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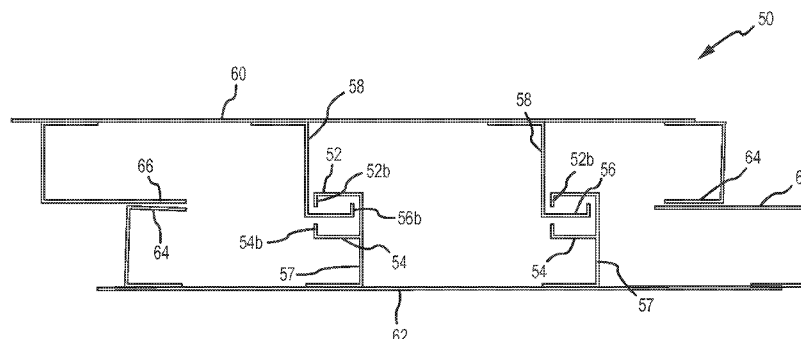


FIG. 7

(57) Abstract: A structural assembly for use in building applications is disclosed. The assembly has spaced inner and outer face sheets, as well as one or more intermediate panels positioned between the inner and outer face sheets. The intermediate panels are parallel to the inner and outer face sheets, and are supported by alternating flanged web members that engage either the inner or outer face sheets. The assembly provides an enhanced ability to dissipate blast or projectile impact forces and to carry the forces throughout the assembly, thus maintaining sufficient structural integrity in the building to enable the occupants to evacuate, to enable contents to be evacuated, and to enable reuse of the building itself.



## **EXPLOSIVE BLAST ENERGY DISSIPATING AND CARRYING BUILDING STRUCTURE**

### **RELATED APPLICATIONS**

5           This Non-Provisional Patent Application claims the benefit of priority from co-pending U.S. Patent Application No. 61/599,639, filed February 16, 2012 and U.S. Patent Application No. 61/714,941, filed October 17, 2012, the entire disclosures of which are hereby incorporated by reference in their entireties.

### **FIELD OF THE INVENTION**

10           The invention generally relates to an improved building system for use as walls, roofs, floors and also for use in combination with typical building materials for constructing commercial residences and buildings, as well as a retrofit for existing buildings. More particularly, the invention relates to an improved building system that dissipates and carries blasts or projectile impacts throughout the structure and to the  
15 foundation of the building of which it is a part.

### **BACKGROUND**

Blast and penetration resistant building structures have been used for many years to protect inhabitants from a variety of natural destructive forces (e.g., tornadoes) as well as man-made destructive forces such as impact loads from projectiles and blasts associated  
20 with explosives detonations. These traditional building structures often are constructed of substantial thicknesses of reinforced concrete capable of withstanding the forces associated with the aforementioned loads. An obvious disadvantage of using concrete is its great weight, which makes it difficult to transport and assemble on site. Additionally, although concrete is capable of withstanding large forces or projectile impacts, extreme  
25 loading can cause concrete walls to spall, break apart, or be pushed over.

Building modules are known which comprise sheet metal in lieu of concrete and thus are relatively light. These known building modules may easily be prefabricated and transported to the building site for assembly. An example of such modules are those described in U.S. Patent No. 4,928,468 to Phillips, the entirety of which disclosure is  
30 incorporated herein by reference. These building modules may contain thermo/acoustic insulation, or they may contain supplemental internal structures for preventing forcible entry. The structures in these modules may also prevent penetration of the associated building panel by low level ballistic projectiles.

Still some current building modules may be difficult to handle and transport due to their substantial size and weight, making their procurement and installation expensive and costly to heat and cool.

It would, therefore, be desirable to provide a lightweight, low cost building assembly that would resist and dissipate and carry the forces associated with projectiles or blasts to mitigate damage to the overall building structure.

The desired assembly should be versatile enough to be used in a wide variety of structural applications. In addition to the aforementioned blast or projectile resistance, such an assembly should provide substantial structural load-bearing strength to enable its use in any of a variety of building structures.

### SUMMARY OF THE INVENTION

The disadvantages heretofore associated with the prior art are overcome by the inventive design for a building assembly that is lightweight, cost effective, and that provides enhanced protection from penetration due to projectiles and blasts.

The inventive assembly is designed to accept multiple local bendings without resulting in structural failure of the building in which the assembly is incorporated. Thus, a wall constructed in accordance with embodiments of the inventive assembly can sustain local bending from an explosive blast, but will retain sufficient structural integrity to remain intact, thus allowing evacuation of the occupants and continued use of the structure. Even where the blast force is sufficient to cause a breach of the inner wall, embodiments of the inventive assembly are still designed to maintain sufficient structural integrity to allow occupants to evacuate and contents to be evacuated, and to enable the building itself to be repaired and returned to full service.

Thus, a structural assembly for use in a building is disclosed, the structural assembly may comprise a building, module, wall, roof, column, beam, or floor. The assembly may comprise a first plate forming a first face sheet of the structural assembly, and a second plate forming a second face sheet of the structural assembly. Third and fourth plates may be positioned between the first and second plates and may be laterally offset with respect to each other, such that an end portion of the third plate may overlap an end portion of the fourth plate. A first flanged web member may connect the first plate to the third plate, and a second flanged web member may connect the second plate to the fourth plate. Further, the first and second flanged web members may be offset by a lateral distance.

A structural assembly is further disclosed, comprising first and second spaced apart plate members, and third and fourth plate members disposed between said first and second plate members. The third and fourth plate members may be laterally offset with respect to each other such that an end portion of the third plate member overlaps with an end portion of the fourth plate member. The structural assembly may comprise a building, module, wall, roof, column, beam, or floor. The assembly may further comprise first and second flanged webs, the first flanged web connecting the first and third plate members, and the second flanged web connecting the second and fourth plate members. The first and second flanged webs may be laterally offset with respect to each other.

A structural assembly is further disclosed, comprising: first and second facing panels; first and second interior panels; and first and second flanged webs. The first and second facing panels may be spaced apart by a distance sufficient to receive the first and second interior panels there-between, with the first facing panel connected to the first interior panel by the first flanged web, and the second facing panel connected to the second interior panel by the second flanged web. The first and second interior panels may be laterally offset with respect to each other such that only a portion of the first interior panel overlaps with a portion of the second panel. Additionally, the first and second flanged webs may be laterally offset with respect to each other.

### DESCRIPTION OF THE DRAWINGS

The details of the invention may be obtained by a review of the accompanying drawings, in which like reference numerals refer to like parts, and in which:

FIG. 1. is an isometric cutaway view of a portion of an exemplary structural assembly according to one embodiment of the invention;

FIG. 2A is a cross-section view taken along line 2A of FIG. 1;

FIG. 2B is a detail view of a portion of FIG. 2A showing the interconnection of adjacent assemblies, for embodiments in which the assemblies are provided in modular form;

FIGS. 2C and 2D are a cross-section views of the individual load bearing sheet members that make up a portion of the structural assembly of FIG. 1;

FIGS. 3A-3C are cross-section views of the structural assembly of FIG. 1, before, during and after a blast has been applied to one of the assembly faces respectively;

FIG. 4A is a cross-section view of a conventional structural module;

FIG. 4B is a cross-section view of the conventional structural module of FIG. 4A after being subjected to an explosive blast;

FIGS. 5A-5E are isometric cutaway views of a series of exemplary steps for assembling the structural, assembly of FIG. 1;

FIG. 6 is a cross-section view of a portion of an exemplary structural assembly according to the invention in which the assembly comprises a portion of two walls of a building structure;

FIG. 7 is a cross-sectional view of a structural assembly according to one embodiment;

FIG. 8 is a top cross-sectional view of a structural assembly according to one embodiment;

FIG. 9 is a top cross-sectional view of a structural assembly according to one embodiment;

FIG. 10 is a top cross-sectional view of a structural assembly according to one  
15 embodiment;

FIG. 11 is a top cross-sectional view of a structural assembly according to one embodiment; and

FIG. 12 is a top cross-sectional view of a structural assembly according to one embodiment.

20 **DETAILED DESCRIPTION**

A new structural assembly is disclosed for use in building applications in which a high resistance to large explosive blast and projectile impact loads is desired. The structural assembly design incorporates a pair of outer face sheets, spaced apart to form a void there between. Within the void are a plurality of particularly situated and oriented structural members configured to resist and mitigate by dissipating explosive blast or projectile loads applied to one of the outer wall faces. The internal structural members are designed and positioned to bend in response to such loads, thereby minimizing the chance that one or both of the external faces will be breached. In addition to breach-prevention, the new structural assembly design also will maintain the structural integrity of the building for sufficient time to enable the occupants to evacuate, to enable the contents to be evacuated, and to allow the building to be repaired and reused.

Thus, embodiments of the present invention provide for inward movement of one of the outer faces (typically the face (e.g., building, module, wall, roof, column, beam, or floor) that is closest to the explosive blast or projectile impact), to thereby dissipate and

carry forces rather than to completely withstand it. For cases in which the blast or projectile are of such magnitude that the assembly (wall, roof, floor, etc.) is penetrated, sufficient structural integrity is maintained to allow the occupants to safely evacuate, the contents of the building to be removed, and the building to be repaired and reused.

5 Referring to FIGS. 1 and 2A, an exemplary structural assembly 1 is shown. The structural assembly 1 may comprise a wall, module, floor/ceiling, roof, column, beam, or building section. The structural assembly 1 may be pre-fabricated at the factory in a modular fashion that can then be fully assembled at the installation site. The structural assembly 1 is shown as having first and second face sheets 2, 4, and a plurality of internal  
10 structural members 6 configured to provide strength and stability to the assembly 1 to support the typical vertical and horizontal loads associated with a building structure. In various embodiments, the internal structural members 6 comprise a plurality of individual vertically positioned sheet elements having portions oriented either substantially parallel to, and/or substantially perpendicular to, the first and second face sheets 2, 4. It will be  
15 appreciated that although the internal structural members 6 are shown in the figures as being oriented parallel and/or perpendicular to the first and second face sheets 2, 4, one or more of the members could be oriented so as to be obliquely angled with respect to the face sheets 2, 4.

As noted, the structural assembly 1 comprises complete and continuous floors,  
20 walls, roofs and buildings having the disclosed arrangement of face sheets 2, 4 and internal structural members 6 in various embodiments. The structural assembly 1 is manufactured in at least one of a variety of sizes, depending upon what the installation equipment and site conditions will allow. Thus, for some applications, the structural assembly 1 is pre-manufactured at the factory to comprise an entire floor, wall, roof or  
25 building and then shipped to the site for installation. In other applications, such as for retrofit applications, the assembly is manufactured in discrete modules at the factory, shipped to the installation site, transported into the building and fastened together to form a larger overall assembly 1.

In the embodiments depicted in Figs. 1-2A, the internal structural members 6  
30 comprise a plurality of opposing intermediate panels 8, 10 oriented substantially parallel to the first and second face sheets 2, 4, as well as a plurality of flanged web members 12, 14 oriented substantially perpendicular to the first and second face sheets. Each of the intermediate panels 8, 10 is connected to one of the first and second face sheets 2, 4 by an associated flanged web member 12, 14. As shown, the opposing intermediate panels 8, 10

are alternately positioned along the length "L" of the assembly 1 so that immediately adjacent panels 8, 10 are connected to different face sheets 2, 4. The immediately adjacent intermediate panels 8, 10 also are linked to each other by channel shaped members 9, 11 formed at the distal edges of each intermediate panel 8, 10.

5           In certain embodiments, the structural assembly 1 further comprises additional supportive flanged web members 16 positioned opposite to some of the intermediate panels. In the illustrated embodiment of Fig. 2A, these additional flanged web members 16 are positioned opposite to intermediate panels 8 and are directly connected to the second face sheet 4. The additional flanged web members 16 are positioned so that they  
10   are laterally offset along the X-axis (by "OD" (FIG. 2A)) from the flanged web members 12 that connect the intermediate panel 8 to the first face sheet 2. This lateral offset forms a cantilever arrangement in which intermediate panel 8 is supported by two opposing but offset flanged web members (12, 16). Thus, when a load is applied to the second face sheet 4 (the one to which flanged web member 16 is attached), the load is carried from the  
15   face sheet 4, through the flanged web member 16, to intermediate panel 8, such that panel 8 bends, but is restrained at each end by the channel shaped members 9, 11 and also by flanged web member 12 near the center of the structural assembly 1 (see FIG. 3B). This bending of intermediate panel 8 (and also intermediate panel 10, as the channel shaped members 9, 11 interlock) dissipates and carries the blast forces throughout the interior  
20   structure of the assembly and to the foundation.

It will be appreciated that where the structural assembly 1 comprises a complete wall, floor, roof, column, beam, or building, that the reaction to an explosive blast will be substantially the same all the way along the length of the assembly, since the arrangement of the flanged web clusters (i.e., those formed by flanged web members 12 and 16) and the  
25   interlocking channel shaped members 9, 11 is carried throughout the assembly, as will be described in greater detail. Thus, the flanged web cluster and channel shaped member arrangement serves to effectively dissipate a blast throughout the interior structure to minimize the chance that any of the structural members will fail, at the same time, carrying a substantial portion of the horizontal and vertical blast force to the foundation.

30           The additional flanged web members 16 do not directly contact the intermediate panels 8 in preferred embodiments and during normal use and/or positioning of the assembly 1. Rather, members 16 are offset from the intermediate panels 8 by a gap such that the additional flanged web members 16 only contact the intermediate panels 8 when an explosive blast or projectile impact load is applied to one of the first or second face

5 1. Thus, the gap is preferably of sufficient size to allow for the installation of a desired thickness of thermal insulation or epoxy.

Thus configured, the internal arrangement of the structural assembly 1 provides for efficient dissipation and carriage of forces in response to a blast or projectile impact load applied to one of the external faces 2, 4. For example, when an explosive blast or projectile impact load of sufficient force is applied to the first or second face sheets 2,4, the portion of the assembly immediately adjacent to the flanged web clusters (12, 16) remains substantially rigid, while the intermediate panel 8, 10 associated with the impacted face sheet moves toward the opposing intermediate panel, causing the channel shaped members 9, 11 to engage. The engagement of the channel shapes prevents the face sheet 2 (with its associated flanged web member 12 and intermediate panel 8) from completely separating from face sheet 4 (with its associated flanged web member 14 and intermediate panel 10), during a blast or projectile impact. Interlocking also connects the intermediate panels 8, 10 to the immediately adjacent flanged web clusters 12, 16, thus providing support and facilitating the efficient carriage of force between the face sheets 2,4 and the intermediate panels 8, 10. The bending of the intermediate panels 8, 10 and face sheets 2,4 substantially dissipates the forces from explosive blast and projectile impacts, thus maintaining sufficient structural integrity in the structure to allow occupants to evacuate and contents to be evacuated, and to enable the building itself to be repaired and returned to full service.

25 An example of how the internal structures of the structural assembly 1 react in response to an applied blast is shown in FIGS. 3A-3C. Although these figures show only a portion of the structural assembly 1, it will be appreciated that the response to a blast will generally be consistent along the entire length, width and height of a full structural assembly 1. FIG. 3A shows the assembly 1 configuration prior to the blast. FIG. 3B shows the assembly 1 configuration during application of a blast to the second face sheet 4. As can be seen in FIG. 3B, the second face sheet 4 is substantially bent inward toward the first face sheet 2 at a point located between the flanged web clusters 12, 16. This bending partially dissipates and carries the blast, moving flanged web members 14 and intermediate panel 10 inward until the channel shaped members 9, 11 interlock



intermediate panels 10 with intermediate panels 8 to carry the load throughout the assembly 1 and to the foundation of the building in which it is incorporated. As noted, the points of maximum movement can be seen to be the mid-points of face sheets 2, 4 between the flanged web clusters 12, 16. These points may be "designed-in" to the module, for example, by designing the channel shaped members 9, 11 to be less resistant to deflection as compared to the surrounding structural members, by adjusting the length of the flange(s) on the flanged web members 16, or by using lighter gauge steel at or near the point at which maximum deflection is desired. FIG. 3C shows the post-blast configuration in which the first and second face sheets 2, 4 and some of the internal structures (intermediate panels 8, 10; channel shaped members 9, 11) have been permanently bent. It can be seen that although these internal structures have been bent, the structural assembly 1 has not been breached, and none of the interconnections between structural members has completely failed.

The structural assembly 1 may be oriented to protect the inside as well as the outside of the building. In various embodiments, structures of the present disclosure are arranged to protect the building from internal blasts, such as where the building is an armory, a chemical plant, or the like.

This is in sharp contrast to conventional building module designs, one of which is illustrated in Figs. 4A and 4B. As can be seen in Fig. 4A, conventional module 22 has inner and outer face sheets 24, 26, and an interior panel 28 supported by a single flanged web member 30. In response to an explosive blast force directed at the outer face 26, the outer face sheet 26, interior panel 28 and flanged web member 30 are breached, and substantial deformation (denoted as "DD") of the inner face sheet 24 occurs.

As previously noted, the structural assembly 1 may be used in retrofit applications in which an existing wall, floor, roof or portion of an existing building requires blast or projectile impact protection. In such applications, the confines of the existing building prevents the installation of large assemblies 1 (i.e., full walls, roofs or floors), and thus the assembly is manufactured in discrete modules, shipped to the installation site, transported into the building and joined together to form a larger overall assembly 1.

In various embodiments, adjacent modules are fixed together using any suitable connection method, such as welding, gluing, bolting, and the like. An example of how adjacent modules may be fixed together is shown in FIG. 2B, wherein adjacent modules M1, M2 are provided with slightly overlapping face sheets 2,4 (e.g., the face sheets 2, 4 of one module may overlap the adjacent panel by a distance shown as "OL"). This enables

the face sheet of the first module M1 to be overlapped and connected to the adjacent module M2. It will be appreciated that where one or more face sheets 2, 4 overlap an adjacent module, the overlapped portion of that adjacent module will be provided without a face sheet. This ensures an even finished external surface configuration for the finished joined modules. Again, this overlapped face sheet approach may only be required for retrofitting applications.

FIGS. 2C and 2D depict individual flanged web members 12, 16 formed by the conjunction of a pair of wide-flange channels 12a, b; 16a, b. Initially, the individual channels are formed from appropriately sized sheets of steel (or other material), which are formed into the channel shapes shown in the figures. The channels 12a, b; 16a, b are then connected to form the individual flanged web members 12, 16 by welding, gluing or other appropriate technique. Although not shown, it will be appreciated that flanged web member 14 can be constructed in much the same manner.

As previously noted, the internal arrangement of structural members within the structural assembly 1 is repeated throughout the assembly, and thus the force dissipating flanged web clusters 12, 16 and interlocking features 9, 11 are carried throughout the entire assembly. This will also be true for retrofit applications, in which individual modules are formed and joined together at the installation site. Thus, the multiple flanged web clusters are formed throughout the assembly when multiple individual modules are joined together, enabling the invention to be applied to buildings of virtually any size.

As previously noted, the end regions 18, 20 (Fig. 2A) of each of the intermediate panels 8, 10 comprise corresponding channel shaped members 9, 11 which allow adjacent internal panels 8, 10 to interlock when the panels 8, 10 bend in response to an explosive blast or projectile impact. As shown in Fig. 2A, these channel shaped members 9, 11 may be separated on all sides from each other by a gap "G," in order to minimize the transmission of thermal and acoustical energy between the face sheets 2, 4. These gaps "G" may also be formed between adjacent internal panels 8, 10, again, to reduce total thermal and acoustical energy transmission between the first and second face sheets 2, 4 of the structural assembly 1. Providing these gaps "G" controls the conduction of heat between the first and second face sheets 2, 4, which reduces heating/cooling costs associated with daily operation of a building formed in whole or in part by the structural assembly 1. Further improvements are provided wherein one of the face sheets 2, 4 is subjected to fire or source of extreme heat, as the amount of time required to heat up the opposite face sheet is increased, thereby enabling the building to retain sufficient structural

integrity to allow occupants to evacuate and contents to be evacuated, and to enable the building itself to be repaired and returned to full service.

It is noted that the channel shaped members 9, 11 also serve to hold the first and second face sheets 2, 4 together when one of the face sheets is subjected to heat of sufficient magnitude that it weakens a portion of one of the structural assembly and its associated structural members. This is important where building integrity must be maintained for a sufficient time to enable the occupants to evacuate and contents to be evacuated.

In various embodiments, the gaps "G" are filled with insulation material, epoxy or other filler materials to further reduce conduction heat transfer across the structural assembly 1. It will be appreciated, however, that providing gaps between these structures is not critical, and thus, the structural assembly 1 may be formed without such gaps.

In further embodiments, the structural assembly 1 is filled with foamed and/or blown insulation, or precut and formed insulation material or board, to enhance the overall thermal and acoustical efficiency of the building of which it is a part. Other materials also may be provided in the space between face sheets 2, 4, such as a material appropriate to the specific requirements of the building to provide the assembly with additional mass and resistance to blast or projectile impacts. Additionally, where prevention or inhibition of electronic eavesdropping is desired, the assembly 1 is partially or completely filled with shredded copper or other appropriate material. Other filler materials include, but are not limited to, copper steel slag filler material (mineral wool and silica), fire resistant insulation, or impact resistant insulation. Additionally, impact resistant insulation such as fiberboard may be applied to one or more surfaces within the assembly. Such impact resistant insulation substantially enhances the assembly's resistance to crushing.

Sheets of the present disclosure may be cut to various user-desired sizes, and bent into the appropriate form to impart desired structural features, and then connected to form site specific structural assemblies 1 (e.g., walls, roofs, columns, beams, floors) which are ultimately formed into a complete building structure.

Further, the structural assembly 1 (e.g., walls, roofs, columns, beams, floors) can be manufactured at the factory in a size as large as the installation equipment and site conditions will allow. When used in a retrofit application, smaller, discrete modules are be manufactured and delivered to the site for assembly with one or more other discrete modules. In one embodiment of the retrofit application, the individual structural elements that form a module are formed and shipped to the installation site as individual pieces or

sub-modules where they may be joined together to construct one or more modules. This provides the advantage(s) in that it enables the inventive structural assembly 1 to be transported and installed anywhere in the world, and minimizes or eliminates problems associated with long-range shipping of oversized loads. Additionally, these features enable unobtrusive installation of the modules for reinforcing all or part of existing buildings. Such unobtrusive installation has the benefit of enabling discreet installation, for example, in protecting classified domestic or foreign building installations or portions thereof.

In various embodiments, structural assemblies of the present disclosure may be formed on-site through the use of one or more portable or semi-portable forming machines. For example, where larger jobs require various structural assemblies in accordance with the present disclosure, the provision of on-site forming machines is contemplated to provide ease of access and rapid construction of the appropriate structural unit.

Any desired fabrication/shipping method may be used, and, as noted, the decision about which method to undertake is based on site-specific requirements, such as the size of the installation equipment and the space available for installation. For example, in new construction applications it may be more cost-effective and efficient to fabricate an entire structural assembly 1 (walls, roofs, floors, columns, beams, etc.) at the factory and ship them to the installation site. For retrofit applications, however, it may only be practical to fabricate and transport relatively smaller modules that can be hand carried into existing building structures for assembly.

Referring to Figs. 5A through 5E, exemplary steps are shown for fabricating a portion of the inventive structural assembly 1 of FIG. 1. As previously noted, the structural assembly 1 (here shown as an individual module) may be assembled from a plurality of individual sheet steel sub-units 36a, 36b, 38a, 38b, which have been cut and bent to have a desired shape. The individual sub-units may themselves be made of one or more pre-shaped individual pieces which are then joined together (via welding, gluing or the like) to form the desired structural assembly 1. As noted, the entire manufacturing process can be performed prior to shipping, or sub-units or modules may be manufactured and shipped and then joined at the installation site.

FIG. 5A shows the fabrication of a pair of sub-assemblies 36a, 36b that comprise the first face sheet 2 and its associated flanged web members 12, 12a, 12b. In the illustrated embodiment, the individual sheet elements comprise flanged web members 12, 12a, 12b which are joined to the panel face sheet 2 via welding or fastening. FIG. 5B

similarly shows the fabrication of a pair of subassemblies 38a, 38b that comprise the second face sheet 4 and its associated flanged web members 14, as well as the additional supportive flanged web members 16, 16a, 16b. The individual sheet elements comprising the flanged web members are joined to the face sheet 4 via welding or fastening. It will be appreciated, however, that joining techniques other than welds may also be used (e.g.,  
5 gluing, mechanical fasteners, use of double-sided adhesive strips).

FIG. 5C shows the fit-up of sub-assemblies 36a, 38a and 36b, 38b. As can be seen, the respective sub-assemblies (36a, 38a; 36b, 38b) are positioned end-to-end so that their respective channel shaped members 9, 11 align. The sub-assemblies are then placed  
10 together in an interlocking position, with sub-assemblies 36a, 36b moving with respect to sub-assemblies 38a, 38b in the direction of arrows "A." The sub-assemblies 36a, 38a and 36b, 38b may form larger sub-assemblies 40a, 40b.

Larger sub-assemblies 40a, 40b are then moved together (along respective arrows "B") as shown in FIG. 5D. FIG. 5E shows the sub-assemblies 40a, 40b in the engaged  
15 position, whereupon they may be joined together. Completed flanged web members 12, 14 and 16, as well as their sub components 12a, 12b, 16a, 16b, can be seen in the engaged assembly.

The completed module shown in FIG. 5E may then be joined to other such modules to form a completed wall, roof, floor or building, as desired. Alternatively, a  
20 single module may be used to protect a discrete portion of a wall, roof, column, beam, or floor.

Referring now to FIG. 6, structural assembly 1 is shown in a cross-sectional top plan view, the assembly comprising a pair of walls 42, 44 joined at a corner 46. As can be seen, the internal arrangement of structural members within the structural assembly 1 of  
25 FIG. 6 is the same as previously described in relation to FIGS. 1 and 2A. Thus, the specified arrangement of flanged webs 12, 14, 16, channel shaped members 9, 11 and intermediate panels 8, 10, is repeated throughout the assembly 1, and thus the force dissipating flanged web clusters 12, 16 and interlocking features 9, 11 are carried throughout the entire assembly 1. As before, the flanged web cluster and channel shaped  
30 member arrangement shown in FIG. 6 serve to effectively dissipate a blast throughout the interior structure of both walls 42, 44 to minimize the chance that any of the structural members will fail. It will be appreciated that this structural scheme can be repeated to obtain a unitized wall, floor, column, beam, panel, roof or building in any of a wide variety of sizes.

Although welding has been described for use in joining the individual elements that make up the finished structural assembly 1, other joining techniques may also be used to connect some or all of the sub-units together. For example, one or more of the sub-units may be glued together, such as with an appropriate high-strength epoxy. Alternatively, a combination of epoxy and welding techniques may be used. Thus, in one embodiment, a low-modulus, high-strength epoxy is used in combination with welding to connect the flanged web member subcomponents (12a, 12b; 14, 16a, 16b). Epoxy may also be used to strengthen corner members, which may be subjected to extreme loading during an explosive blast or projectile impact.

In addition to its use in fixing individual elements of the structural assembly 1 together, a layer of epoxy may also be provided over one or more interior surfaces of the assembly 1 to increase strength and enhance the energy dissipating characteristics of the assembly. Further, a layer of impact resistant insulation may be applied to one or more interior surfaces of the structural assembly 1.

The individual structures used to fabricate the structural assembly 1 may be any of a variety of appropriate materials known for use in structural building applications. In one embodiment, cold drawn sheet steel is provided. Alternatively, some or all of the structural members are made from other metals or a suitable non-metallic material such as PVC, vinyl, etc. Various combinations of such materials are also provided in further embodiments.

The inventive module comprises a modular, lightweight, and cost effective building system that can be used in a variety of applications, including blast walls, safe rooms, hurricane shelters, vandal-resistant garage or storage structures, and the like. It can be applied to existing buildings, as well as new construction, for virtually any structure that requires higher security than can be provided with commercial construction techniques.

Referring now to FIG. 7, a structural assembly 50 according to one embodiment is shown in a cross-sectional top plan view. The depicted embodiment provides various features and benefits of additional embodiments of the present disclosure, and provides improved blast resistance in part due to structure of channel shaped members 52, 54, 56.

The structural assembly 50 of FIG. 7 comprises a wall, a floor/ceiling, a column, a panel, a beam, a roof, or a building section, to name a few. The structural assembly 50 may be pre-fabricated at the factory in a modular fashion that can then be fully assembled at the installation site. The structural assembly 50 is shown having first and second face

5 sheets 60, 62, and a plurality of internal structural members configured to provide strength and stability to the assembly 50 to support the typical vertical and horizontal loads associated with a building structure. In various embodiments, the internal structural members 57, 58 comprise a plurality of individual vertically positioned sheet elements having portions oriented either substantially parallel to, or substantially perpendicular to, the first and second face sheets 60, 62. It will be appreciated that although the internal structural members are shown in the figures as being oriented parallel or perpendicular to the first and second face sheets 60, 62, one or more of the members could be oriented so as to be obliquely angled with respect to the face sheets 60, 62.

10 In various embodiments, the structural assembly 50 comprises complete and continuous structures having the disclosed arrangement of face sheets 60, 62 and internal structural members 57, 58. The structural assembly 50 is manufactured in at least one of a variety of sizes, depending upon what the installation equipment and site conditions will allow. Thus, for some applications, the structural assembly 50 is pre-manufactured at the factory to comprise an entire floor, wall, roof or building and then shipped to the site for installation. In certain applications, such as for retrofit applications, the assembly is manufactured in discrete modules at the factory, shipped to the installation site, transported into the building and fastened together to form a larger overall assembly 50.

20 In the embodiment depicted in FIG. 7, the internal structural members comprise a plurality of opposing intermediate panels 64, 66 oriented substantially parallel to the first and second face sheets 60, 62, as well as a plurality of flanged web members 52, 54, 56 oriented substantially perpendicular to the first and second face sheets. As shown, the opposing intermediate panels 64, 66 are positioned along a length of the assembly 50 so that immediately adjacent panels 64, 66 are connected to different face sheets 60, 62.

25 In order to connect adjacent panels, sections are spaced apart and butt welded to each other. For example, a prefabricated assembly 50 is connected to one or more additional prefabricated sections by providing the assemblies in close proximity and butt welding the assemblies together.

30 Fig. 8 depicts adjacent assemblies 50a, 50b of the present disclosure. As shown, adjacent assemblies comprise various features as shown and described herein. Adjacent assemblies 50a, 50b are joined at two or more internal members 64, 66, 70, with opposing face sheets spaced apart and welded together through, for example, one or more butt welds.

An infinite wall can thus be fabricated at almost any desired width or height as may be desired. In various embodiments, a wall is provided with a width of between approximately three inches and approximately eighty inches. In more preferred embodiments, a wall may be provided with a width of between approximately six inches  
5 and approximately forty inches.

In certain embodiments, the structural assembly 50 comprises at least two flanged members 52, 54 extending substantially perpendicularly from internal structural members 57 and at least one flanged member 56 extending substantially perpendicularly from internal structural members 58. Flanged members 52, 54 extend generally perpendicularly  
10 from structural member 57 toward structural member 58 and further comprise secondary flanged members 52b, 54b, respectively. In various embodiments, secondary flanged members 52b, 54b extend substantially perpendicularly from flanged members 52, 54 and extend toward flanged member 56. Flanged member 56 is disposed generally between additional flanged members 52, 54 and, in one embodiment, is provided approximately at  
15 a mid-point between flanged members 52, 54.

Thus, when a load is applied to the second face sheet 62 (the one to which flanged web member 57 is attached), the load is carried from the face sheet 62, through structural member 57 to the flanged members which absorb energy from the load.

Flanged members 52b, 54b and 56b provide a substantially interlocking  
20 arrangement for improved blast and fire resistance. At least one of flanged members 52b, 54b and 56b are provided to engage at least one other flanged member 52b, 54b and 56b regardless of the specific direction and/or vector of force that is applied to the assembly.

It will be appreciated that where the structural assembly 50 comprises a complete wall, floor, roof, or building, that the reaction to an explosive blast will be substantially the  
25 same all the way along the length of the assembly, since the arrangement of the flanged web clusters is carried throughout the assembly. Thus, the flanged web clusters and channel shaped member arrangements serve to effectively dissipate a blast throughout the interior structure to minimize the chance that any of the structural members will fail, at the same time, carrying a substantial portion of the horizontal and vertical blast force to the  
30 foundation.

Fig. 9 provides yet another embodiment of the present disclosure wherein an assembly is provided comprising two channel shaped members 57, 58 and two respective flanged members 80a, 80b. The assembly 50a of the embodiment provided in Fig. 9 comprises various features of the embodiment provided in Figs. 7-8. As shown in Fig. 9, a



plurality of channel shaped members 57, 58 and a plurality of flanged web members 80a, 80b are provided and oriented substantially perpendicular to the first and second face sheets. The plurality of channel shaped members and flanged members in Fig. 9 comprise two flanged web members.

5 Fig. 10 provides yet another embodiment of the present disclosure wherein an assembly 50a is provided comprising internal structural members 82, 84, 86, 88, 88b, 90, 90b extending from face sheets 60, 62. As shown, internal structural member 82 extends generally from face sheet 62 and is interconnected to laterally extending intermediate panel 84. Laterally extending intermediate panel 84 comprises a terminus, the terminus  
10 comprising a first 86, second 88, and third 88b internal structural member. First 86, second 88, and third 88b internal structural members are provided to interact with corresponding members 90b, 90, 92 extending from laterally extending intermediate member 94. Intermediate member 94 extends toward additional force-transmitting means 98 and/or is secured to face sheet 60.

15 In various embodiments, plug welding methods are employed to form and/or join members of a structural assembly in accordance with the present disclosure. Plug welds are provided, for example, to reduce the number of requisite welds to join various portions of the assembly, increase the structural integrity of the assembly, and facilitate manufacturing processes related to forming assemblies of the present disclosure. Plug  
20 welds may be provided at various locations including, but not limited to, locations for joining internal structural members 57, 58 to respective first and second face sheets 60, 62. In alternative embodiments, plug welds are provided at unions of face sheets 2, 4 and respective internal members 12, 14, 16.

Specific weld structures, arrangements, positioning, and type of the present  
25 disclosure vary based on usage requirements. In preferred embodiments, full seam welding is provided. In alternative embodiments, such as where cost considerations are present, internal structures can be skip welded to the face and spaced at approximately nine inch centers or less.

30 Figs. 11-12 depict one embodiment of an assembly 50a of the present disclosure, wherein various weld locations 100 are indicated. It will be expressly recognized, however, that Figs. 11-12 are merely exemplary embodiments of structures formed with certain weld locations. The present disclosure is not limited to any particular type, arrangement, or positioning of welds and various welding options as will be recognized by

one of skill in the art are contemplated as within the scope and spirit of the present disclosure.

5 It will be understood that the description and drawings presented herein represent an embodiment of the invention, and are therefore merely representative of the subject matter that is broadly contemplated by the invention. Thus, for example, although the drawings do not represent the invention as part of a completed building structure, it will be appreciated by one of ordinary skill in the art that such a completed building structure is contemplated. It will be further understood that the scope of the present invention encompasses other embodiments that may become obvious to those skilled in the art.

What is claimed is:

1. A substantially rectangular building panel module for defining at least a portion of a building wall, a floor, and a ceiling, the module comprising:

5 at least two substantially planar metallic plate members arranged in parallel and spaced apart by a predetermined distance to define a hollow, generally rectangular void space, each of the at least two plate members including at least one inwardly extending support member, the at least one inwardly extending support member extending into the void space and being substantially perpendicular to the at least two plate members;

10 the inwardly extending support member of each of the at least two plate members comprising a laterally extending planar member, the laterally extending planar members oriented substantially parallel to the plate members and extending toward an opposing inwardly extending support member;

15 the inwardly extending support members providing longitudinal stiffness to the panel module to withstand compression loads and to provide transverse strength to the panel module to withstand transversely applied bending loads;

20 the laterally extending planar members being substantially planar and positioned relative to each other in overlapping relationship and spaced from each other in a transverse direction of the module to prevent direct transmission therebetween of heat and sound and to prevent unimpeded passage through the module of ballistic projectiles that penetrate one face of the module, and thereby provide resistance to passage through the module of at least one of a blast load, a ballistic projectile, a thermal energy, and a sound wave.

25 2. The building panel module according claim 1, wherein the laterally extending planar members further comprise a secondary inwardly extending support member, the second inwardly extending support member provided at an opposing end of the laterally extending support member with respect to the inwardly extending support member, and disposed substantially parallel to the inwardly extending support member.

30 3. The building panel module according claim 1, wherein the laterally extending planar members are provided in an overlapping manner and overlap each other over substantially their entire surfaces.

4. The building panel module according claim 1, wherein the laterally extending planar members extend in two laterally opposing directions away from respective inwardly extending support members.

5. The building panel module according claim 4, wherein the laterally extending planar members extend in two laterally opposing directions by substantially the same distance and further comprise a secondary inwardly extending support member.

6. The building panel module according claim 1, wherein the building panel  
5 module is provided in a plurality of discrete sections adapted for on-site assembly.

7. The building panel module according claim 1, wherein the inwardly extending support members are joined to the plate members by at least one of welding, chemical bonding, insulation material, and mechanical fasteners.

8. The building panel module according claim 1, wherein opposing laterally  
10 extending planar members are spaced from each other to define a longitudinally extending gap therebetween.

9. The building panel module according claim 8, wherein the longitudinally extending gap is provided with at least one of an aggregate and an epoxy.

10. The building panel module according claim 2, wherein the secondary  
15 inwardly extending support members are spaced apart from opposing laterally extending planar members and adapted to contact at least one of an opposing laterally extending planar member and an opposing secondary inwardly extending support member when the module receives an impact on a face of the module.

11. A structural assembly for use in constructing a building structure, the  
20 assembly comprising:

a first plate forming a first face of the building structure;

a second plate forming a second face of the building structure;

the first and second plate being substantially parallel to one another and spaced  
apart to form a void space;

25 third and fourth plates positioned in the void space and being laterally offset with respect to each other, a portion of the third plate overlapping a portion of the fourth plate;

a first flanged member connecting the first plate to the third plate, and

a second flanged member connecting the second plate to the fourth plate;

wherein the first and second flanged members are disposed substantially  
30 perpendicular to the first and second plates and the first flanged member is offset by a lateral distance from the second flanged member.

12. The structural assembly according claim 11, wherein the third and fourth plates further comprise inwardly extending support members, the inwardly extending support members provided at an opposing end of the third and fourth plates with respect to

the first and second flanged members, and disposed substantially parallel to the first and second flanged web members.

13. The structural assembly according claim 11, wherein the third and fourth plates are provided in an overlapping manner and overlap each other over substantially  
5 their entire surfaces.

14. The structural assembly according claim 11, wherein the third and fourth plates extend in two laterally opposing directions away from respective flanged members.

15. The structural assembly according claim 14, wherein the third and fourth plates extend in two laterally opposing directions by substantially the same distance and  
10 further comprise a secondary inwardly extending support member.

16. The structural assembly according claim 11, wherein the structural assembly is provided in a plurality of discrete sections adapted for on-site assembly.

17. The structural assembly according claim 11, wherein the first and second flanged members are joined to the first plate and second plate members by at least one of  
15 welding, chemical bonding, insulation material, and mechanical fasteners.

18. The structural assembly according claim 11, wherein third and fourth plates are spaced from each other to define a longitudinally extending gap therebetween.

19. The structural assembly according claim 18, wherein the longitudinally extending gap is provided with at least one of an aggregate and an epoxy.

20. The structural assembly according claim 12, wherein the inwardly extending support members are spaced apart from the third and fourth plates and are adapted to contact at least one of an opposing third or fourth plate and an opposing inwardly extending support member when the module receives an impact on a face of the  
20 module.

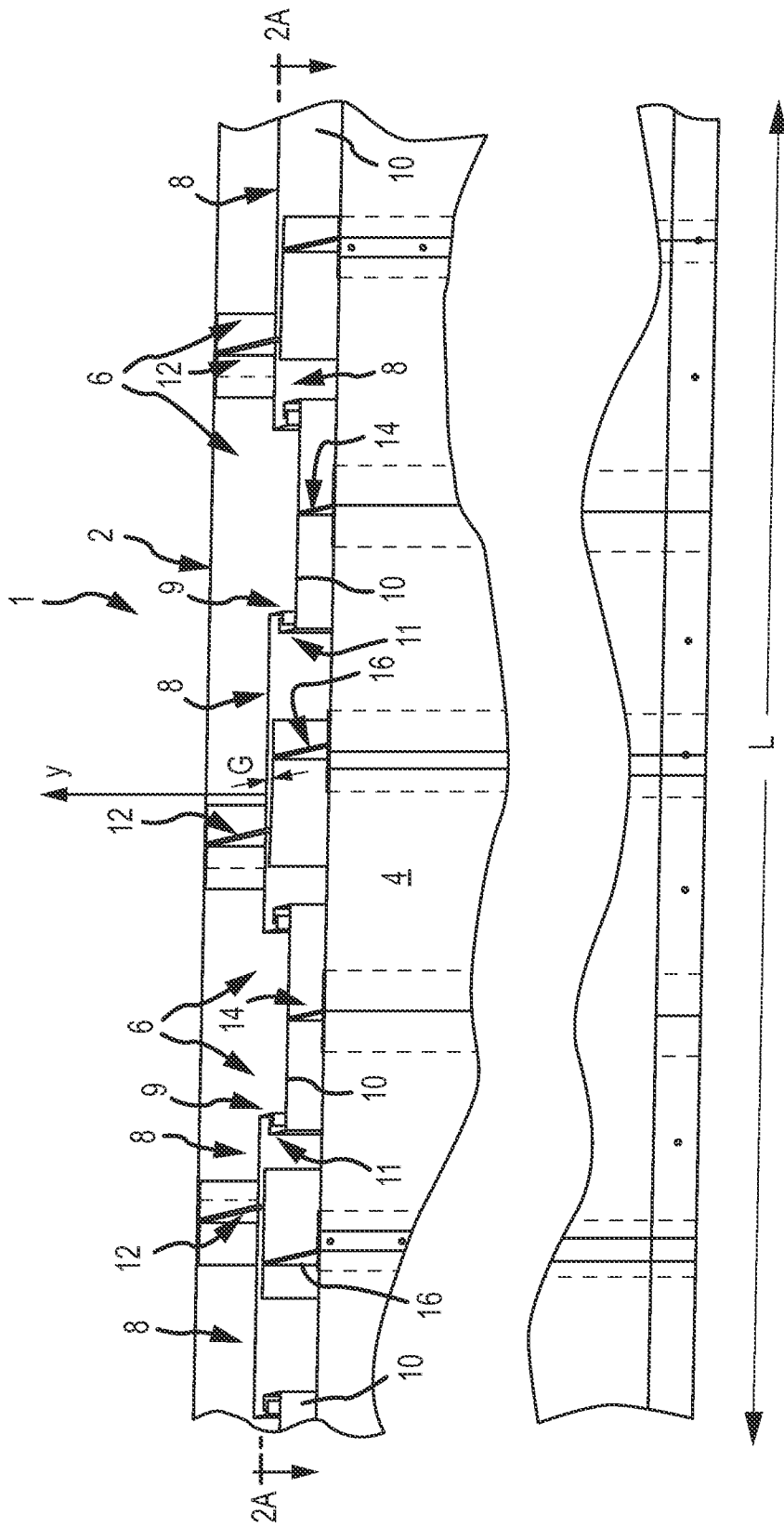
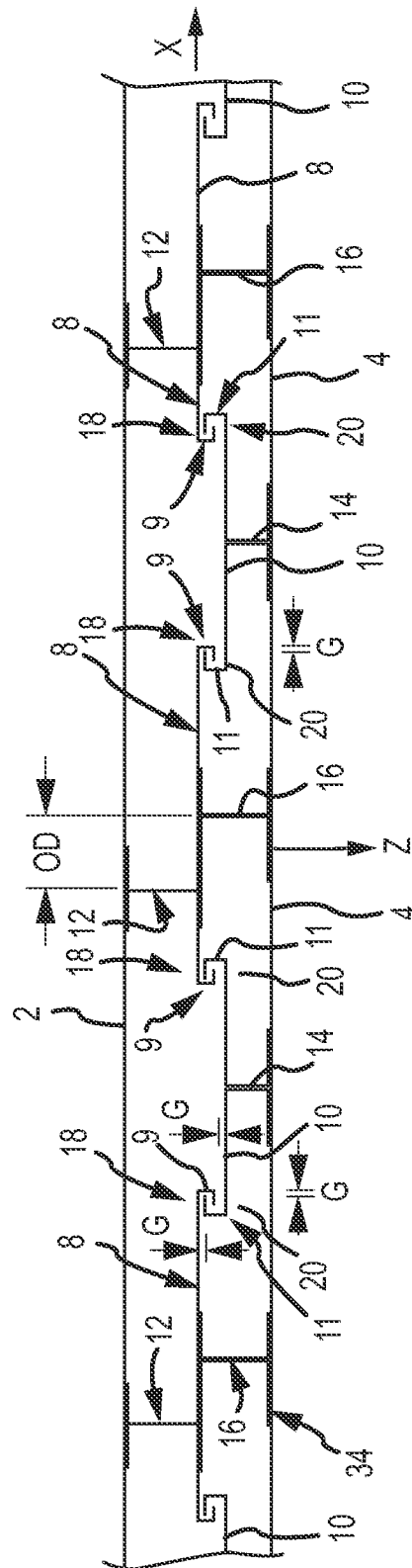


FIG.1



# FLIGS

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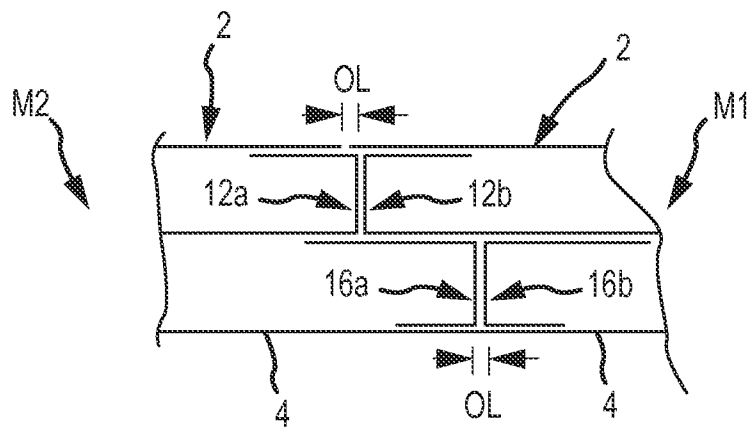


FIG. 2B

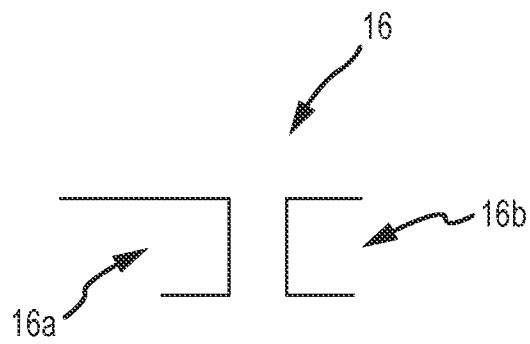


FIG. 2C

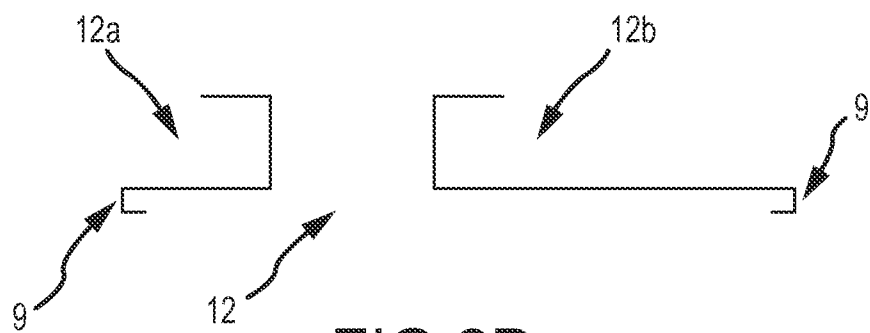


FIG. 2D



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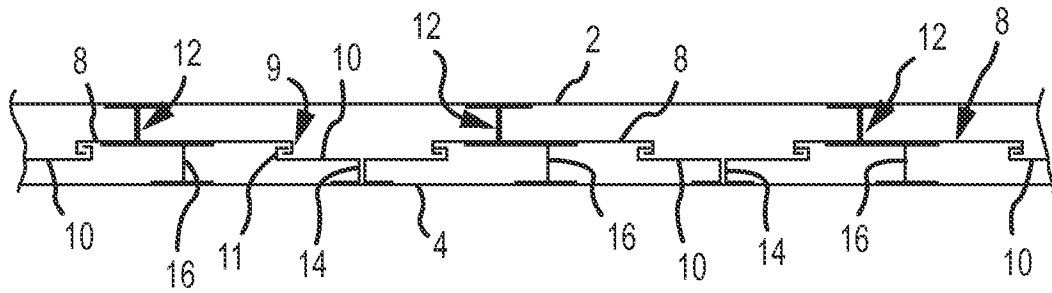


FIG. 3A

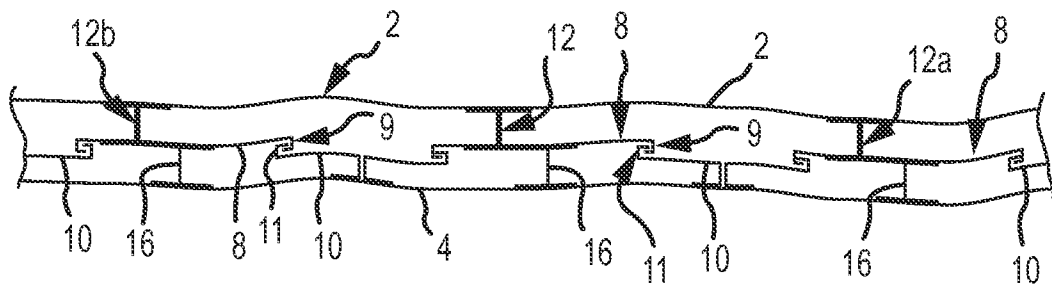


FIG. 3B

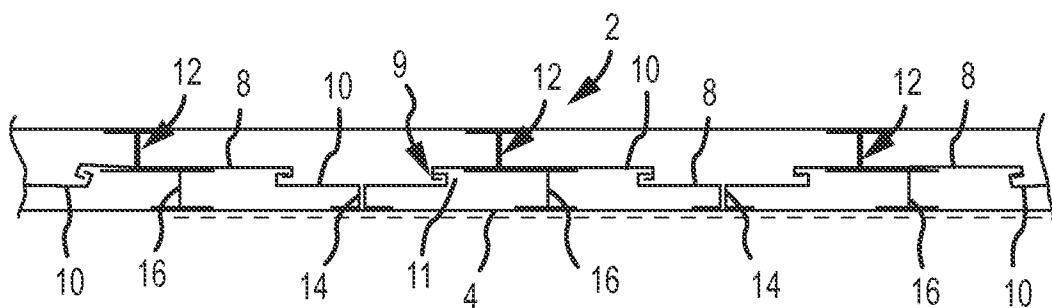


FIG. 3C

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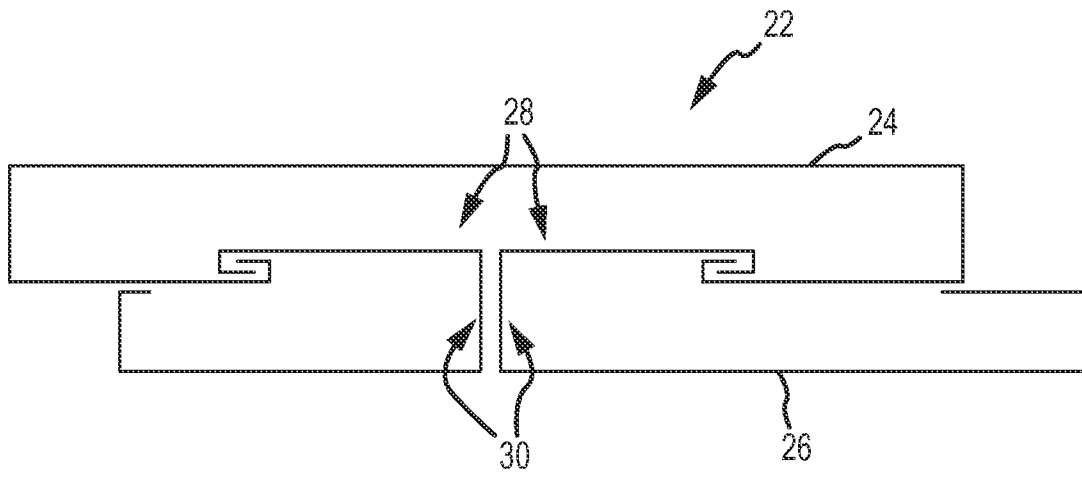


FIG. 4A

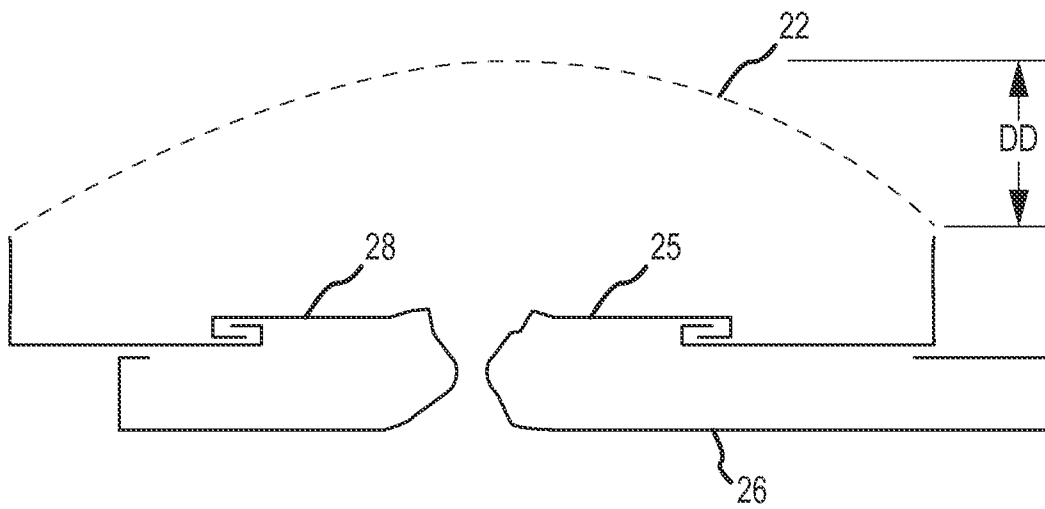


FIG. 4B

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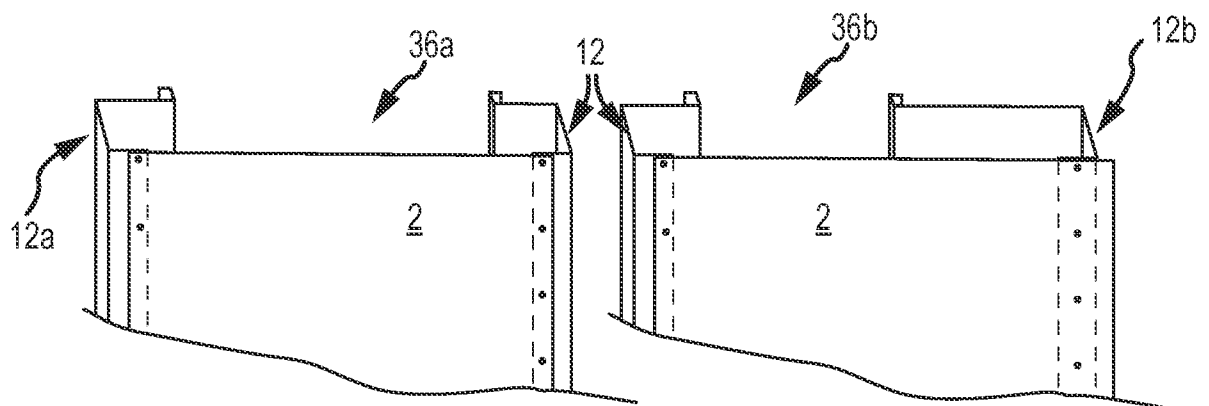


FIG. 5A

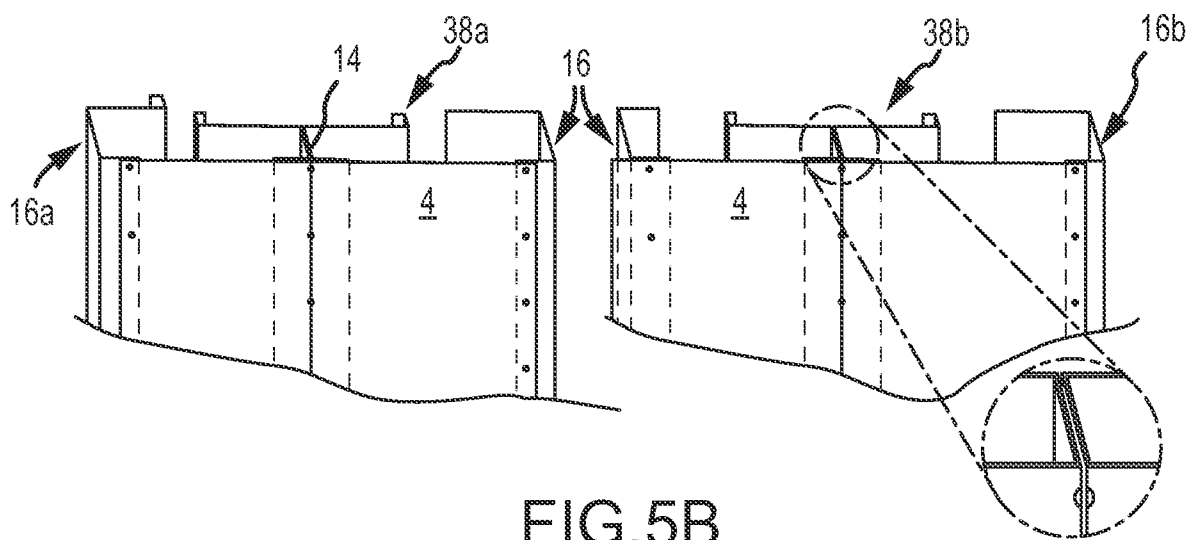


FIG. 5B

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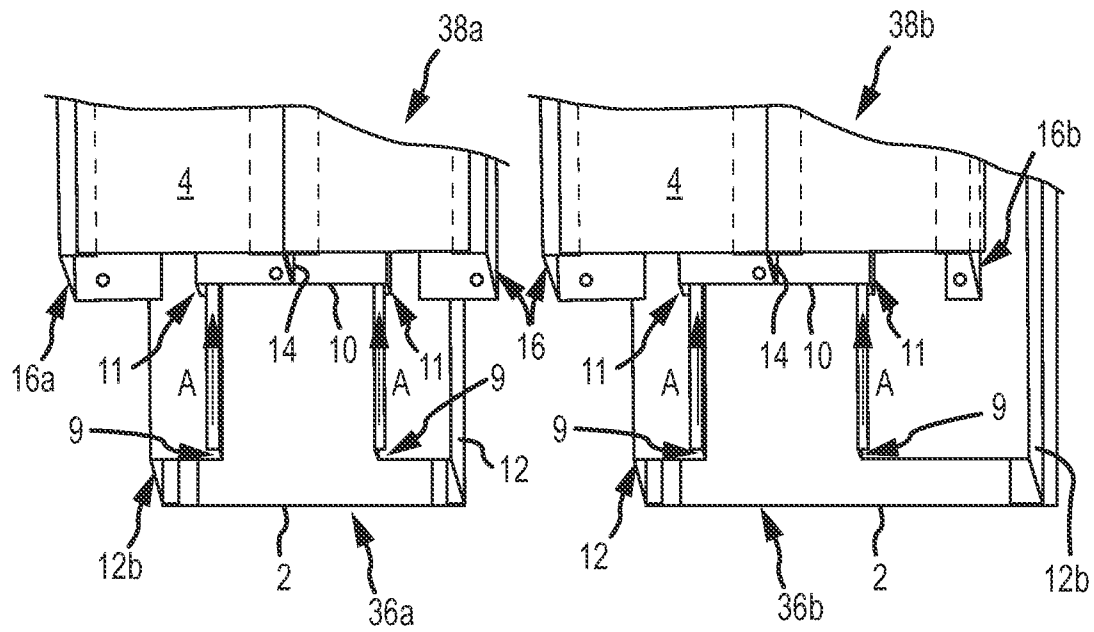


FIG. 5C

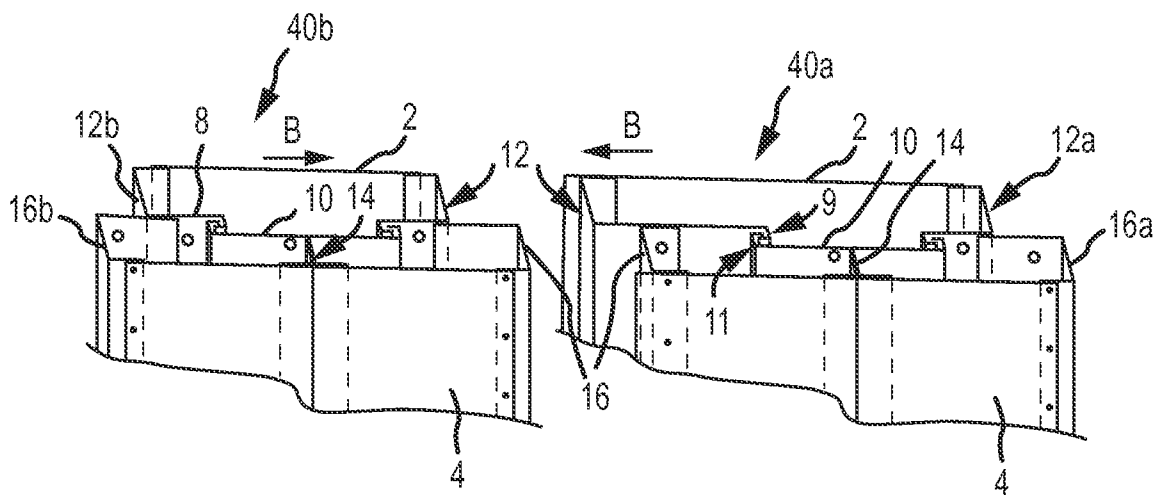


FIG. 5D

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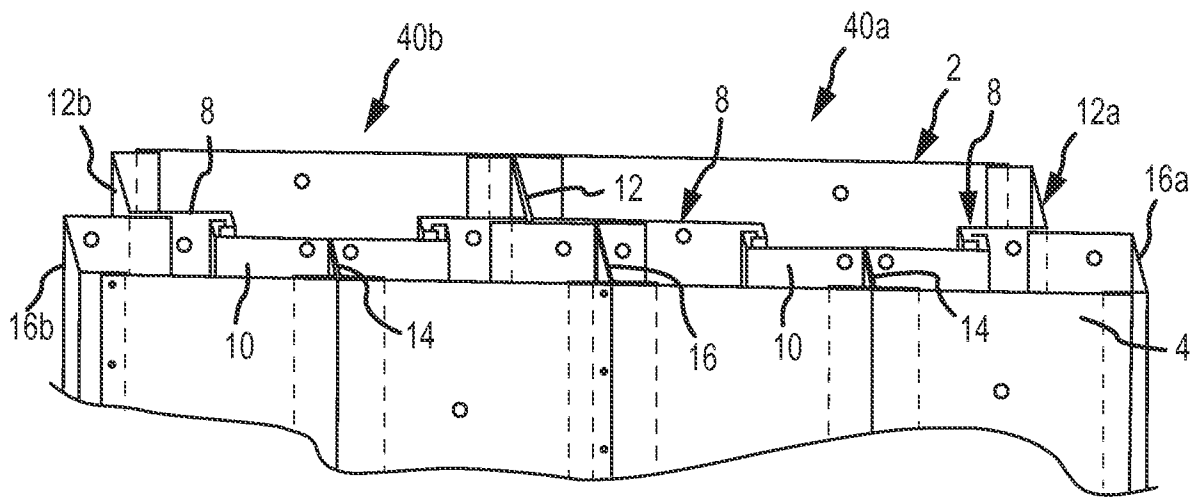


FIG. 5E

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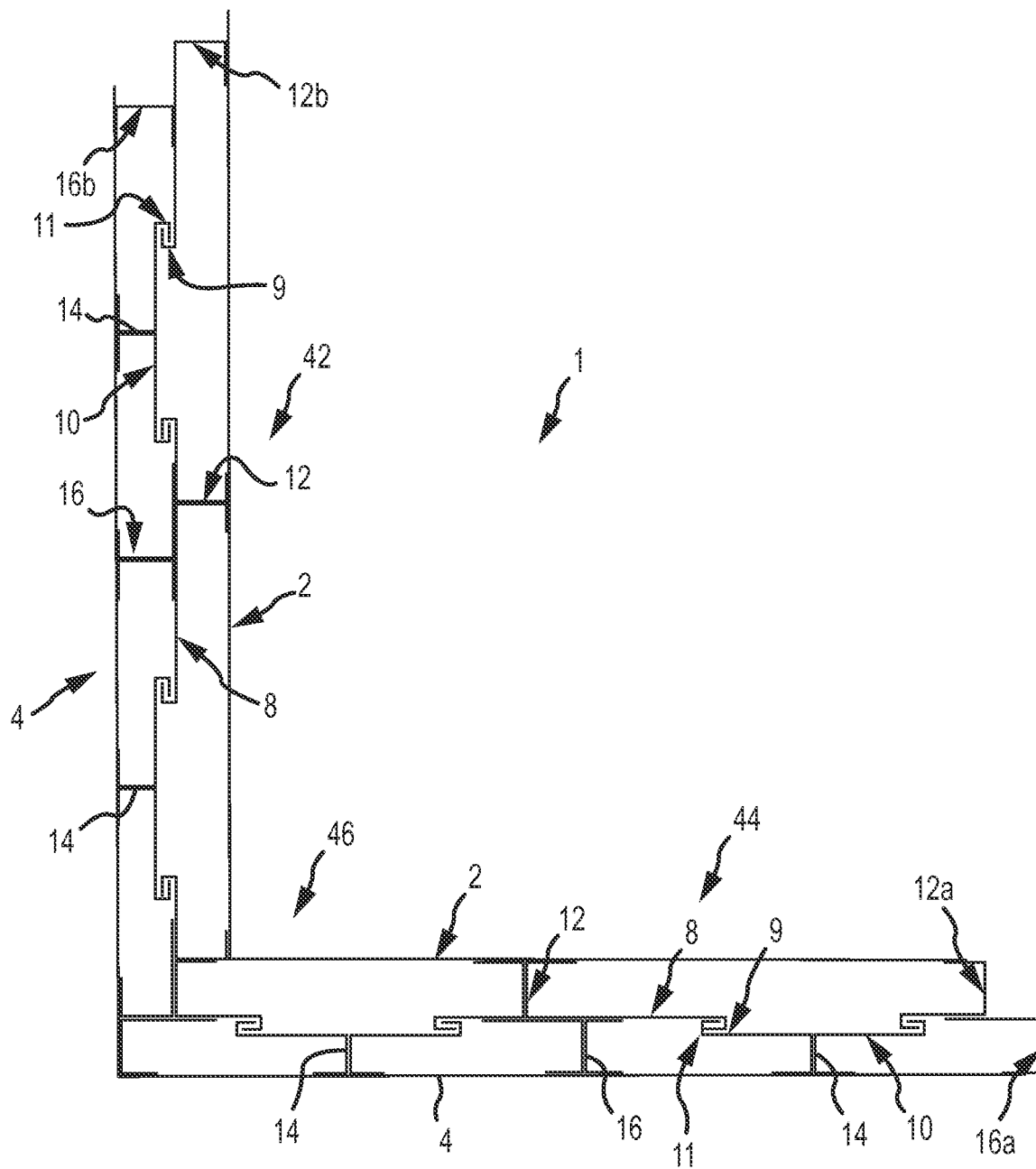


FIG. 6

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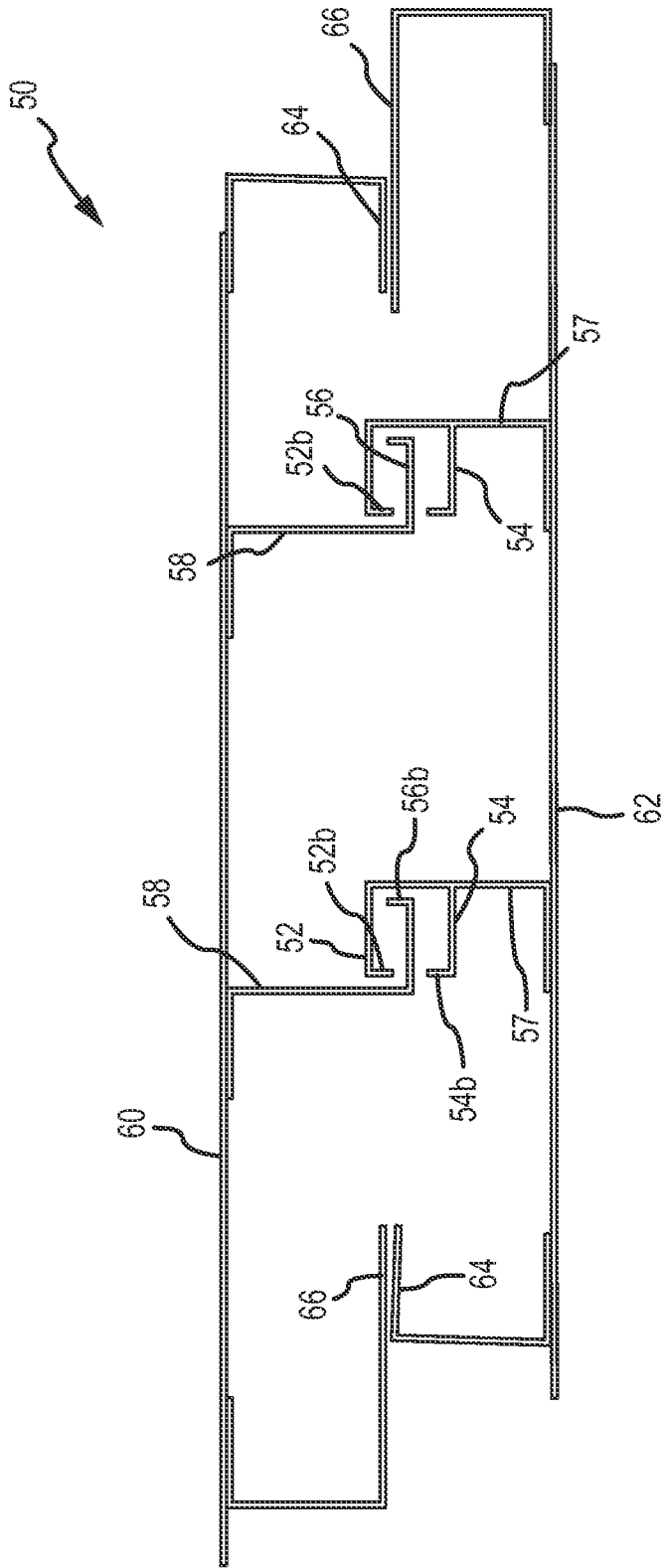


FIG. 7

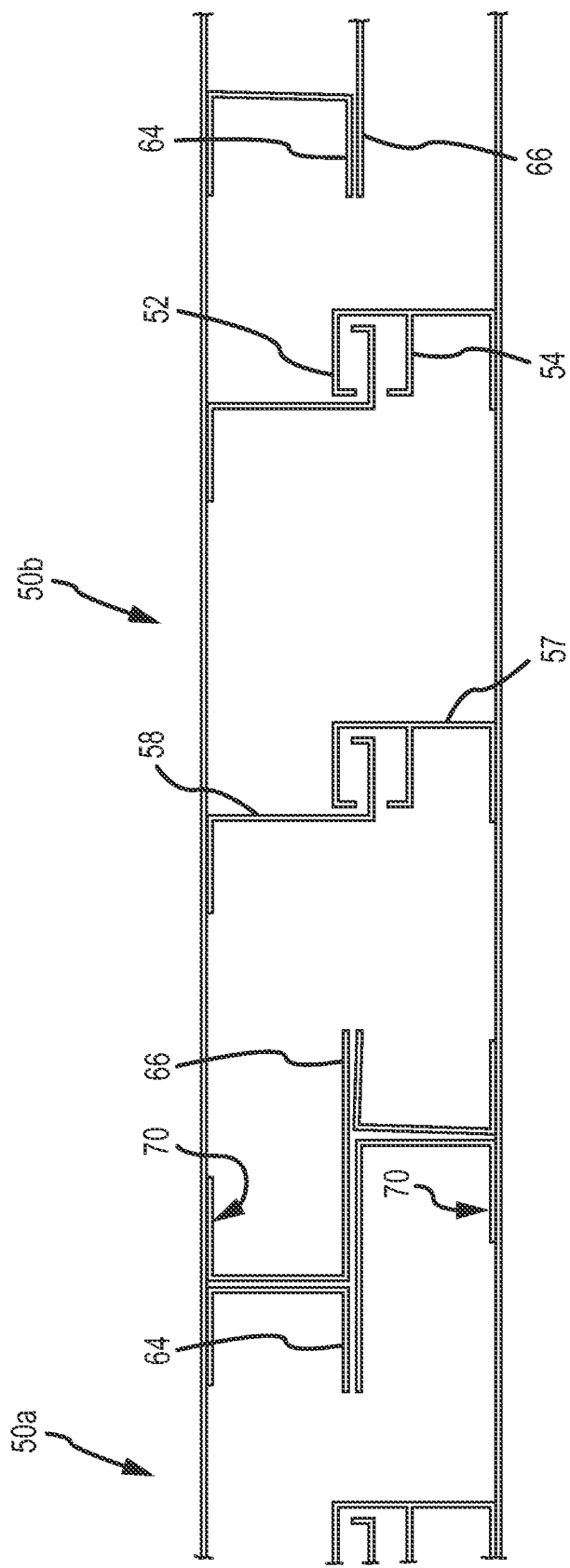
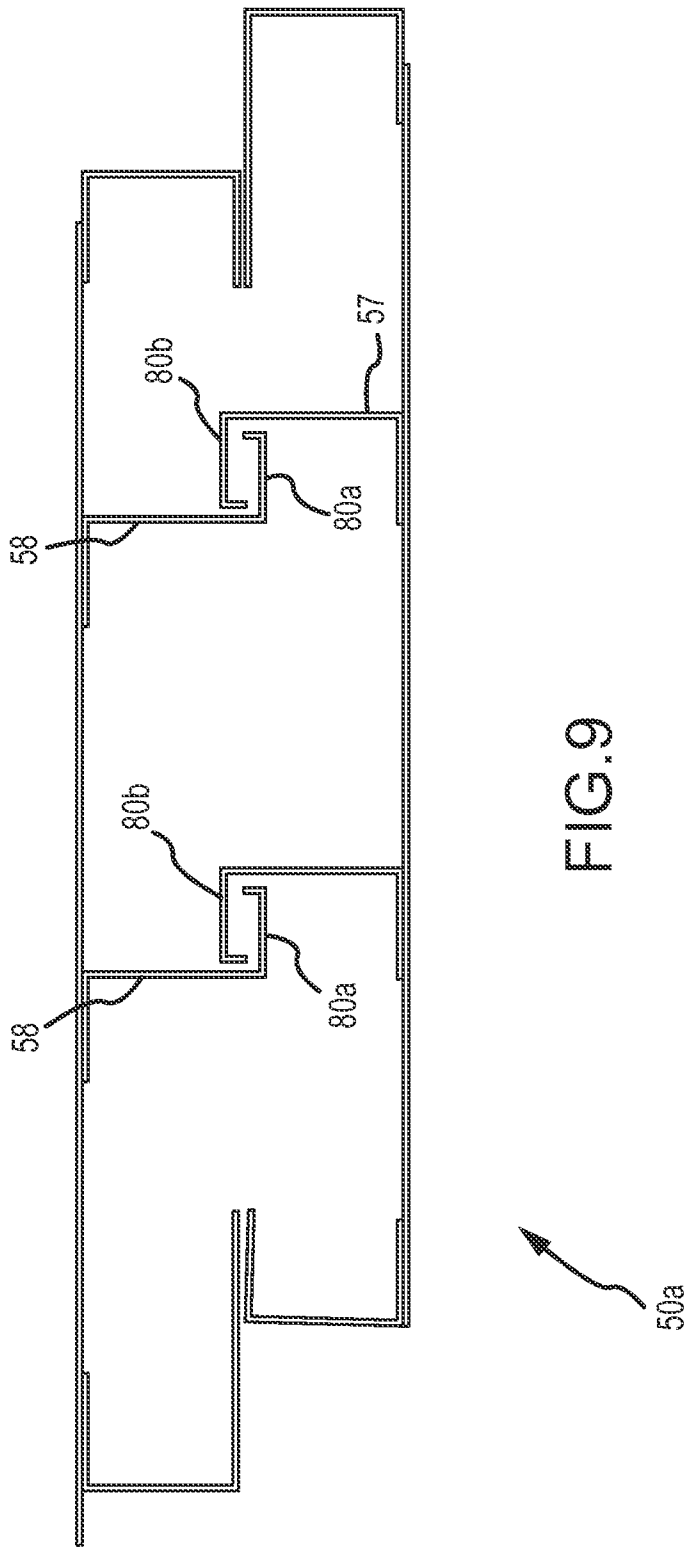
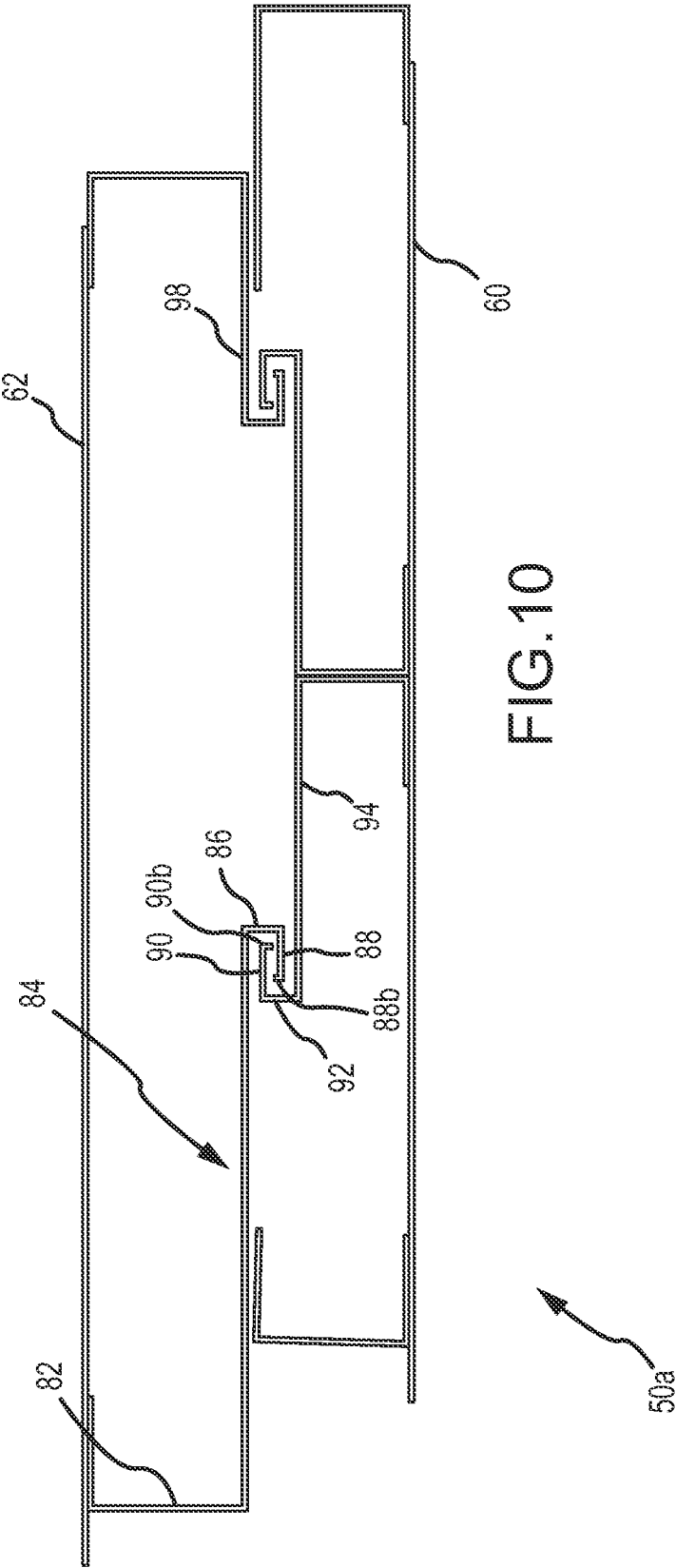


FIG. 8







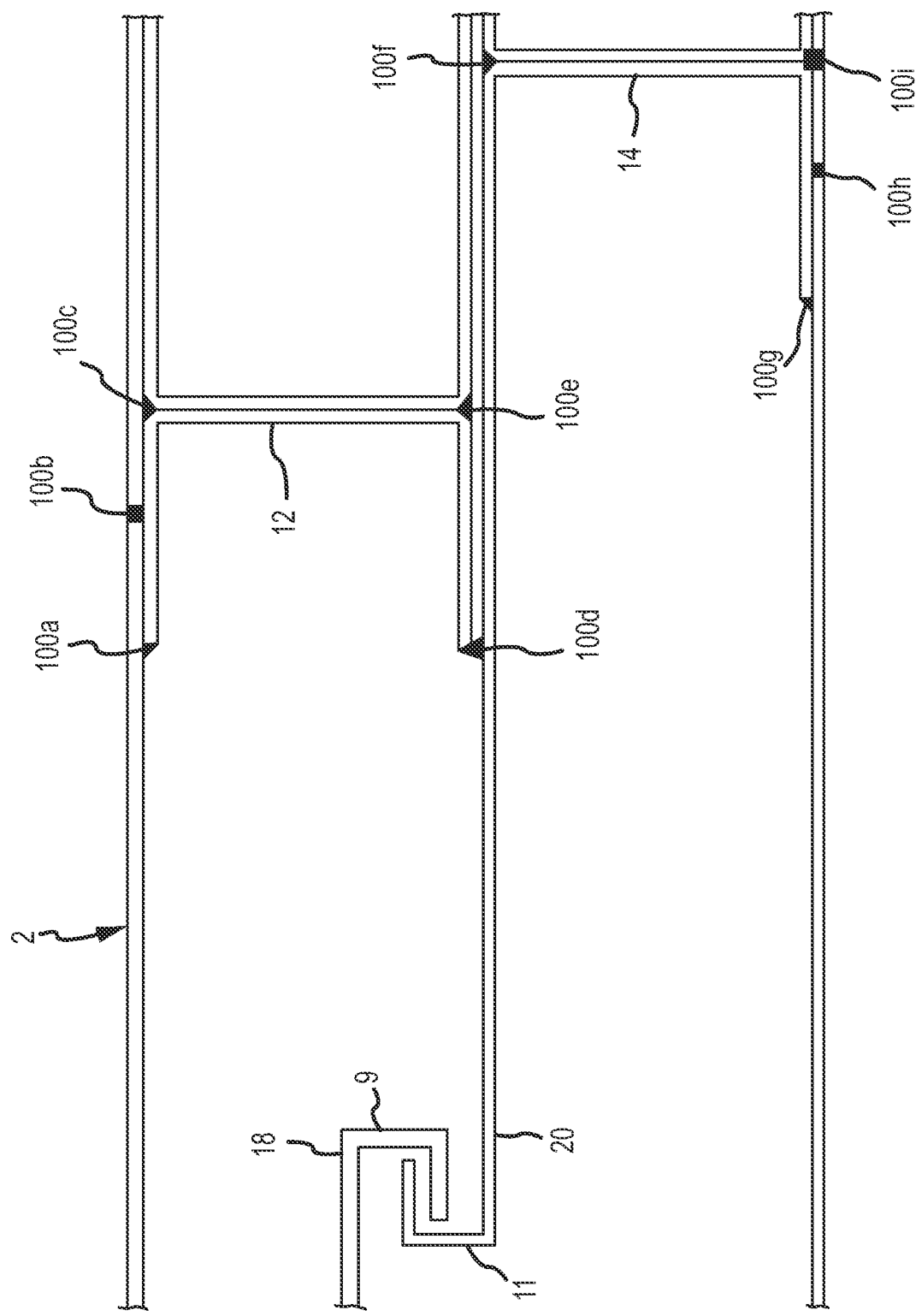


FIG.11

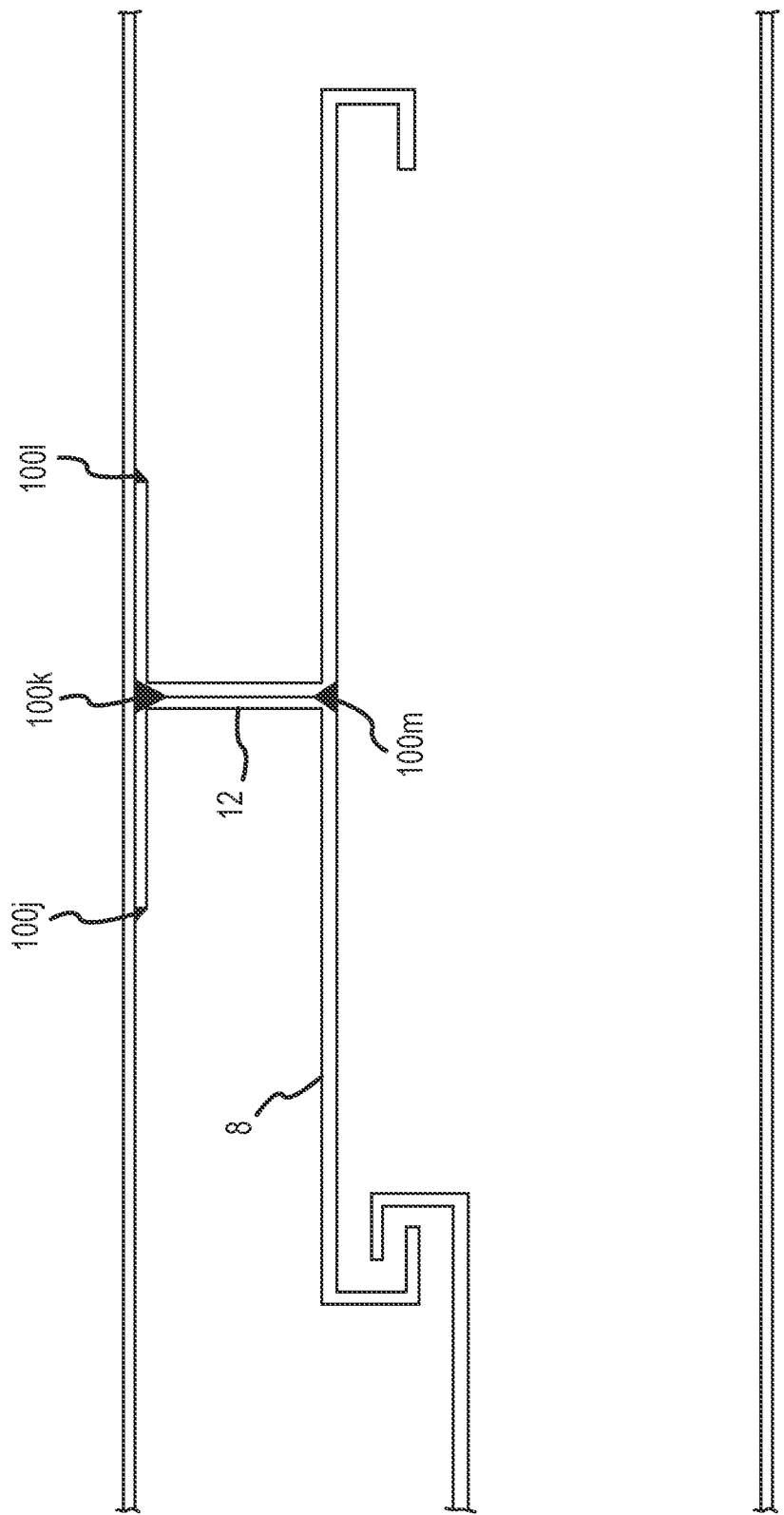


FIG.12

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US2013/026402

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - E04C 2/38 (2013.01)

USPC - 52/481.1

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

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - E04C 2/38, 3/07, 3/09 (2013.01)

USPC - 52/241, 426, 481.1, 588.1, 837, 842, 846

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

CPC - E04C 2/382, 2/384, 2/386, 2/388 (2013.01)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatBase, Google Patents, Google

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,928,468 A (PHILLIPS) 29 May 1990 (29.05.1990) entire document	1, 3, 4, 6-9
Y		2, 5, 11-19
Y	US 4,299,070 A (OLTMANN et al) 10 November 1981 (10.11.1981) entire document	2, 5, 12, 15
Y	US 2010/0101171 A1 (CLIFTON et al) 29 April 2010 (29.04.2010) entire document	11-19
A	US 4,433,522 A (YERUSHALMI) 28 February 1984 (28.02.1984) entire document	1-20
A	US 7,870,698 B2 (TONYAN et al) 18 January 2011 (18.01.2011) entire document	1-20
A	US 7,651,751 B2 (HASCH et al) 26 January 2010 (26.01.2010) entire document	1-20

☐ Further documents are listed in the continuation of Box C.

\* Special categories of cited documents:

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

26 March 2013

Date of mailing of the international search report

08 APR 2013

Name and mailing address of the ISA/US

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