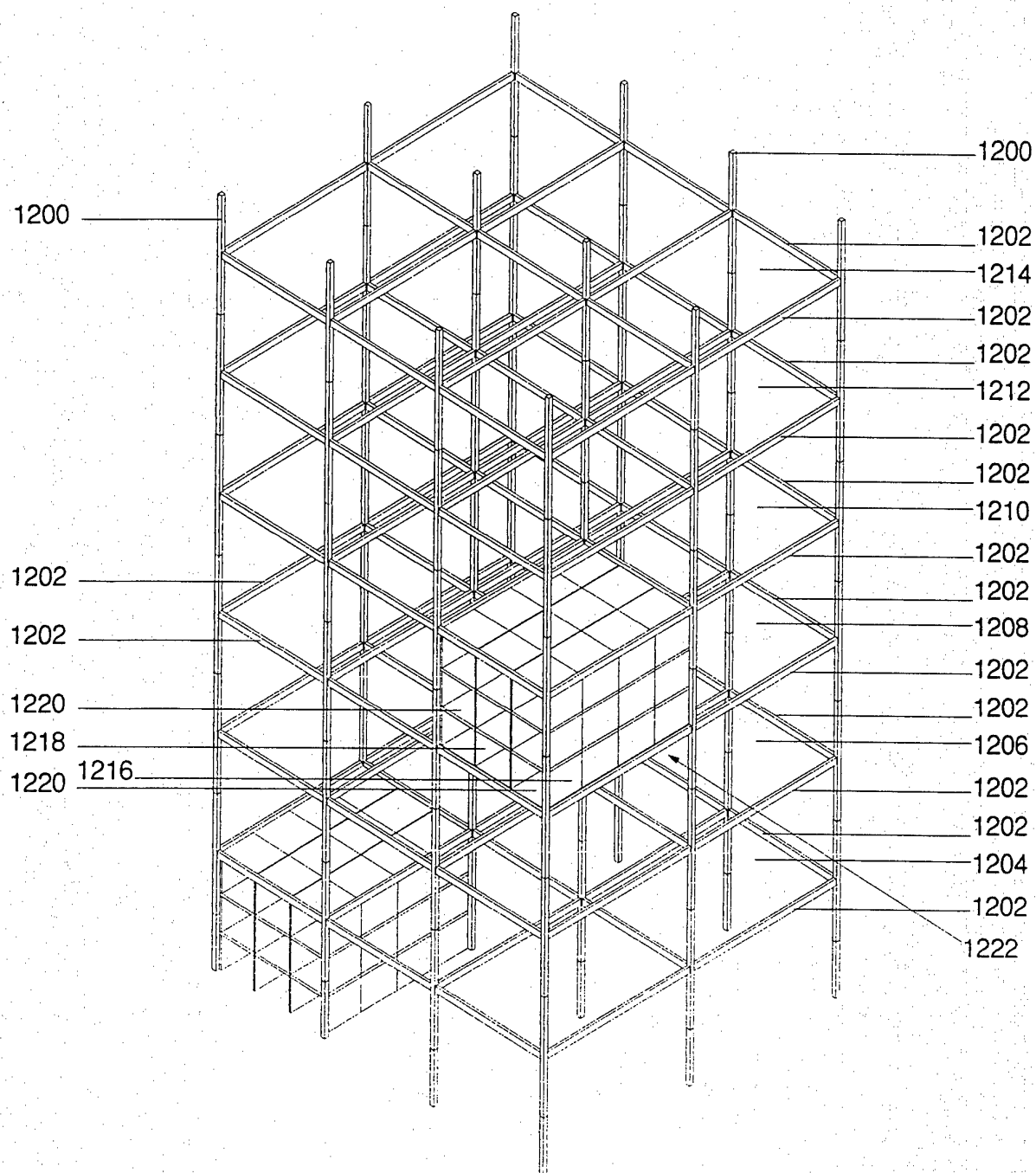


Figure 58

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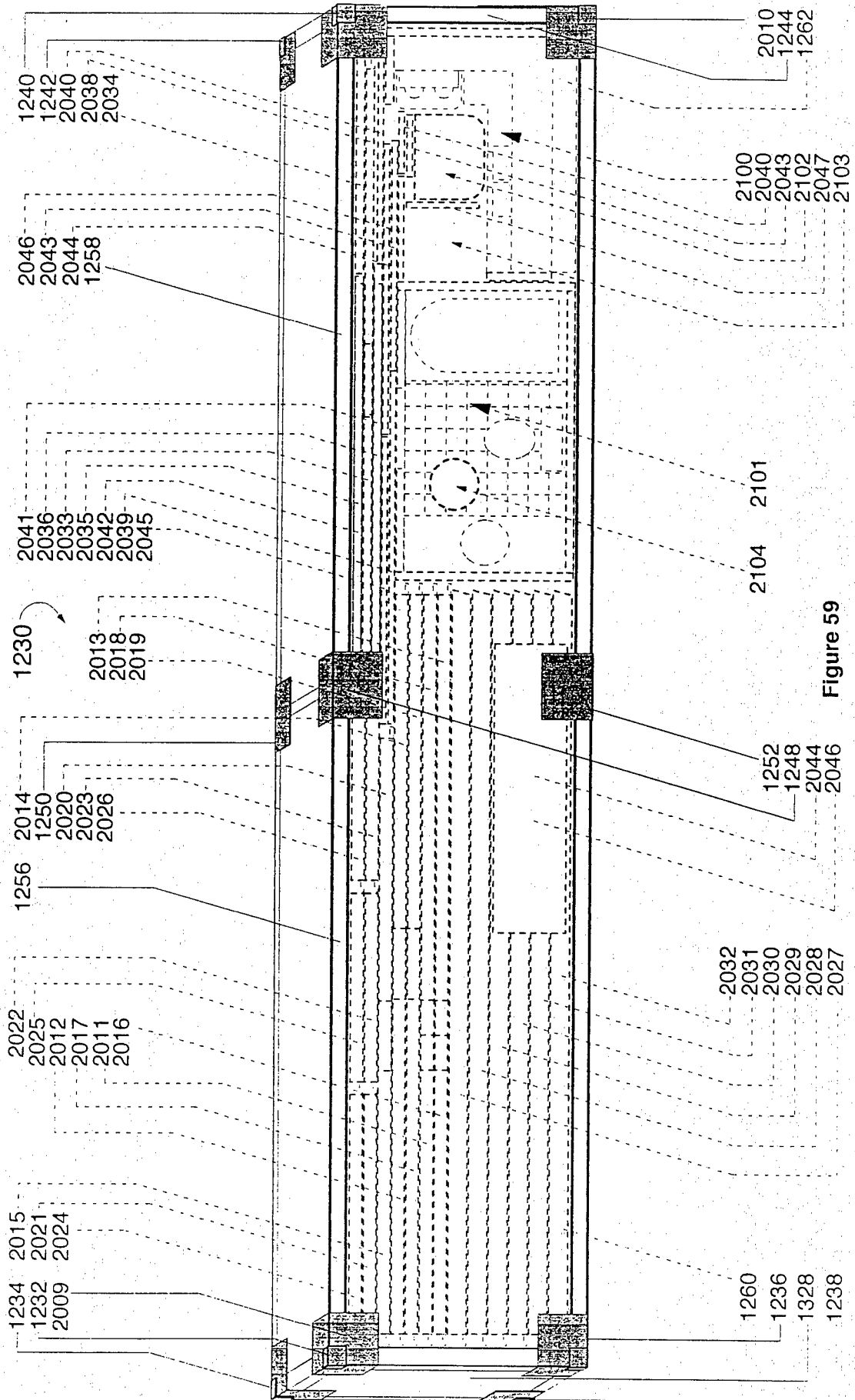


Figure 59

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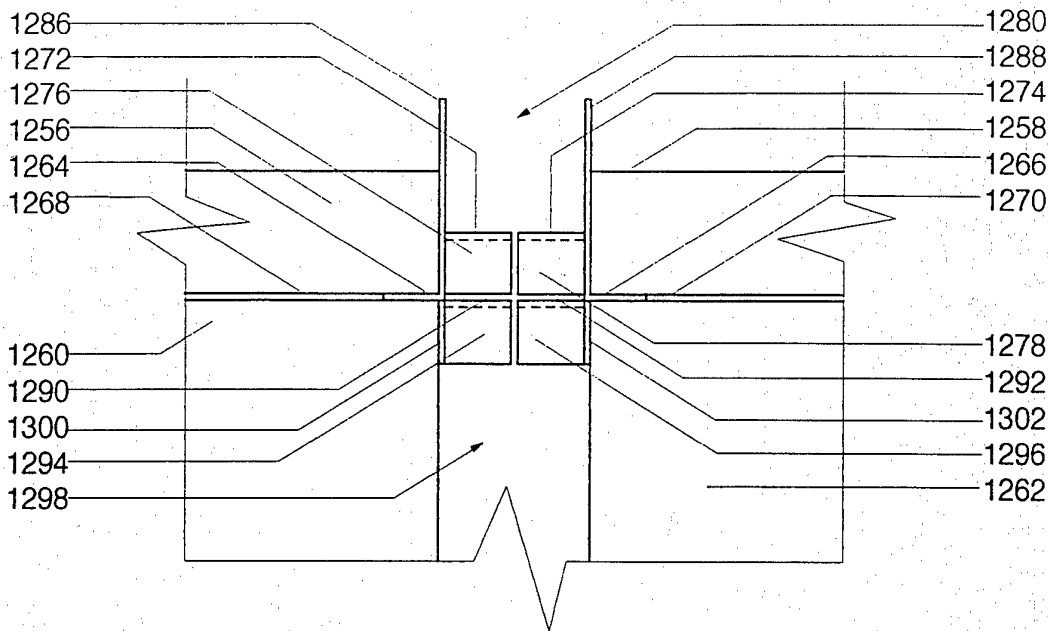


Figure 60a

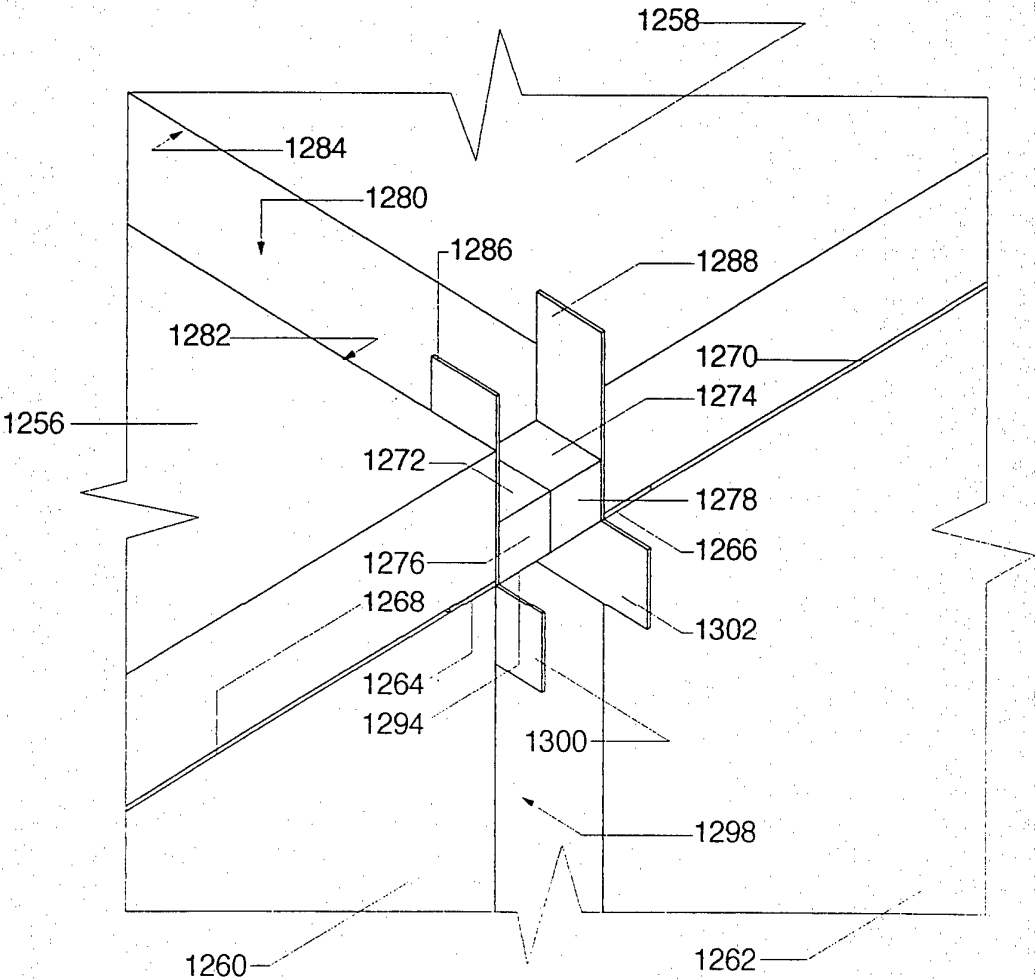


Figure 60b

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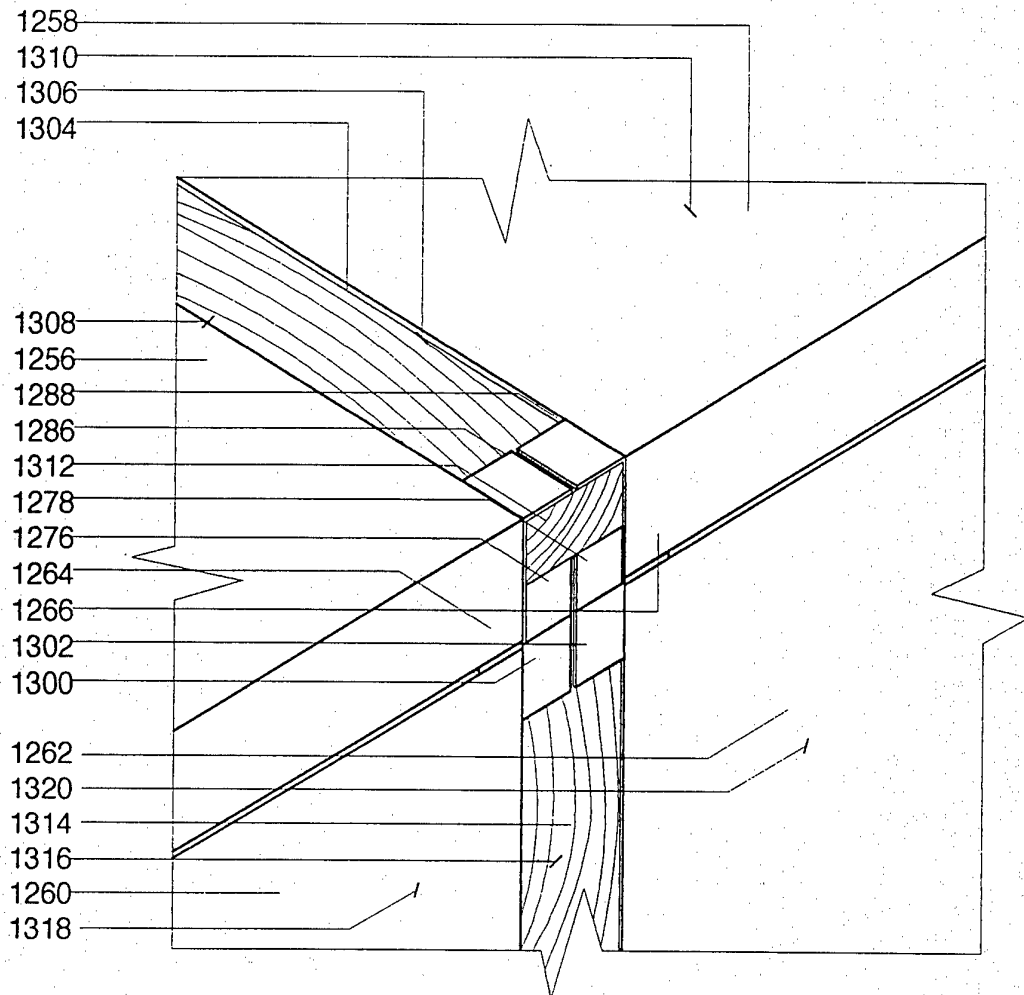
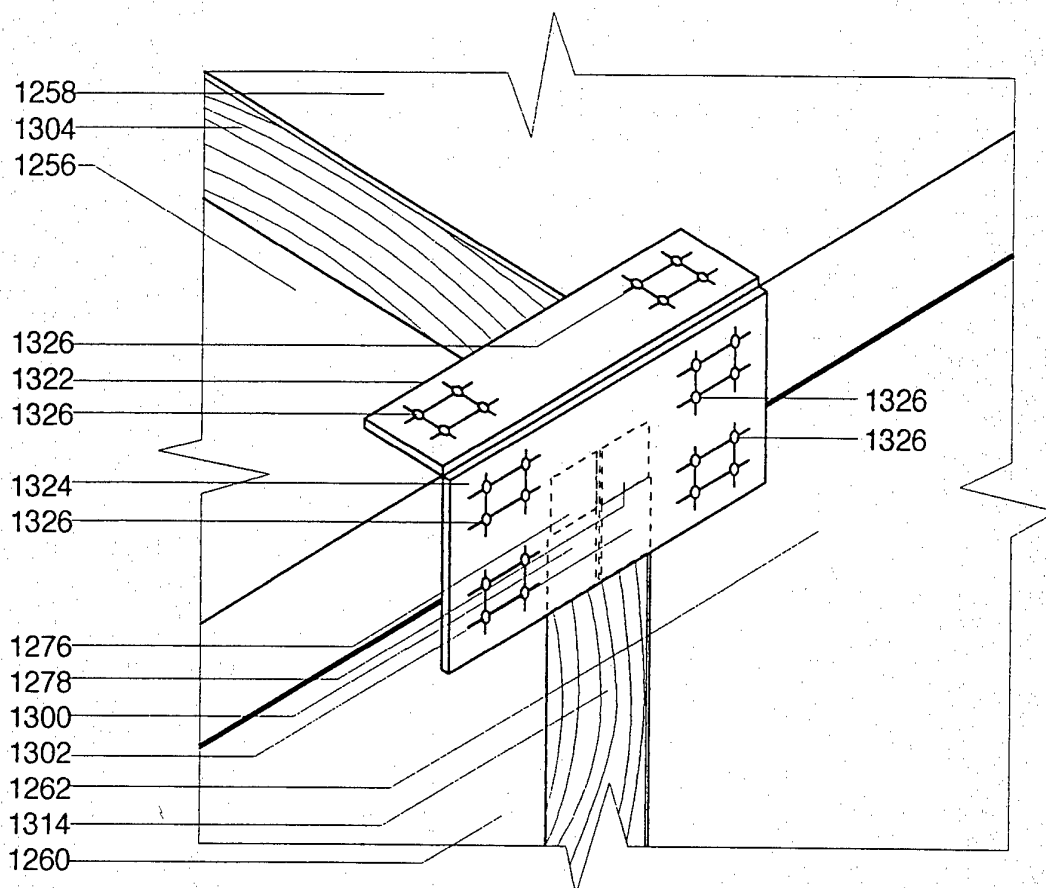


Figure 60c

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**Figure 60d**

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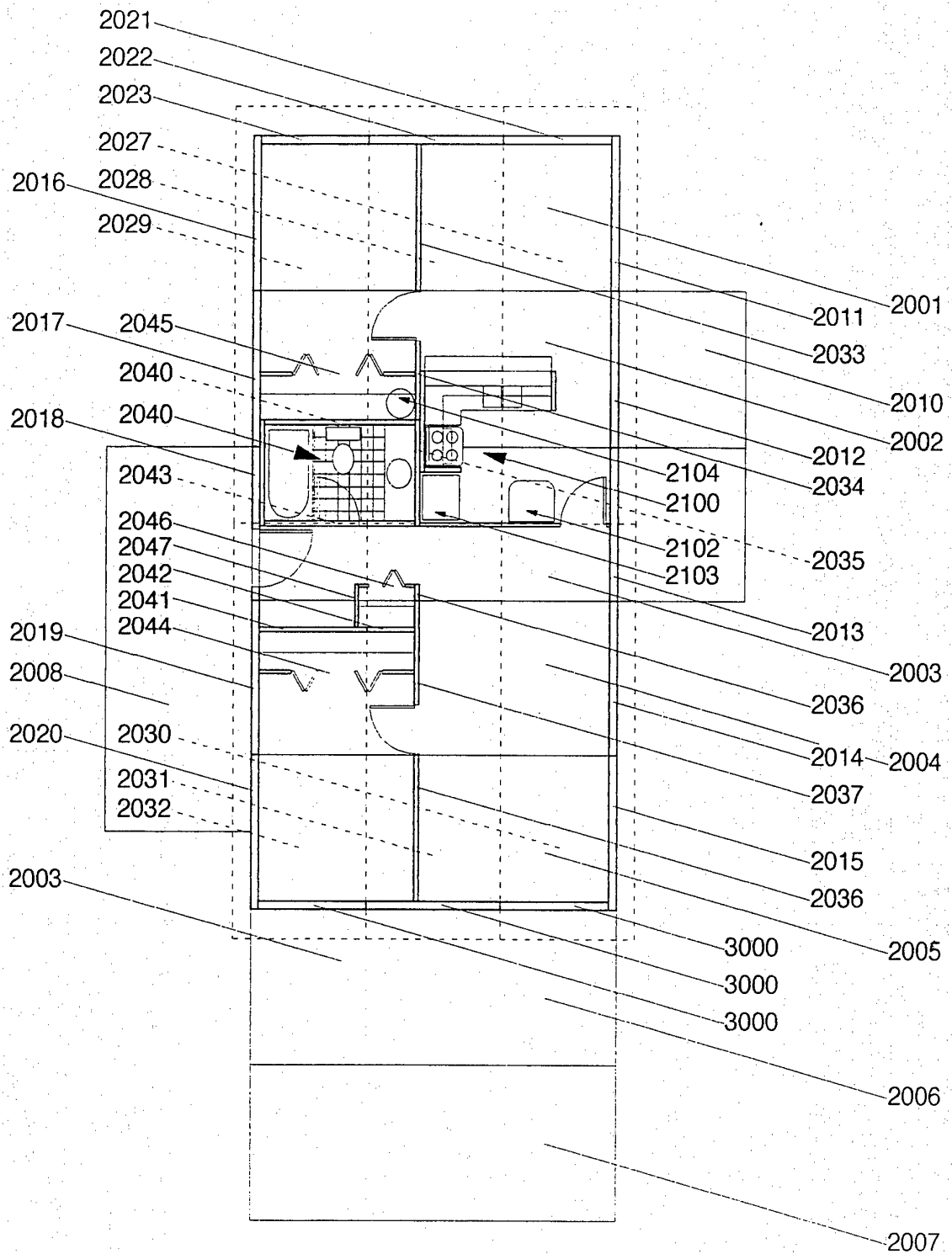


Figure 61

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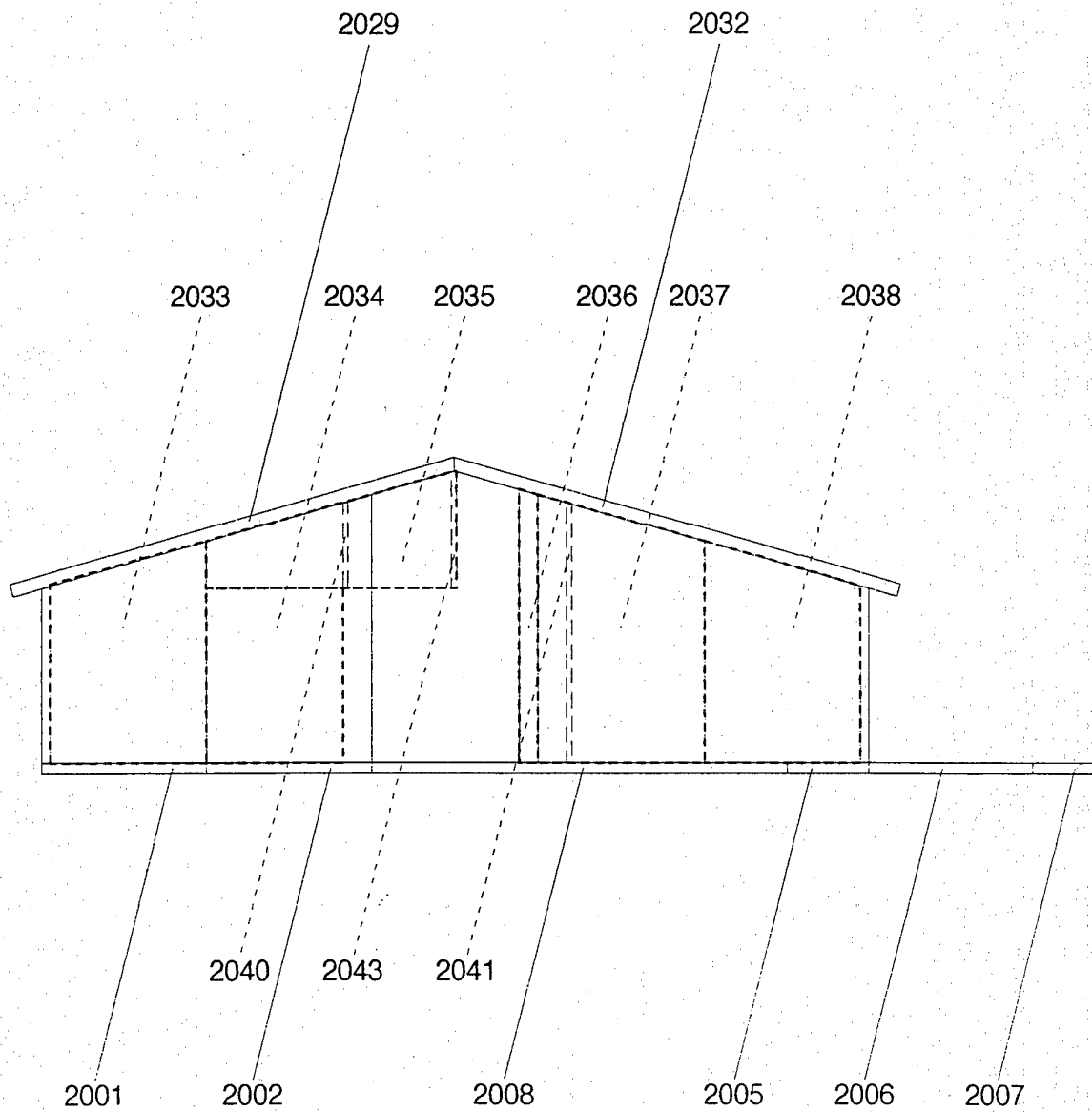


Figure 62

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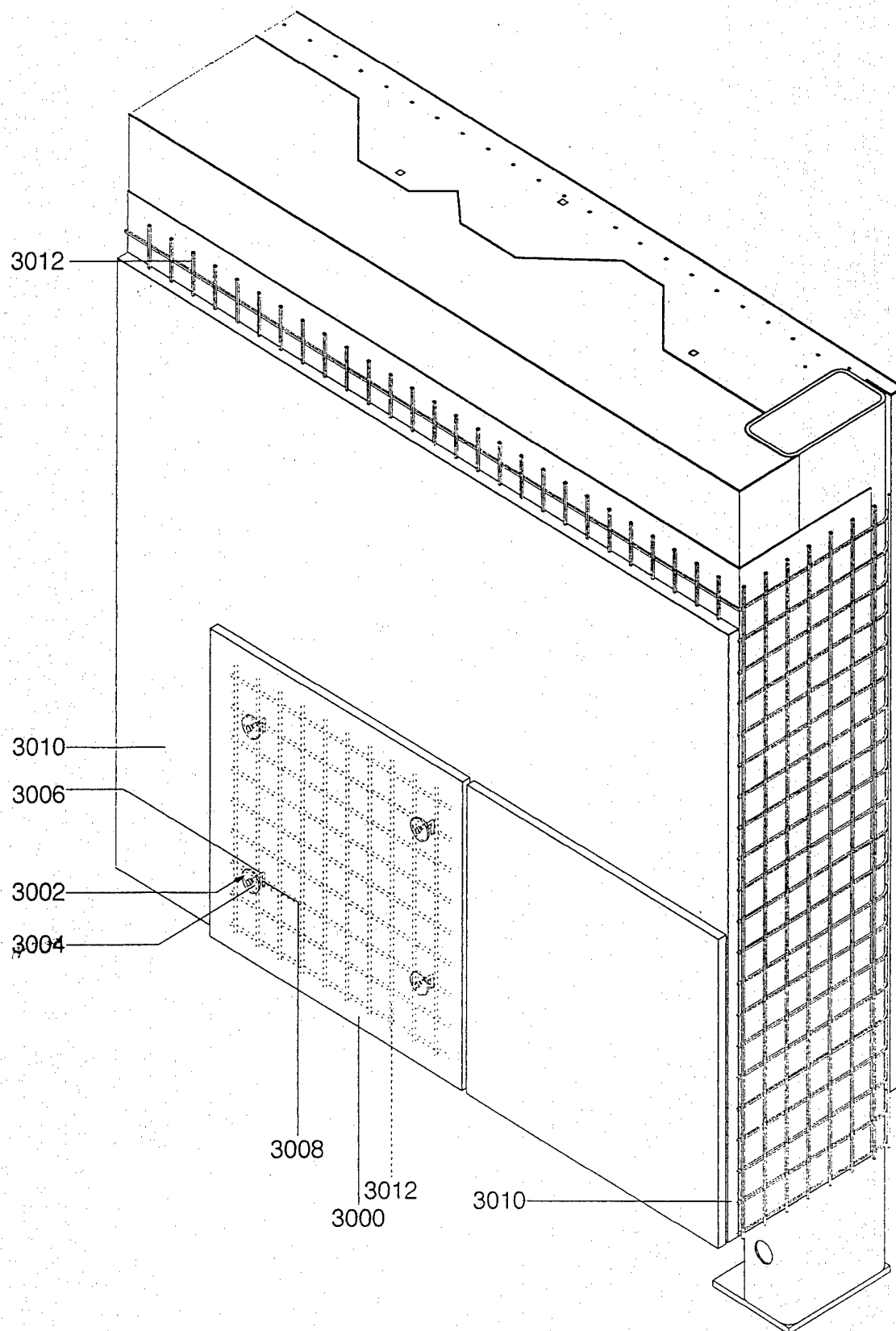


Figure 63

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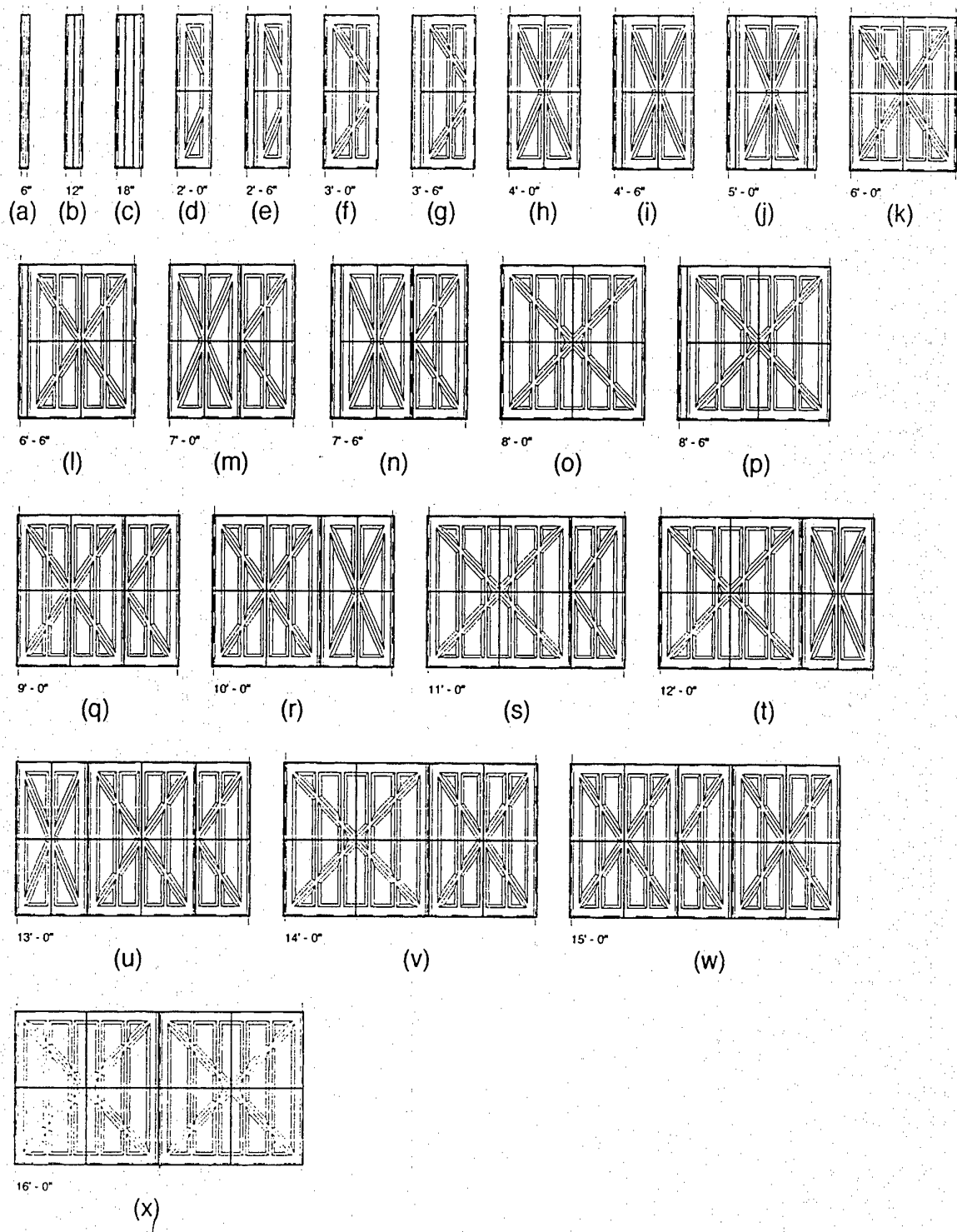


Figure 64

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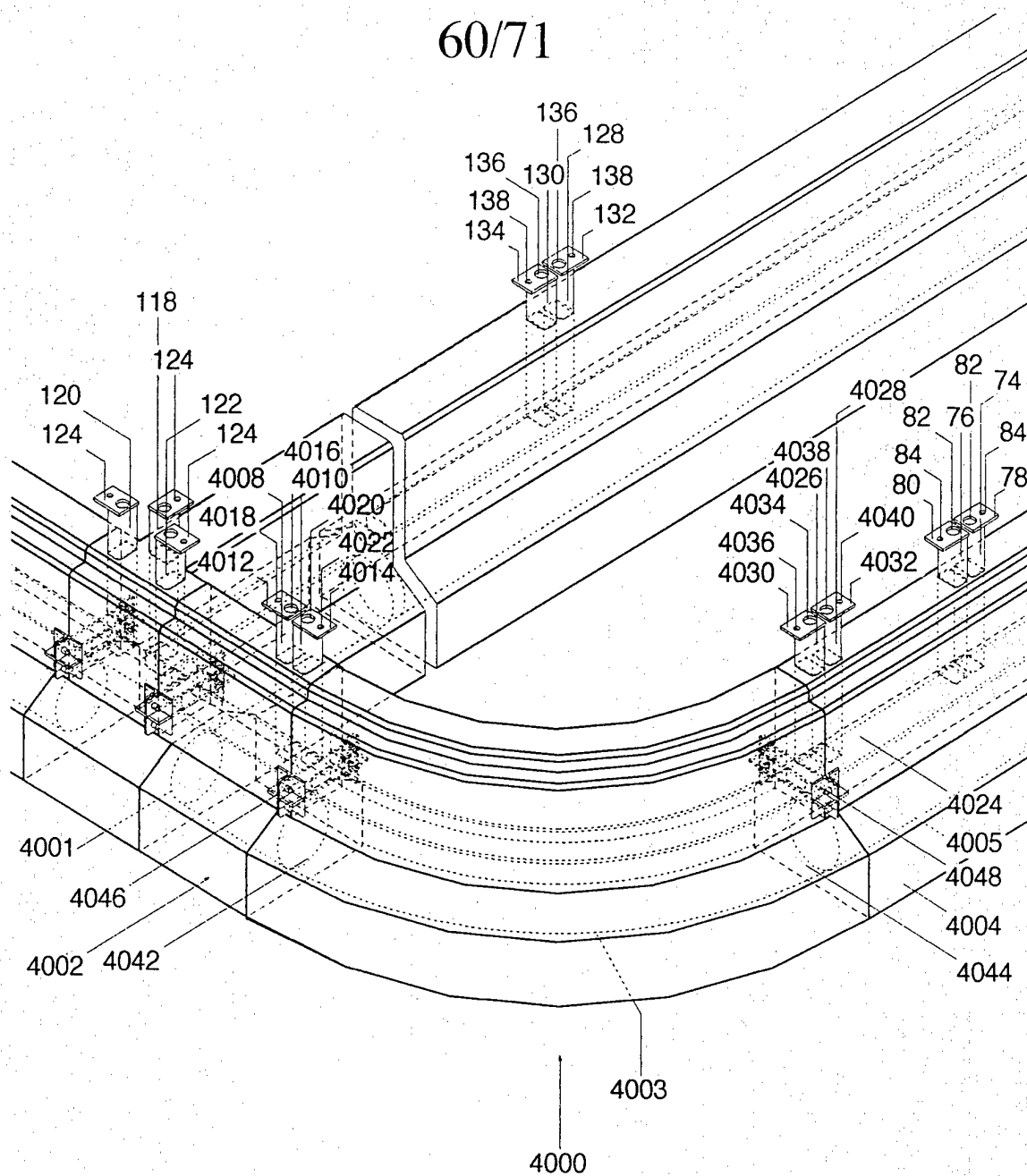


Figure 65

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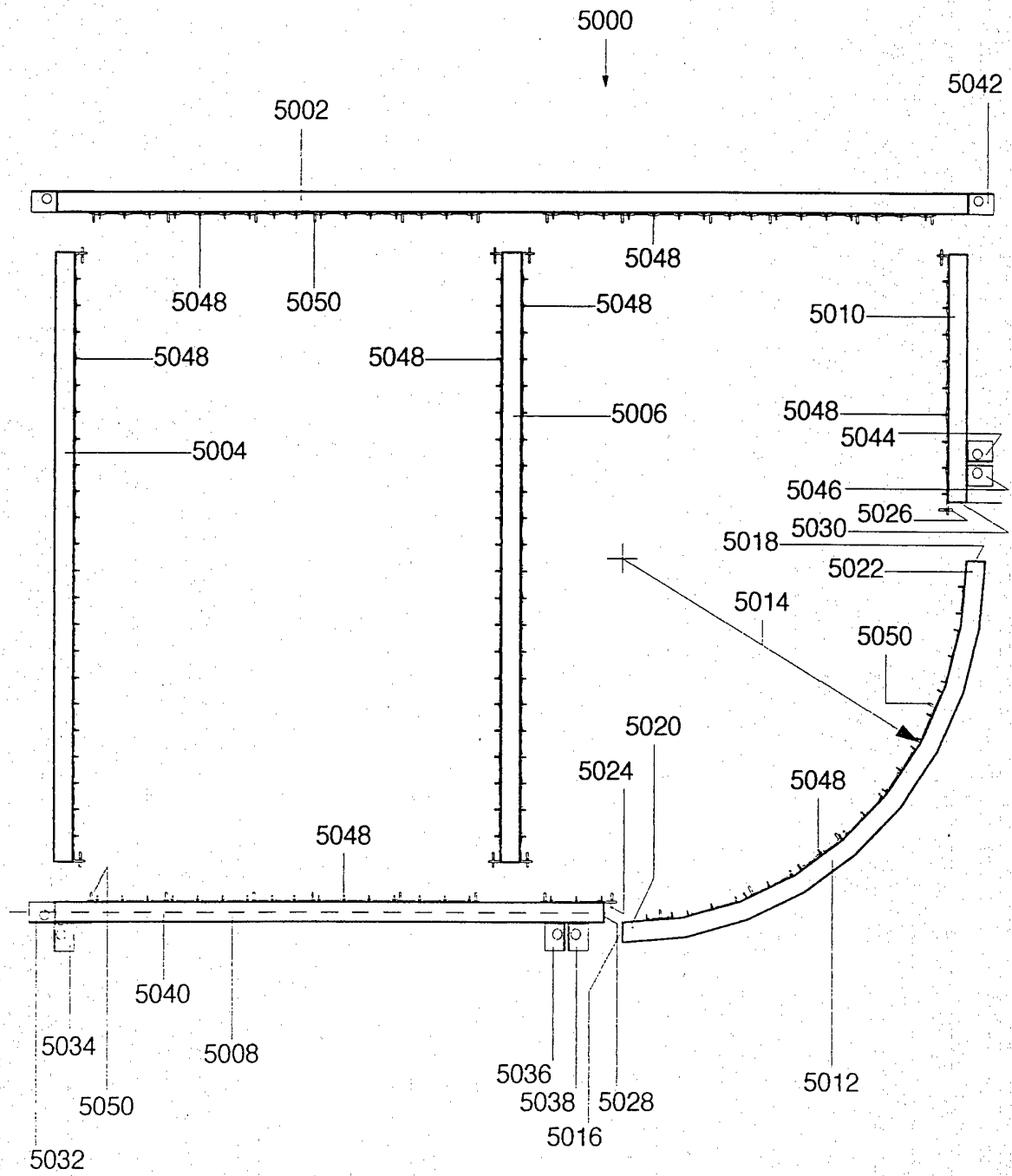


Figure 66

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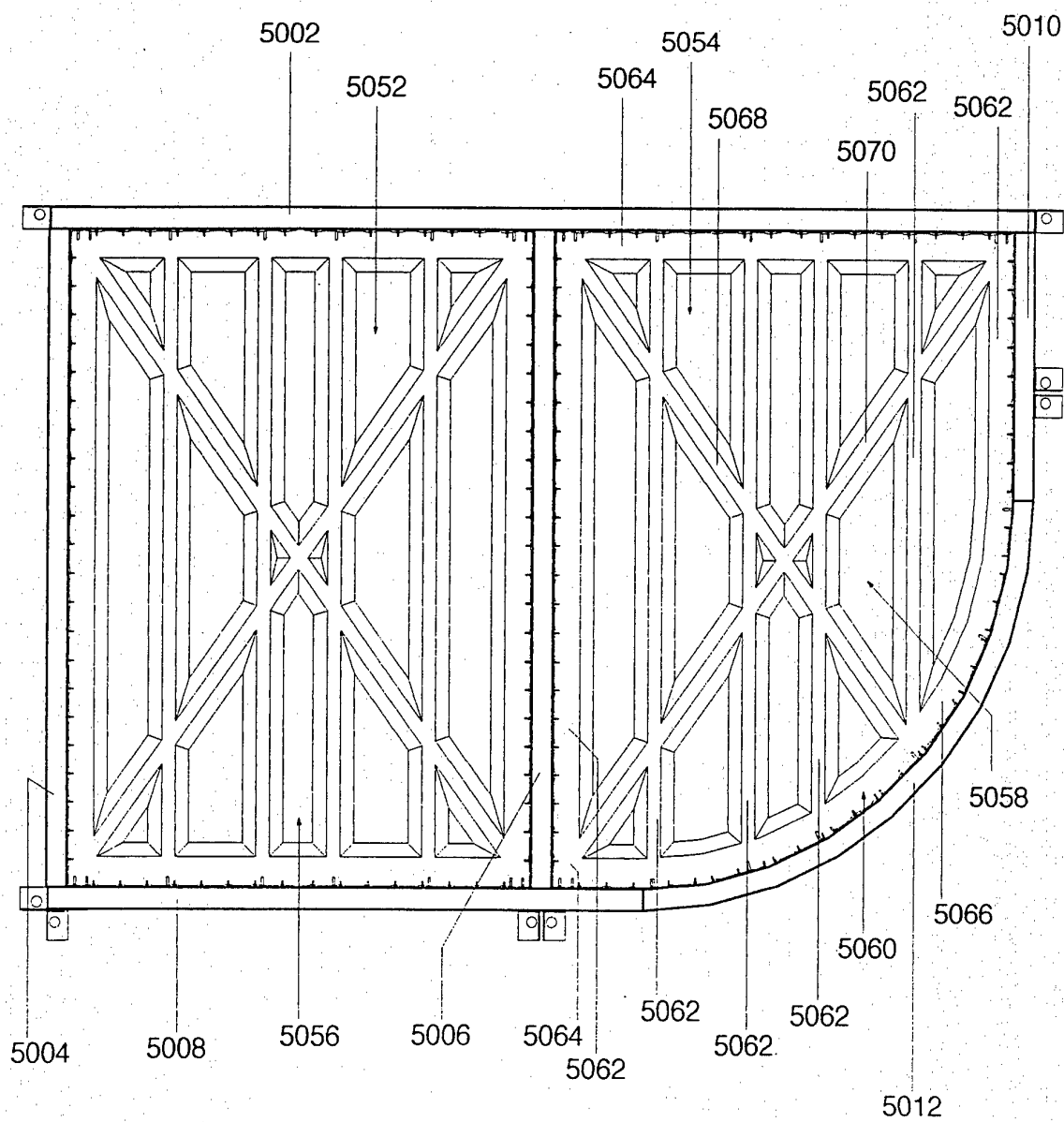


Figure 67

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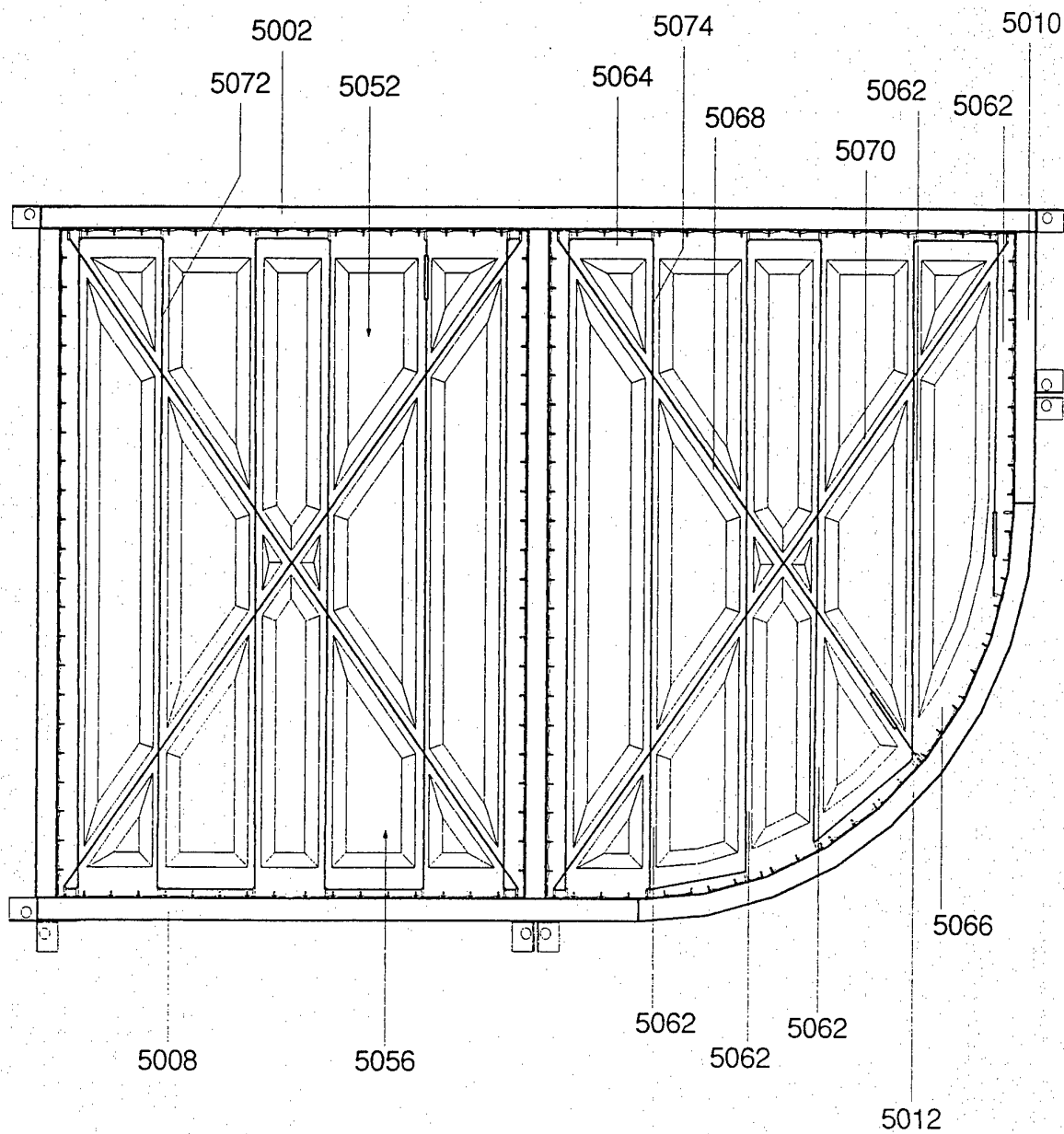


Figure 68

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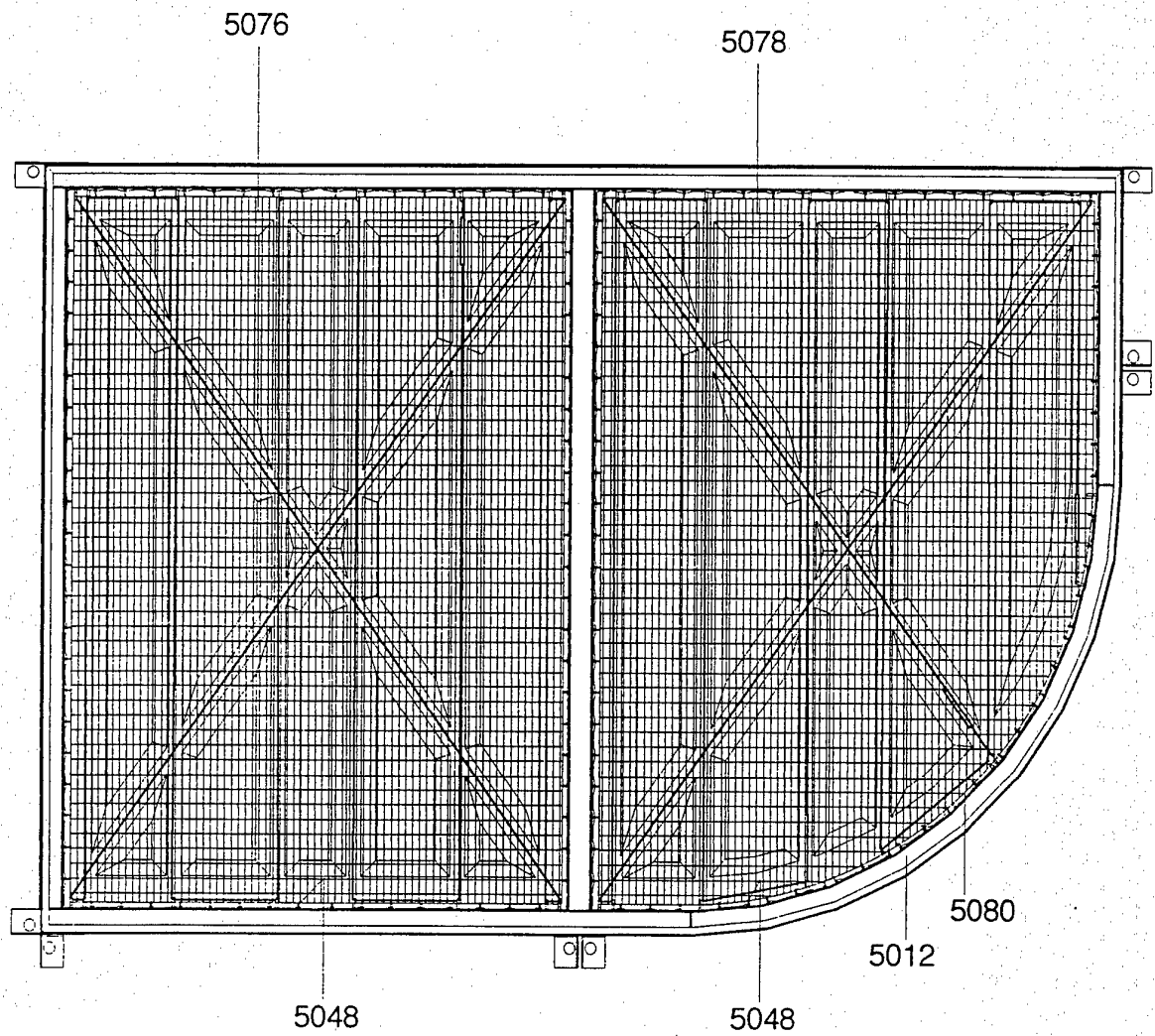
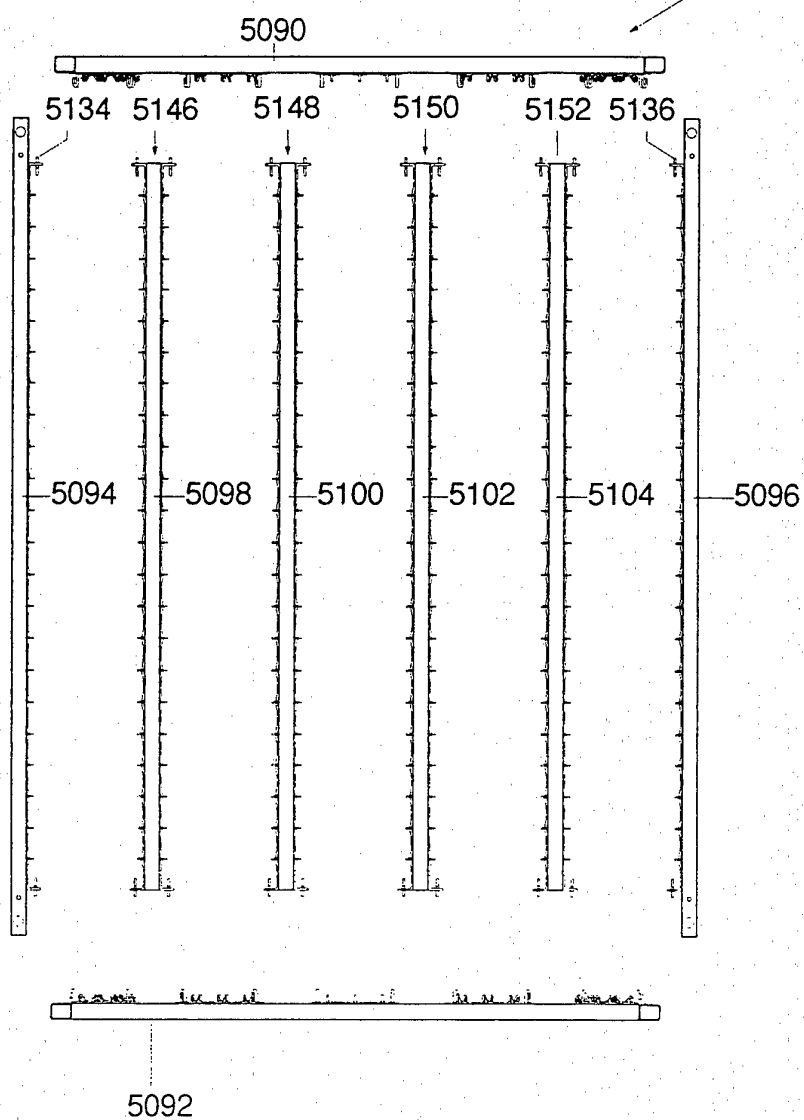
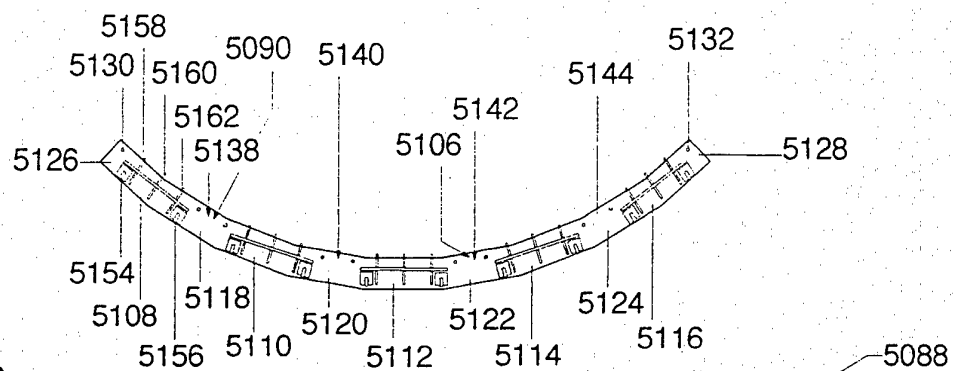


Figure 69

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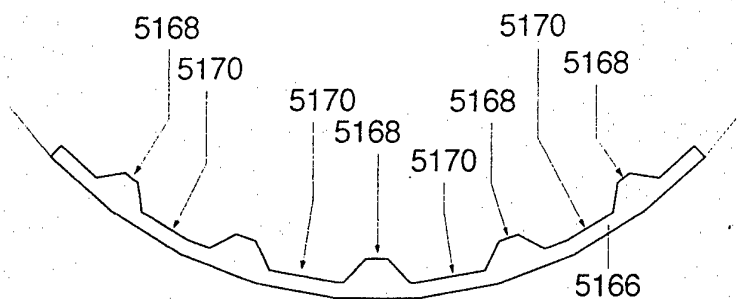


Figure 73

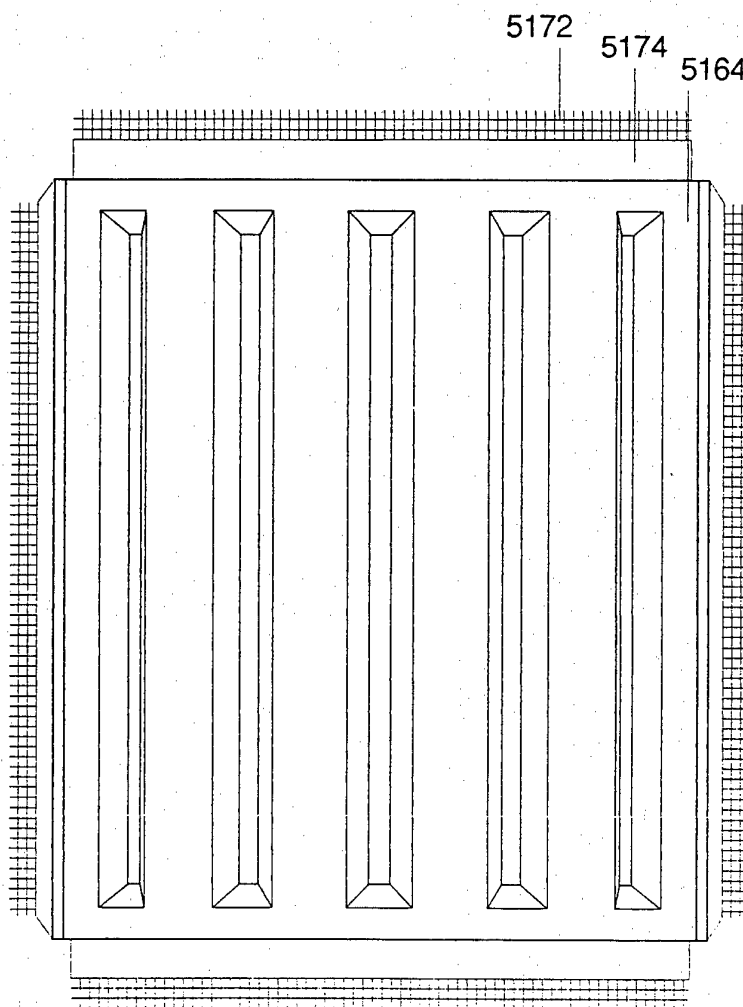


Figure 74

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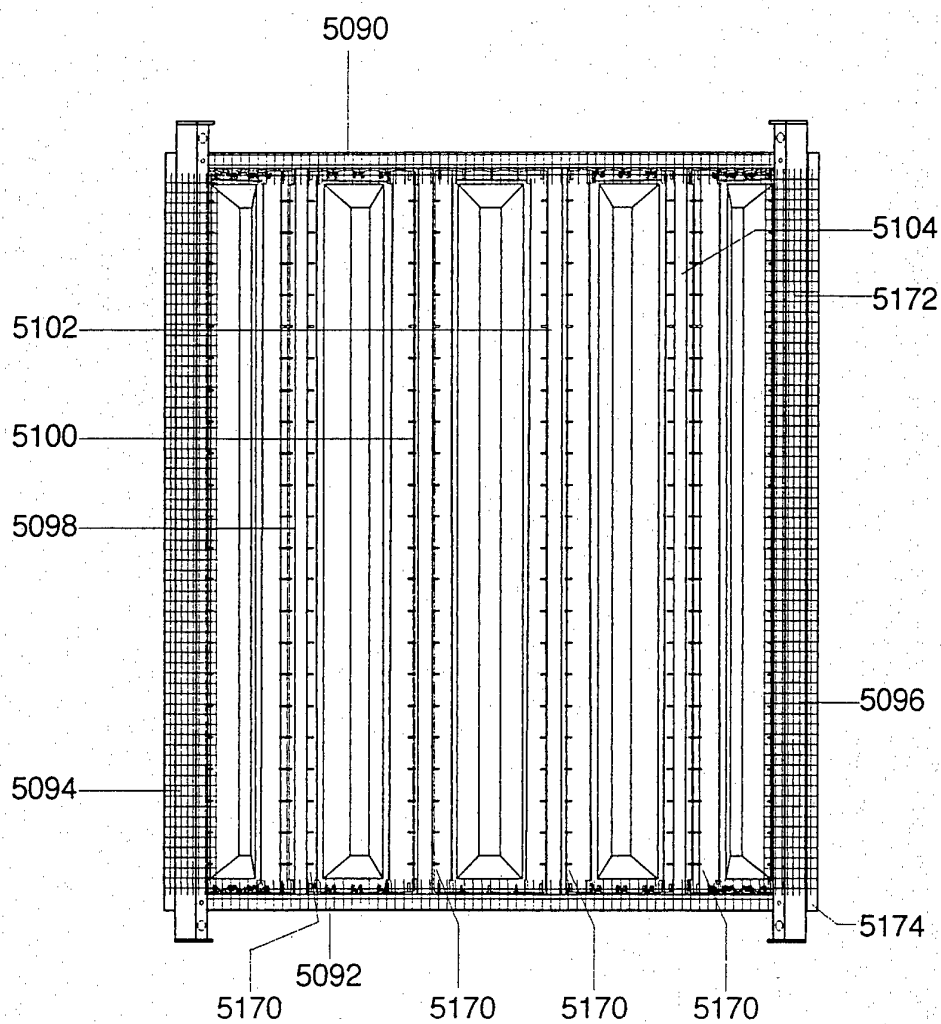


Figure 75

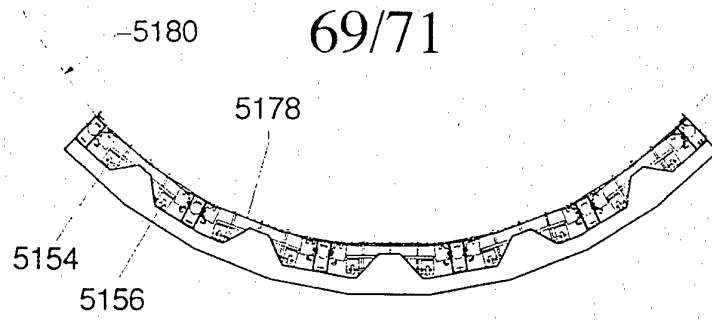


Figure 77

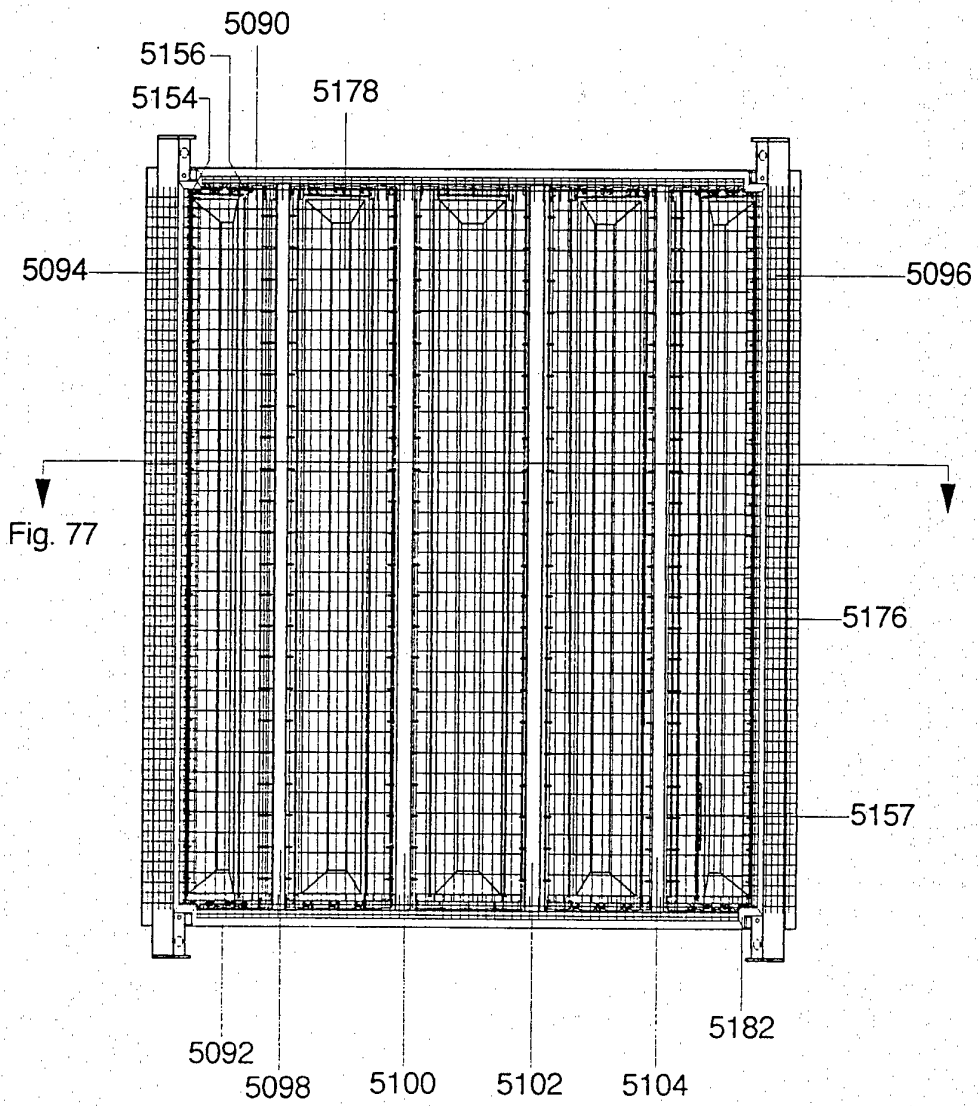


Figure 76

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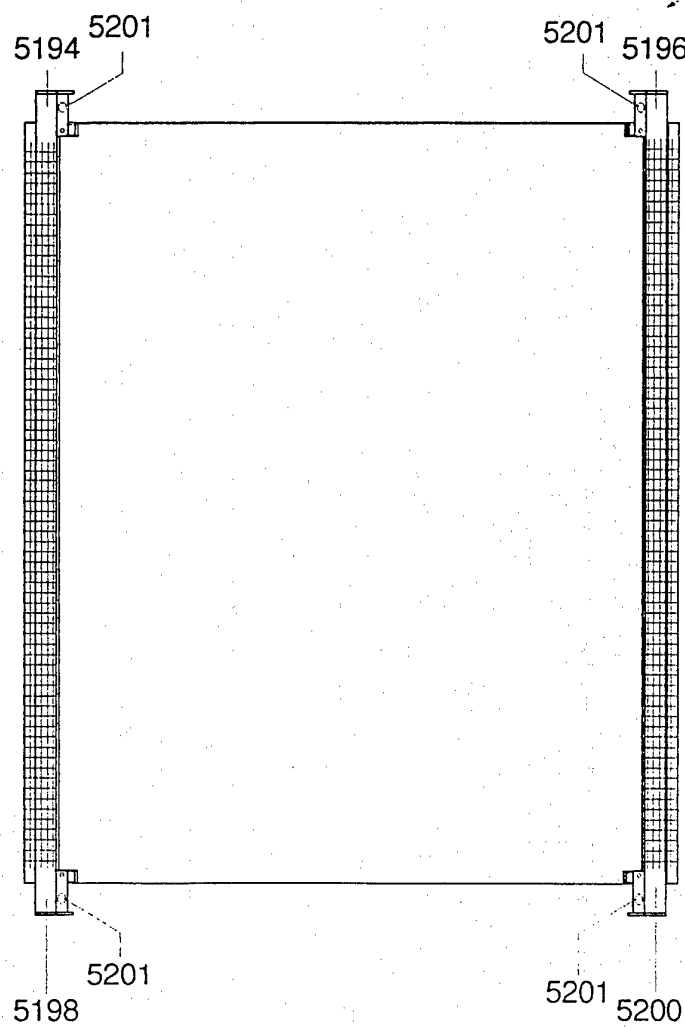
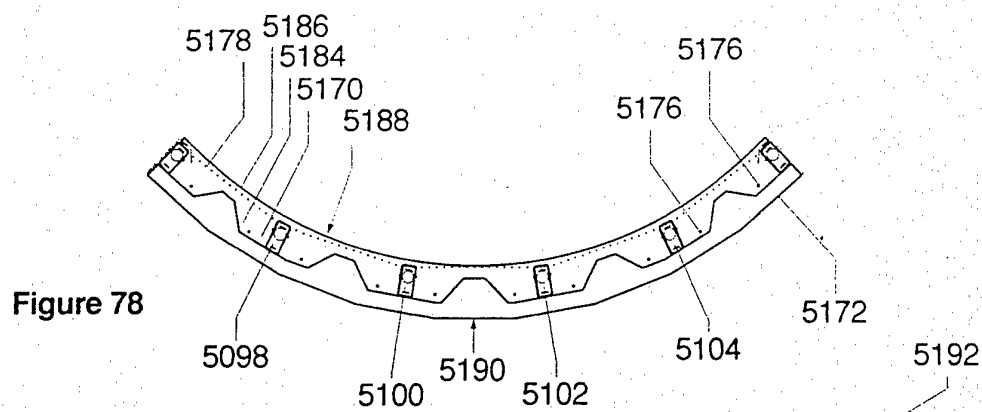


Figure 79

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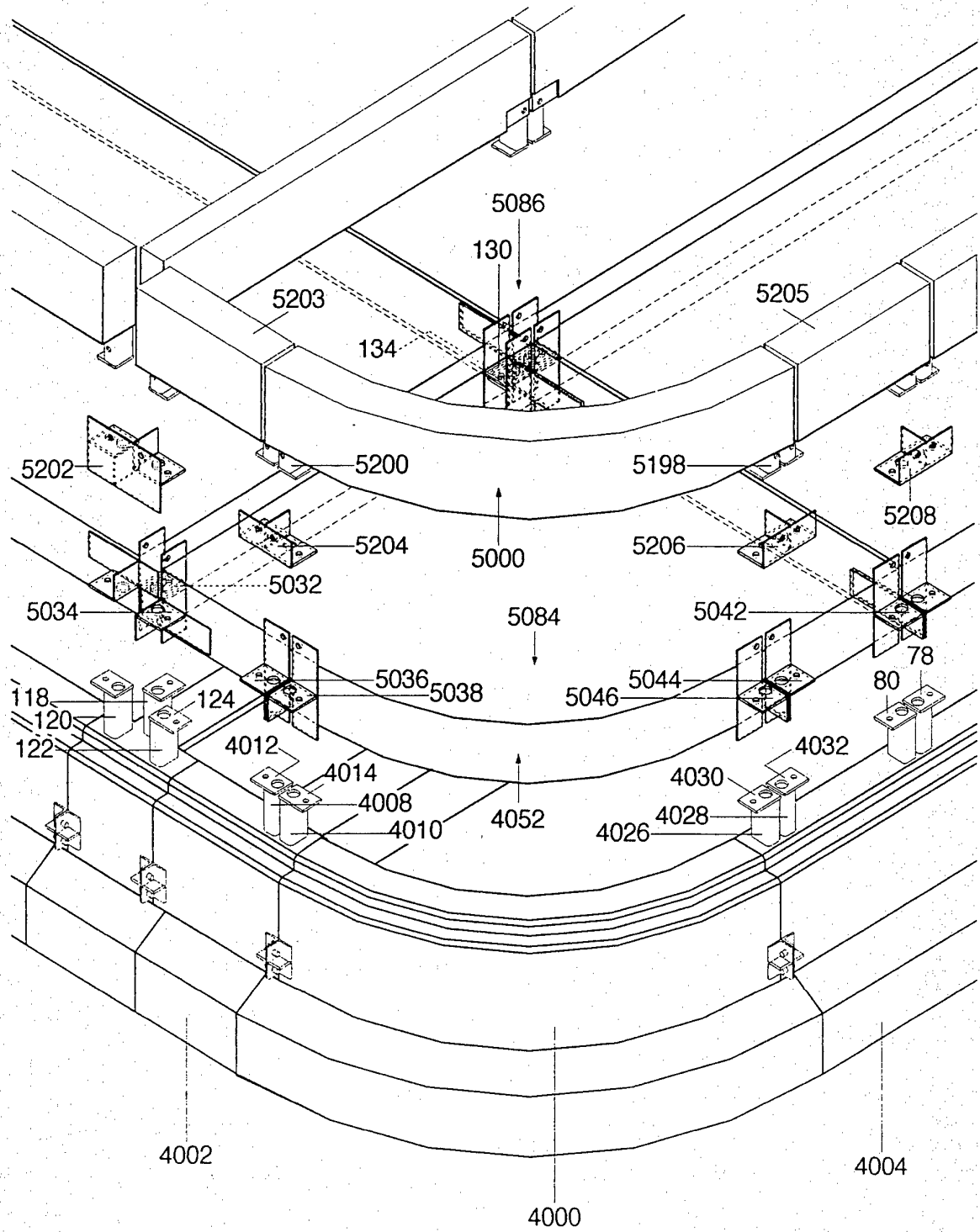


Figure 80