

Blast Restraint Devices

Related Applications

[001] The present invention claims priority to Singapore application no. 10201705985W
5 filed on 21 July 2017, the disclosure of which is incorporated in its entirety.

Field of Invention

[002] The present invention relates to blast restraint devices that are deployed on windows,
doors or shutters, and so on, to absorb shock forces during an explosive blast and to
10 minimise panes of windows, doors or shutters from shattering or dislodging.

Background

[003] Blast doors are designed to protect occupants or assets in buildings from blast
15 pressures caused by explosions. Many years ago, blast doors are installed on important
installations, at petrochemical sites, in government buildings and so on. The threat of
terrorism is now global, and doors, windows, shutters, and so on, in a multitude of buildings
may need to be protected against blast pressure.

20 [004] The drawback of a blast door is that each is typically designed specifically for a
perceived threat scenario; this entails customization (for eg. single/double leaf, swinging
/sliding doors). Customization also depends on structural requirements, such as dimensions
of an opening and loading restrictions. Because of the need for customization, the costs of
blast doors are astronomical, making it uneconomical for deployment in many buildings. It is
25 also impossible to retrofit buildings with conventional blast doors due to the structural load
limitations and construction constraints. In additional, the sheer weights of conventional
blast doors make them physically demanding to be operated on a daily basis.

[005] It can thus be seen that there exists a need for blast restraint devices to protect doors,
30 windows, shutters, and so on, of a building from blast forces. Desirably, the restraining
components of the blast restraint devices can be dismantled or repositioned, or each device
is removeable, for eg., to allow human entry and exit, movement of vehicles or goods, and

so on. Desirably, each blast restraint device is modular, so that it can be assembled, disassembled or retrofitted with considerable short lead times; modularity in design will also mean significantly lower costs of fabrication and maintenance.

Summary

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[006] The following presents a simplified summary to provide a basic understanding of the present invention. This summary is not an extensive overview of the invention, and is not intended to identify key features of the invention. Rather, it is to present some of the inventive concepts of this invention in a generalised form as a prelude to the detailed description that is to follow.

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[007] The present invention seeks to provide blast restraint devices that can be deployed on windows, doors, shutters, openings and so on in a building wall. Window panes, doors or shutters are used to closed these openings but provide little protection against blast forces.

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The present blast restraint devices are designed to capture the window panes, doors, shutters, etc and dissipate blast forces and, thus, minimise shattering of window panes, doors, shutters, etc and minimise injury to human occupants or damage to the building or property inside the building. These blast restraint devices are modular, lighter and easier to fabricate, install and maintain, compared to massive conventional blast doors.

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[008] In one embodiment, the present invention provides a blast restraint member comprising: a blast restraint member being stretched across a window, door or shutter opening; a shock absorbing sub-assembly connected to an end of the blast restraint member; and a mounting channel supporting the shock absorbing sub-assembly; wherein, during an explosion, blast energy causes a tension in the blast restraint member and resulting in deformation of the shock absorbing sub-assembly, thereby dissipating the blast energy and minimising property damage or human injury.

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[009] Preferably, the shock absorbing sub-assembly is connected to each of two ends of the blast restraint member and each shock absorbing sub-assembly is supported in an associated mounting channel. The shock absorbing sub-assembly comprises a pair of shock effectors connected to the end of the blast restraint member to form a V-shaped, U-shaped or W-shaped edge, which V-, U- or W-shaped edge is arranged to engage and cooperate with two

bent edges/ends formed on a pair of shock transfer members, and with a pair of shock absorber, so that when the blast restraint member is tensioned, the V-, U- or W-shaped edge urges onto the bent edges/ends on the shock transfer members and deformation of the shock transfer members causes crushing of the shock absorbers, thereby dissipating the blast energy. Preferably, each of the shock absorber is connected (adhesively and/or mechanically) to the associated shock transfer member. Also, the shock absorber is made of a honeycomb or spatially porous and hollow structure, which comprises steel, aluminium, reinforced glassfibre, reinforced carbon nanotube or fire-retardant high-density polymer or a combination thereof.

[0010] In one embodiment, the blast restraint device is configured in a roller shutter; in another embodiment, the blast restraint device is configured for a window or door. Such configuration can be a new installation or a retrofitting of an existing roller shutter, window or door.

[0011] When the blast restraint device is configured as a roller shutter, each blast restraint member is a flat bar and the V-, U- or W-shaped edge is formed by connecting two wedge-shaped shock effectors onto each of the flat bar. Space clearances between the V-, U or W-shaped edges and the bent edges are provided so that panel slats making up a barrier of the roller shutter can be rolled up or down in a header box. A space or spaces between each blast restraint member and each associated inside of a panel slat is/are filled with a fire-proof material, which comprises rockwool, glassfibre and so on. Preferably, a metal strip/plate is adhesively attached onto each outside face of each panel slat to provide additional strength and rigidity.

[0012] When the blast restraint device is configured for a window or door, a window or door, wherein the blast restraint member is a wire rope, round bar or hollow bar, and the shock effector is configured as a unitary end terminal fitting. The blast restraint members may be arranged in a vertically, a horizontally or in a combination of vertical and horizontal arrangements. Preferably, the blast restraint device is configured as two or more modules.

Brief Description of the Drawings

[0013] This invention will be described by way of non-limiting embodiments of the present invention, with reference to the accompanying drawings, in which:

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[0014] Figure 1 illustrates a conventional blast door;

[0015] Figure 2A illustrates a roller shutter made with blast restraint according to an embodiment of the present invention; Figures 2B-2I illustrate components of the roller shutter shown in Figure 2A;

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[0016] Figures 3A-3C illustrate a blast restraint device for mounting on a window according to another embodiment;

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[0017] Figures 4A-4B illustrate a blast restraint device for slide mounting on a window sill according to another embodiment;

[0018] Figures 5A-5B illustrate a finite element model of a blast restraint device applied on a window, whilst FIG. 5C illustrates elastic deformation of a front panel of the window;

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[0019] Figures 6 illustrates a blast restraint device formed with horizontal and vertical blast restraint members according to another embodiment;

[0020] Figure 7 illustrates a blast restraint device formed by two modules according to another embodiment;

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[0021] Figure 8 illustrates a blast restraint device formed with strain induced bars according to another embodiment; and

[0022] Figure 9 illustrates a blast restraint device for slide mounting with shock absorbing inserts or coatings according to yet another embodiment.

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Detailed Description

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[0023] One or more specific and alternative embodiments of the present invention will now be described with reference to the attached drawings. It shall be apparent to one skilled in the art, however, that this invention may be practised without such specific details. Some of the details may not be described at length so as not to obscure the invention. For ease of reference, common reference numerals or series of numerals will be used throughout the figures when referring to the same or similar features common to the figures.

[0024] Figure 1 shows a conventional blast protection door 10. As shown, the blast protection door 10 is massive in size and very heavy; it is unsuitable for pervasive use in buildings to protect against blast pressures caused by explosion of terrorist devices.

[0025] Generally, a building has doors, windows, shutter openings, and so on, for human entry and exit, movement of vehicles and goods, etc. These openings create weak portions in the buildings. Besides, openings of these doors or windows often have panels, barriers or front components, including glass panels; it is thus desirable to protect these panels and other barriers from shattering or damage caused by blast pressures. Minimising glass panels from shattering or restraining barriers in their positions after being cracked is also a way to protect human from injuries, at the same time limiting any property damage.

[0026] Figure 2A shows a roller shutter 101 configured with blast restraint according to an embodiment of the present invention. As shown in Figure 2A, the roller shutter 101 has an entry width W and a height H to allow passage through a shutter opening in a building wall. The roller shutter 101 barrier is made of panel slats 103 that are engaged and articulated along the width direction so that the roller shutter 101 barrier can be rolled up into/down from an overhead header box 102 and as guided by guide channels 110 located at the ends of the panel slats 103. Each guide channel 110 is mounted along a vertical edge of the shutter opening. The panel slat 103 is more clearly shown in Figure 2G.

[0027] Figure 2B shows a sectional view of the roller shutter 101 at an end of the panel slat 103. Disposed inside each panel slat 103 is a blast restraint member 120. The ends of the blast restraint member 120 extend into the guide channels 110; a pair of shock effectors 130 formed by two wedge shaped members are mounted on each end of the blast restraint member 120; in one embodiment, the wedge-shaped shock effector members 130 are

arranged to mutually form a V-shaped edge 132. Preferably, the blast restraint member 120 is in the form of a flat bar and the wedge-shaped shock effectors 130 are connected to the blast restraint member 120 by bolts and nuts 134 (as seen in Figure 2E), screws or rivets, etc. for easy assembly, disassembly or replacement.

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[0028] Referring again to Figure 2B, two shock transfer members 150 are fixed inside each of the guide channel 110 but loosely engage with the V-shaped edge 132 of the shock effectors 130. A free edge or end of each shock transfer member 150 is bent 152 (as seen in Figure 2B) to project into the V-shaped edge 132 of the shock effector 130; clearances are provided between the bent edge 152 and the V-shaped edge 132 to allow the panel slat 103 and the shock effectors 130 to slide smoothly or unobstructively along the respective guide channel 110 as the roller shutter 101 barrier is rolled up or down. Preferably, each shock transfer member 150 is fixed to the inside of the guide channel 110 by bolts and nuts 154, screws, rivets, etc. for easy assembly, disassembly or replacement. Also as seen in Figure 2B, a shock absorber 170 is located in the space between the shock transfer member 150 and an associated side of the guide channel 110. Preferably, the shock absorbers 170 are adhesively connected to the associated shock transfer member 150, for eg. by a fire-proof or fire-retardant adhesive. In another embodiment, the shock absorbers 170 are mechanically connected to the associated shock transfer member 150 by rivets, self-tapping screws, and so on. For easy description, a shock absorbing sub-assembly 175 is used to refer to the sub-assembly of the blast restraint member 120, the shock effectors 130, the shock transfer members 150 and the shock absorbers 170. Preferably, each guide channel 110 is connected to an anchor plate 180, for eg. by stitch welding, and the anchor plate 180 is, in turn, mounted to the building wall by some anchor bolts and nuts 182.

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[0029] Figure 2C shows a plan view of a panel slat 103, whilst Figure 2E shows the shock effector 130 sub-assembly located at the end of the blast restraint member 120. Figure 2D shows a side view of the panel slat 103, whilst Figure 2F shows a side view of the shock effector 130 sub-assembly. As seen from the figures, the blast restraint member 120 is in the form of a flat bar. Preferably, the blast restraint member 120 is made from steel; it is also possible that the blast restraint member 120 is strained hardened (for eg., by cold rolling) to provide strength and rigidity, yet maintaining sufficient ductility to avoid brittle fracture.

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[0030] Figure 2G shows a section of the panel slat 103 with each lateral edge being formed with a partially curved cylindrical edge 104 that engages and articulates with an adjoining panel slat 103 to form the roller shutter barrier. Figure 2H shows a section XX of the panel slat with the blast restraint member 120 being disposed inside each associated panel slat 103 such that the space inside the panel slat is filled with a fire-resistant, shock absorbing wool 106, such as rockwool, fibre glass and so on. Preferably, the outside faces of the panel slat 103 are further strengthened by a steel plate or strip 105, which is attached thereon by an adhesive on each outside face.

[0031] In one embodiment, the shock absorber 170 is formed from a honeycomb structure; Figure 2I shows part of the honeycomb structure that is suitable for use as the shock absorber 170; as shown, the honeycomb structure is sandwiched between two face plates 172. The honeycomb structure is made from materials, which includes steel, aluminium, reinforced fiberglass, reinforced carbon nano-tubes, flame-retardant reinforced polymers and so on or a combination thereof. It is also possible that the shock absorber 170 is made from a spatially porous and hollow structure formed, for eg. by blow molding, 3D-printing, etc. with materials such as steel, aluminium, reinforced polymer, reinforced fiberglass, reinforced carbon nano-tubes, flame-retardant reinforced polymer, and so on. Also, the face material can be different from the honeycomb/porous-hollow structural body.

[0032] When the roller shutter 101 barrier is subjected to an exterior blast pressures, the panel slats 103 are deformed inwardly; as a result, the blast restraint members 103 are pulled in (due to induced tension), thereby causing the V-shaped edges 132 at the shock effectors 130 to come into contact with the bent edge 152 of the shock transfer member 150. As the blast pressure is sustained, the shock effectors 130 continue to urge onto the bent edge 152, thereby causing the shock absorbers 170 to crush against the inside of the respective guide channels 110; if the blast pressures are severe, the crushing of the shock absorber 170 leads to deformation of the shock transfer members 150 and the guide channels 110; after such an incident, the guide channels 110, the shock absorbing sub-assemblies 175, some of the damaged panel slats 103 or the entire roller shutter 101 barrier may need to be replaced. By transferring the blast pressures to crush the shock absorbers 170, the blast energy is controlled to dissipate, and damage to property or injury to human beings are minimized.

[0033] The above roller shutter 101 is suited for a new installation. It is also suited for retrofitting by installing the blast restraint members 120 inside panel slats of existing roller shutters, installing the shock absorbing sub-assemblies 175 of the present invention and replacing the roller shutter guides with the guide channels 110.

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[0034] In the above description, the ends of the shock effectors 130 are mutually arranged to form a substantially V-shaped edge 132; it is possible that the ends of the shock effectors 130 form a U-shaped or W-shaped edge 132, so that the bent-ends 152 of the shock transfer members 150 can engage positively with the U- or W-shaped edge 132 of the shock effectors 130 and transmit the blast forces through the shock absorbing sub-assemblies 175; accordingly, description of the V-shaped edge 132 is taken synonymously as the U- or W-shaped edge 132 in description of later embodiments.

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[0035] In another embodiment, Figure 3A-3C shows a blast restraint device 100a for retrofitting behind an existing window 20 or on an existing window frame 22. The blast restraint device 100a employs a number of blast restraint members 120a that are stretched across a rear of a window front component/barrier 24 (such as, a glass panel). In one embodiment, each blast restraint member 120a is configured with a flexible wire cable with an end fitting 130a terminating with a shock absorbing sub-assembly 175a. The number of blast restraint members 120a is dependent on the material of the front component 24, the mode of deflection, magnitude of designed blast pressures, etc. The mode of deflection may give a particular deflection pattern, which then determines the numbers and positioning of the blast restraint members 120a. By using the blast restraint members 120a to place restraints along locations of maximum deflections, the mode of deflection is forced up by one order of magnitude or more; in this way, the chance of the front component/barrier 24 shattering is averted, and human or property damage can be prevented or minimized.

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[0036] Referring to Figure 3C, the shock absorbing sub-assembly 175a includes the end fitting 130a formed with a V-shaped edge 132a, which V-shaped edge 132a contacts and engages with bent edges 152a of a pair of shock transfer members 150a. As in the above embodiment, this shock absorbing sub-assembly 175a is located in an upper mounting channel 110a; it is possible that this shock absorbing sub-assembly 175a is also located in a lower mounting channel 110b, or in both upper and lower mounting channels (as seen in

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Figure 3C). A shock absorber 170 is disposed in each space between the shock transfer members 150a and the inside of the associated mounting channel. Preferably, the shock absorber 170 is attached to the associated shock transfer member 150a by a fire-proof or fire-retardant adhesive or mechanically by rivets, self-tapping screws and so on. Preferably, the shock transfer members 150a are connected to the inside of the mounting channel 110a by bolts and nuts, screws, rivets, etc. for easy assembly, disassembly or replacement.

[0037] As shown in Figures 3A-3C, the upper mounting channel 110a is for mounting onto an upper frame of the window 20. Similarly, the lower mounting channel 110b is also provided for mounting onto a lower frame of the window 20. Similarly, a shock absorbing sub-assembly 175a is also configured inside the lower mounting channel 110b. In another embodiment, it is possible that only one end of the blast restraint members 120a terminates with the shock absorbing sub-assembly 175a; when one shock absorbing sub-assembly 175a is employed, the opposite end of the blast restraint member 120a terminates inside a mounting channel with a simple screw or bolt/nut connection at the end fitting.

[0038] In use, when the window 20 is subjected to blast forces, the front component/barrier 24 deforms and causes a tension in the blast restraint members 120a; as the blast forces are sustained, tensions in the blast restraint members 120a cause the V-shaped edge 132a of the end fitting 130a to pull onto the bent edge 152a of the shock transfer member 150a; when the blast forces are severe, the shock transfer members 150a become deformed and, as a result, crush the shock absorbers 170a, thereby dissipating the blast energy and preventing property damage or human injury.

[0039] It is possible that the above blast restraint device 100a is formed integrally in a frame, which connects the upper and lower mounting channel 110a, 110b together, for mounting on a window opening; such a blast restraint device (now labelled 100b) formed integrally in a frame for mounting on a window sill 26 is shown in Figure 4A-4B. Preferably, the window sill 26 has a slide channel to support the blast restraint device 100b; the window sill thus allows the blast restraint device 100b to be easily installed, removed or replaced. Another advantage of the blast restraint device 100b is that the blast restraint members 120b can be repositioned, dismantled or replaced easily without having to dismantle the entire blast restraint device 100b.

[0040] Figure 5A shows a finite element model of the above blast restraint device 100, 100a, 100b. Figure 5B shows the boundary conditions and positioning of the blast restraint members 120, 120a, 120b. A finite element software is used to design and analyze the structural response of the blast restraint device when it is exposed to blast pressures. Figure 5C shows the deflections of the front component/barrier 24 (ie. window pane) and the blast restraint members 120 disposed at the rear face of the front component. As can be seen, deflections of the front component 24 have been moved up by more than one characteristic order of deflection and shattering of the front component 24 is thus averted.

[0041] Figure 6 shows a blast restraint device 100c according to another embodiment. As shown, the blast restraint members 120 are orientated vertically and horizontally. With additional blast restraint members, the blast restraint device 100c is able to blend in with the aesthetic design of the building or other exterior architecture.

[0042] In Figure 4A or 6, the blast restraint device 100 is formed in a frame. It is possible that the blast restraint device is formed in a modular frame; Figure 7 shows such a blast restraint device 100d is formed with two modular frames. An advantage of making the blast restraint devices 100d in modules allow each module to become smaller, lighter, and easier to fabricate, install and maintain. Another advantage is that only those blast restraint modules 100d or components that are damaged need only to be replaced.

[0043] In another embodiment 100e, Figure 8 shows a blast restraint member 120c is formed from a strain induced bar or hollow tube; the strain induced bar or hollow tube can be swaged from a larger bar or tube and becomes more rigid, yet retains sufficient ductility to avoid brittle fracture, and thus able to constrain the amount of deflections of the front component/panel, so that deformations of the front component remain in the elastic region and fracture is averted. In case of fracture of the front component, the blast restraint members 120c also help to keep the front component from falling or shattering. The above end fittings 130a remain useful for fixing the blast restraint member 120c.

[0044] In the above blast restraint devices 100, 100a-100e, the blast energy caused by an explosion is absorbed by a shock absorbing sub-assembly 175, 175a. It is possible that a shock absorbing device 100f is configured in a slide channel formed on a window sill 26, such as that shown in Figure 9. As shown, the mounting channel 110b of the blast restraint

device 100f may be coated with a shock absorption material 170b. The shock absorption material 170b can also be a lining inserted between the mounting channel 110b and the window sill 26. With the shock absorption material 170b, the response time caused by blast pressures is increased in the order of tenths or hundredths of milli-seconds to avert shattering of the front component/barrier 24. This blast restraint device 100f may be provided separately or in combination with the above blast restraint devices 100, 100a-100e. The blast restraint device 100f can also be retrofitted into an existing window frame 22 or built into a new window frame.

10 **[0045]** From the above description, advantages of the present invention are: the blast restraint devices 100, 100a-100f are simpler, lighter and suitable for pervasive use in many buildings. Also, when modularly formed, these blast restraint devices are cheaper to fabricate, easier to install and maintain.

15 **[0046]** While specific embodiments have been described and illustrated, it is understood that many changes, modifications, variations and combinations thereof could be made to the present invention without departing from the scope of the present invention. For example, the blast restraint devices 100a-100f may be installed behind a door panel, such as a swing or sliding door type. It is also possible that the blast restraint devices are located between
20 two window panels or sandwiched between an outer frame and an inner frame of a window or door.

CLAIMS:

1. A blast restraint device comprising:
 - a blast restraint member being stretched across a window, door or shutter opening;
 - a shock absorbing sub-assembly connected to an end of the blast restraint member;wherein the shock absorbing sub-assembly comprises:
 - a pair of shock effectors connected to ends of the blast restraint member to form a V-shaped, U-shaped or W-shaped edge;
 - a pair of shock transfer members, with an end of each shock transfer member being formed with a bent edge/end, and both the bent edges/ends engage and cooperate with the V-shaped, U-shaped or W-shaped edges located on the pair of the shock effectors; and
 - a pair of shock absorbers, with each shock absorber being connected to an associated end of the pair of shock transfer member; and
 - a mounting channel for supporting the shock absorbing sub-assembly;wherein, during an explosion, blast energy causes a tension in the blast restraint member, resulting in the V-, U- or W-shaped edge being urged onto the bent edges/ends on the pair of shock transfer members and the pair of shock transfer members, in turn, deform or crush the shock absorbers, thereby dissipating the blast energy and minimising property damage or human injury.
2. The blast restraint device according to claim 1, wherein the shock absorbing sub-assembly is connected to each of two ends of the blast restraint member and each shock absorbing sub-assembly is supported in an associated mounting channel.
3. The blast restraint device according to claim 1 or 2, wherein the shock absorber is made of a honeycomb or spatially porous and hollow structure, which comprises steel, aluminium, reinforced glassfibre, reinforced carbon nanotube or fire-retardant high-density polymer or a combination thereof.
4. The blast restraint device according to any one of claims 1-3, wherein each of the shock absorber is connected, adhesively or mechanically, to the associated shock transfer member.

5. The blast restraint device according to any one of claims 1-4, wherein there is a plurality of blast restraint members and the blast restraint device is configured in a roller shutter or configured for a window or door.
6. The blast restraint device according to claim 5, when configured in a roller shutter, wherein each blast restraint member is a flat bar and the V-, U- or W-shaped edge is formed by connecting two wedge-shaped shock effectors onto the blast restraint member.
7. The blast restraint device according to claim 6, wherein space clearances between the V-, U- or W-shaped edges and the bent edges are provided so that panel slats associated with the plurality of blast restraint member and making up a barrier of the roller shutter can be rolled up or down in a header box.
8. The blast restraint device according to claim 7, wherein a space or spaces between each blast restraint member and each associated inside of a panel slat is/are filled with a fire-proof material, which comprises rockwool, glassfibre and so on.
9. The blast restraint device according to claim 7 or 8, wherein a metal strip/plate is adhesively attached onto each outside face of each panel slat for providing strength and rigidity.
10. The blast restraint device according to claim 5, when configured for a window or door, wherein the blast restraint member is a wire rope, round bar or hollow bar, and the shock effector is configured as a unitary end terminal fitting.
11. The blast restraint device according to claim 10, wherein the blast restraint members are arranged in vertically, horizontally or in a combination of vertical and horizontal arrangements.
12. The blast restraint device according to claim 10 or 11 is configured as two or more modules.

Blast Restraint Devices

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Abstract

The present invention describes various configurations of blast restraint devices (100, 100a-100f). The blast restraint devices (100, 100a-100f) are deployed behind windows (20) or doors or in roller shutters (101), and so on, wherein a shock absorbing sub-assembly (175, 175a) absorbs shock forces caused by an explosive blast. In addition, blast restraint member (120, 120a-120c) forming a component of the blast restraint devices keeps the front components/barriers (24) of these windows, door or roller shutters from shattering or dislodging, thereby minimizing or averting further property damage or human injury. The blast restraint devices are also formed in modules to facilitate easy assembly, installing, dismantling or maintenance.

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Figure 3C for publication.

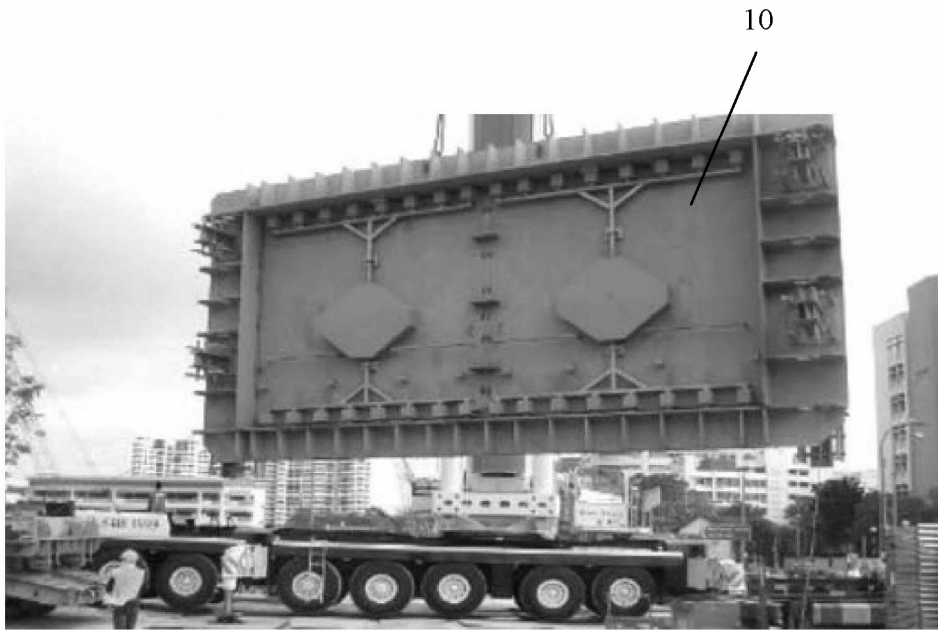


Figure 1

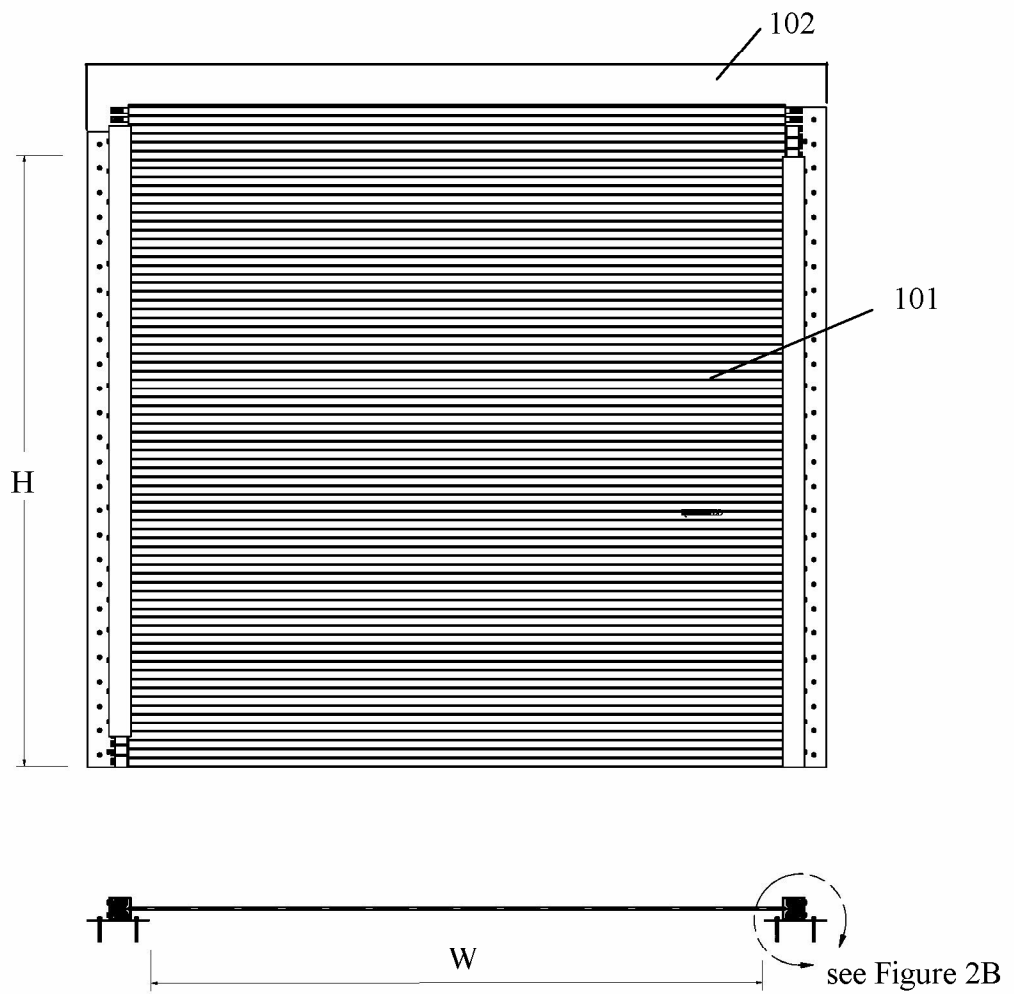


Figure 2A

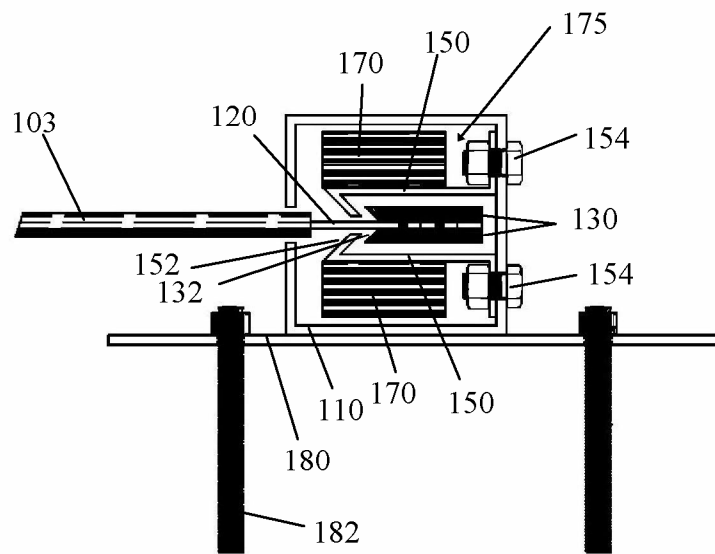


Figure 2B

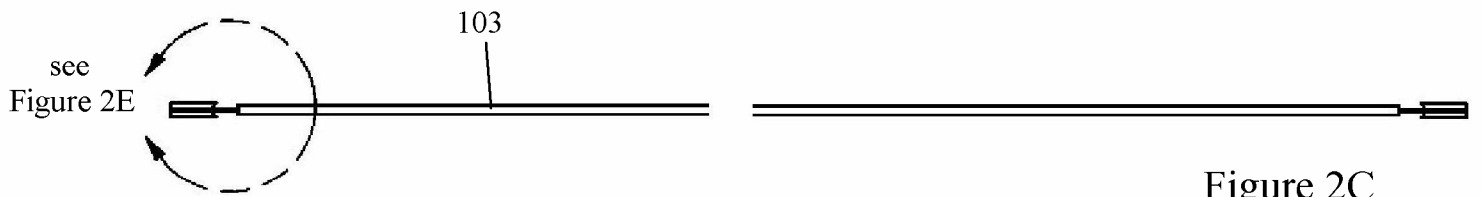


Figure 2C

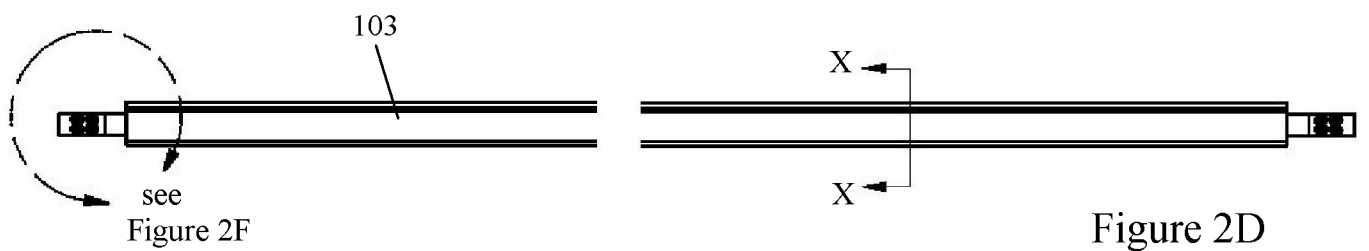


Figure 2D

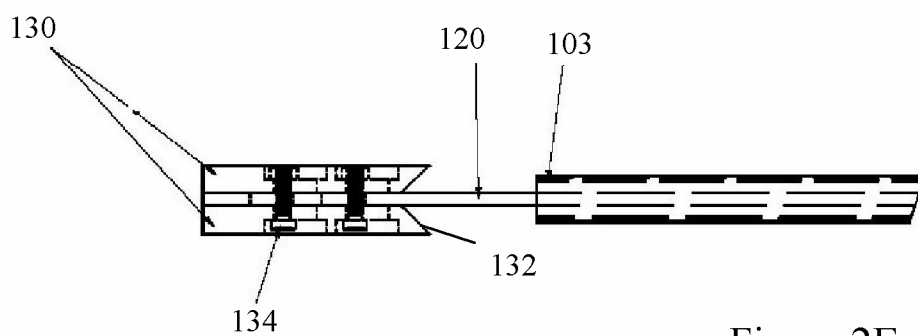


Figure 2E

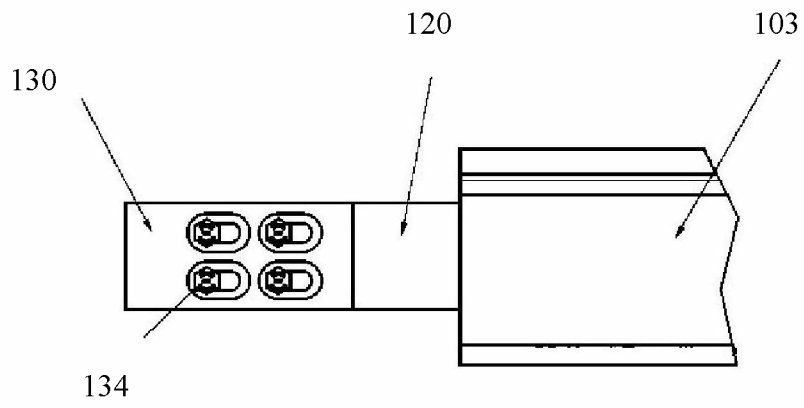


Figure 2F

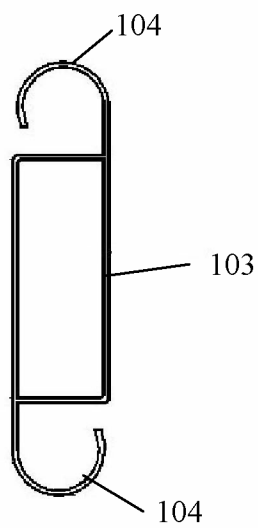


Figure 2G

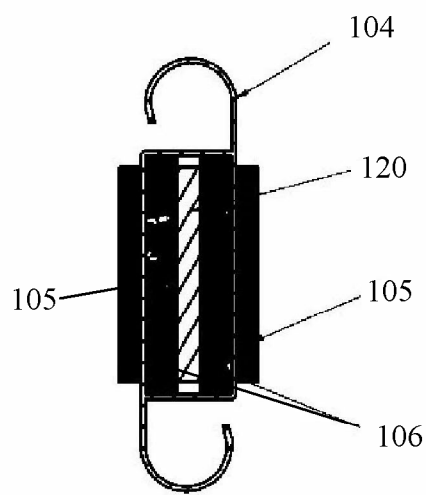


Figure 2H

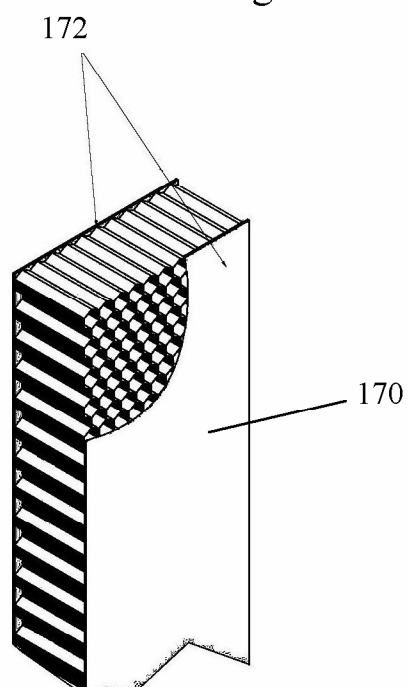


Figure 2I

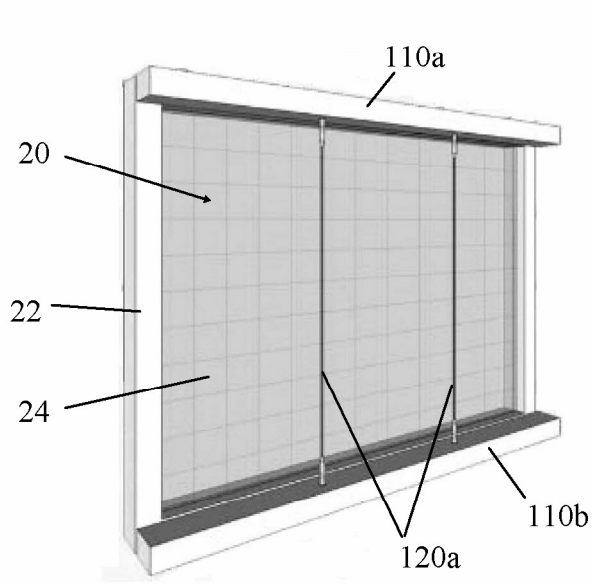


Figure 3A

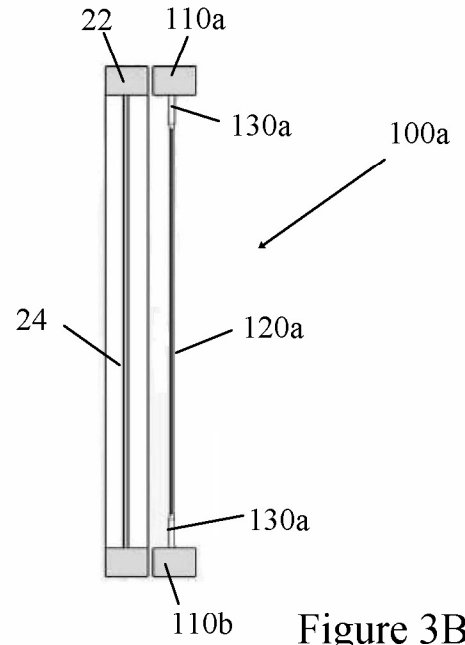


Figure 3B

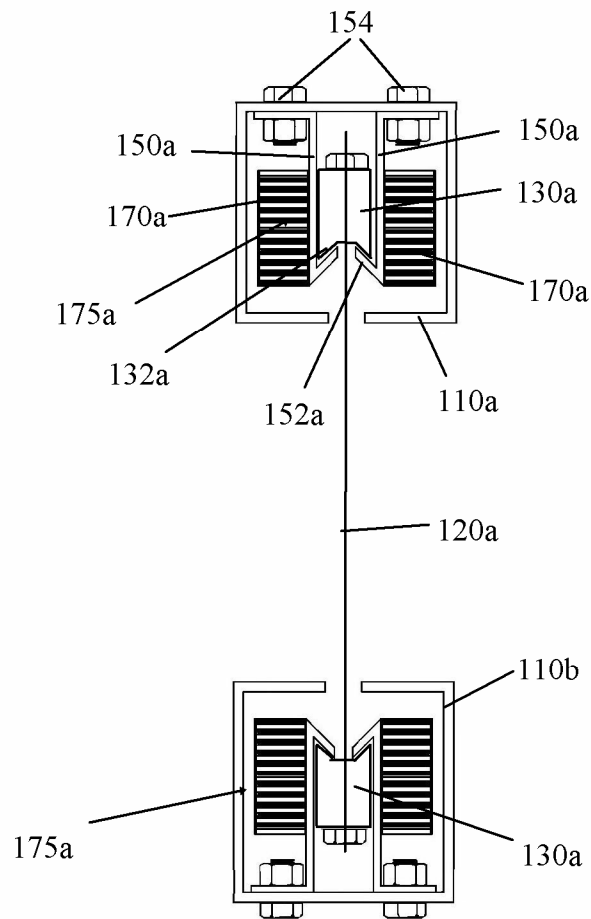


Figure 3C

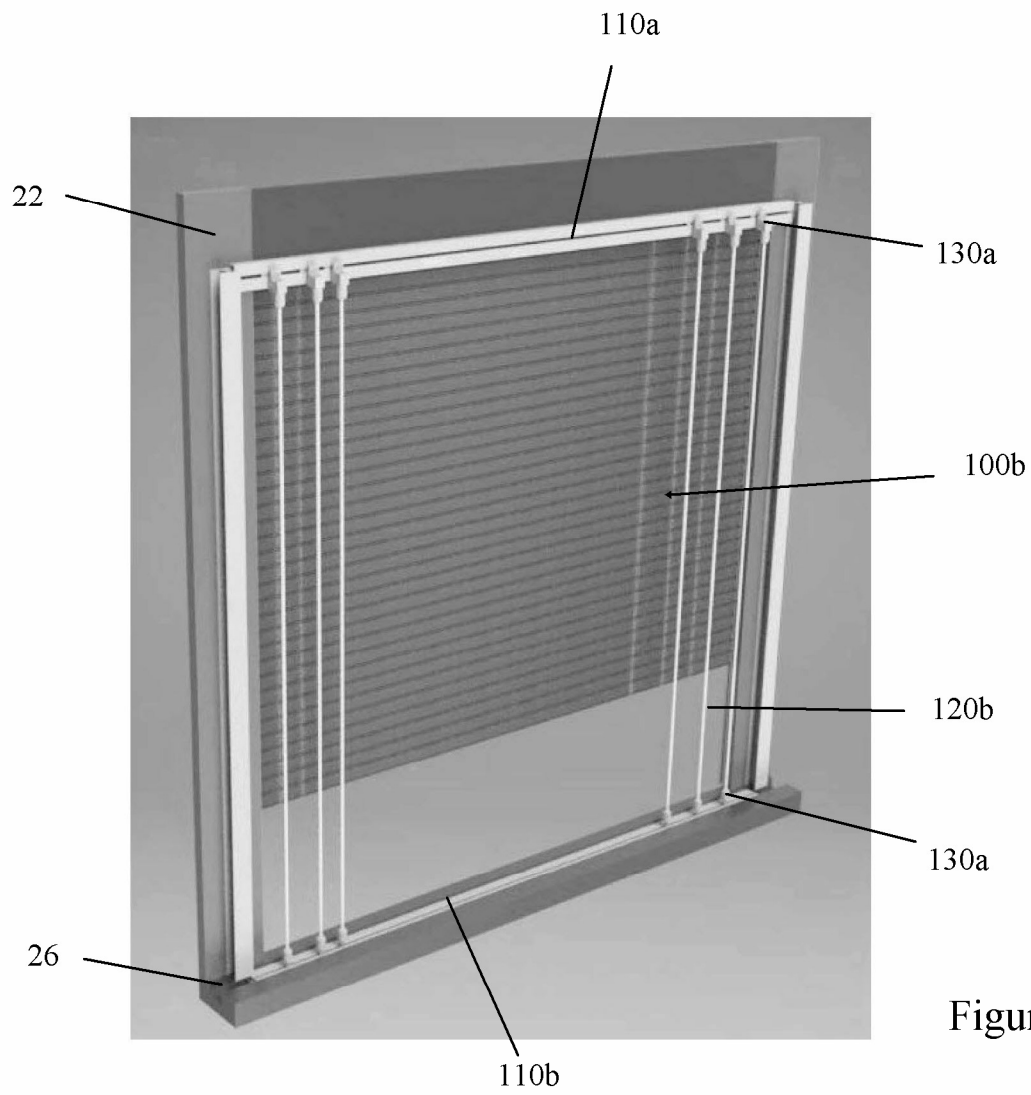


Figure 4A

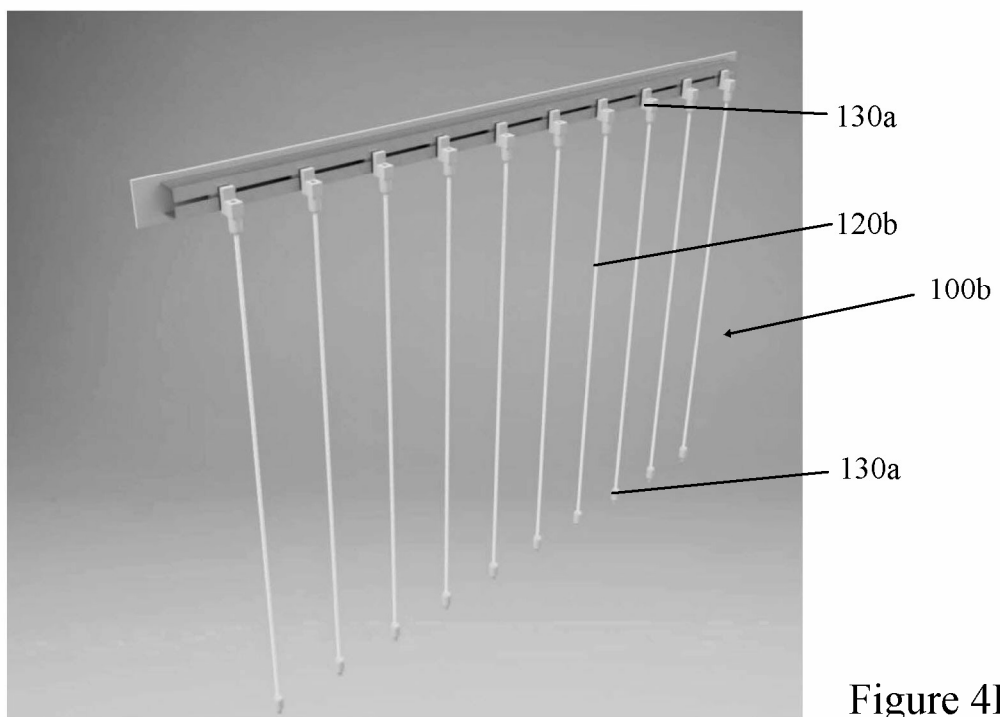
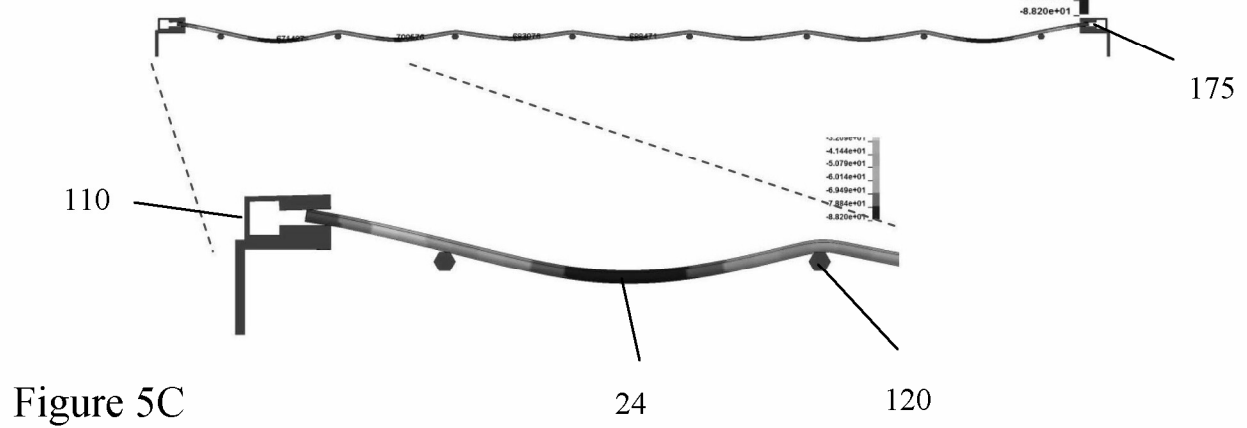
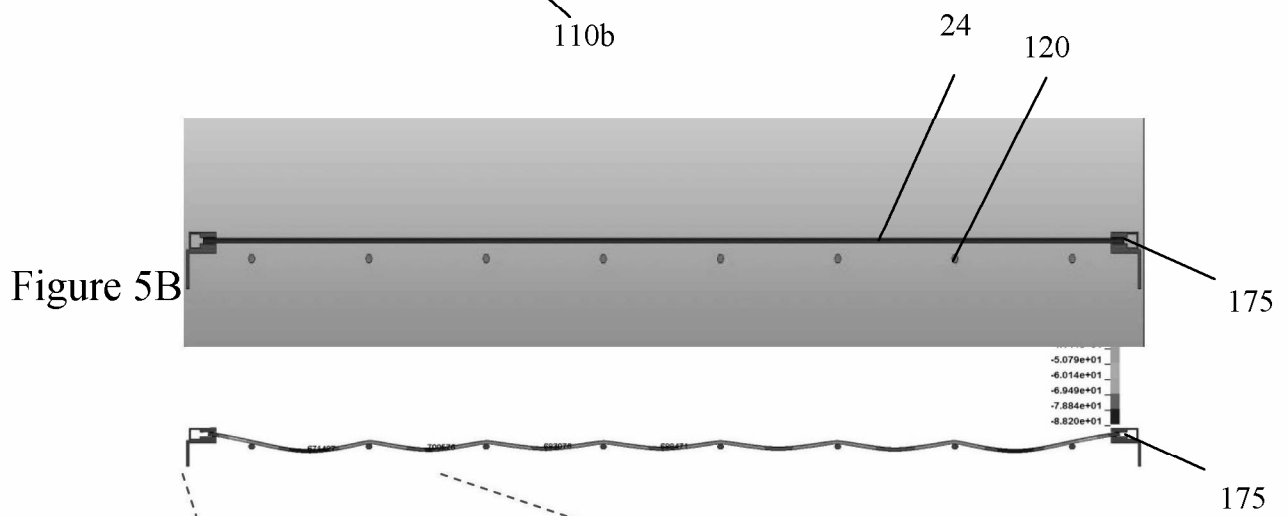
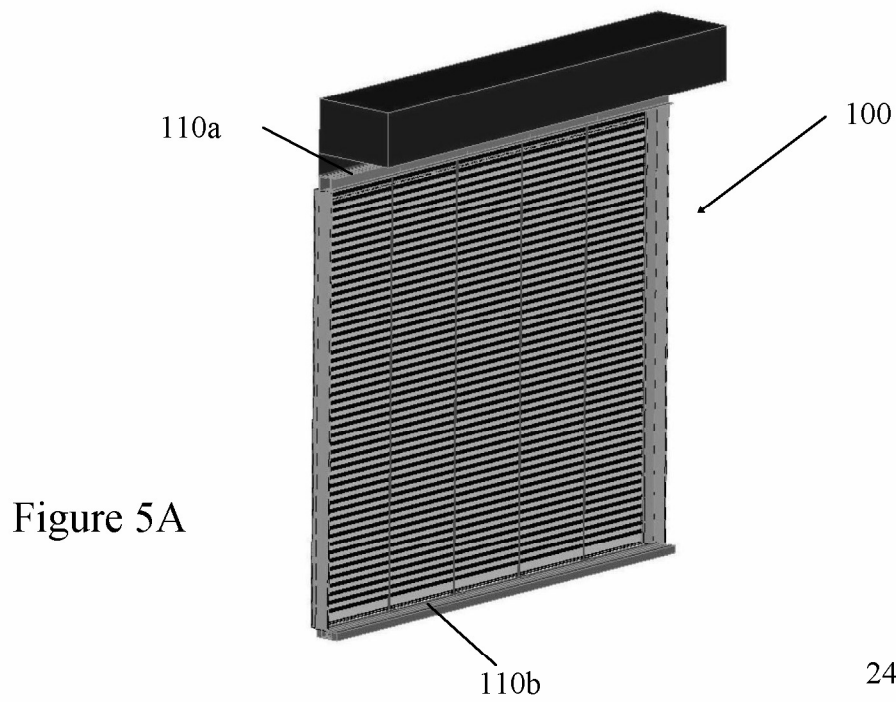


Figure 4B



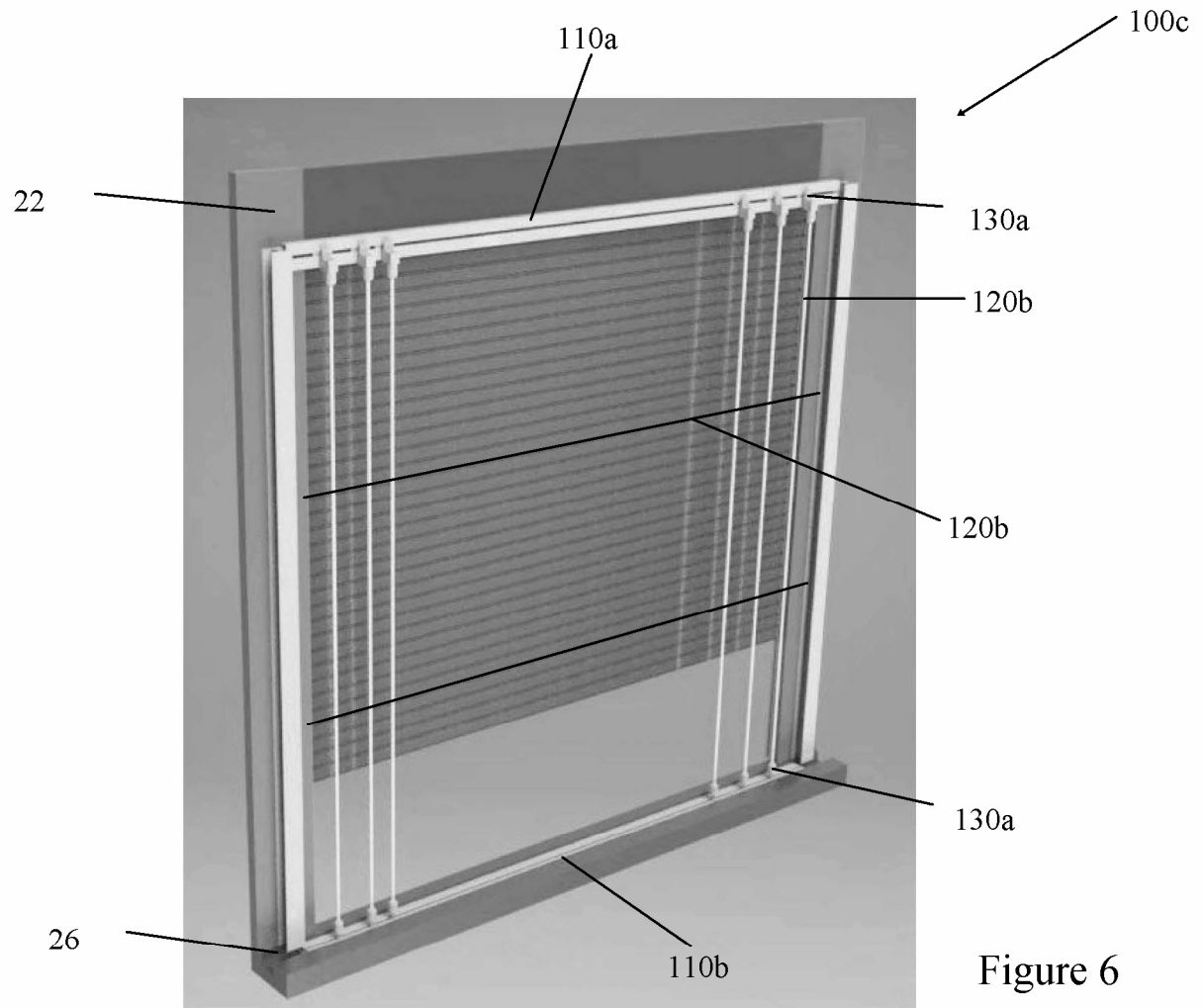


Figure 6

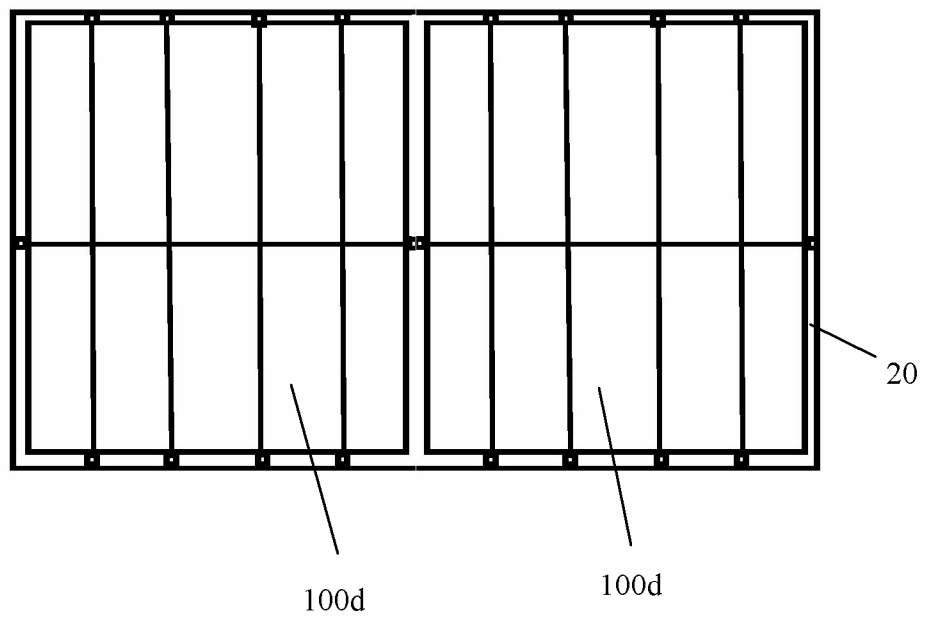


Figure 7

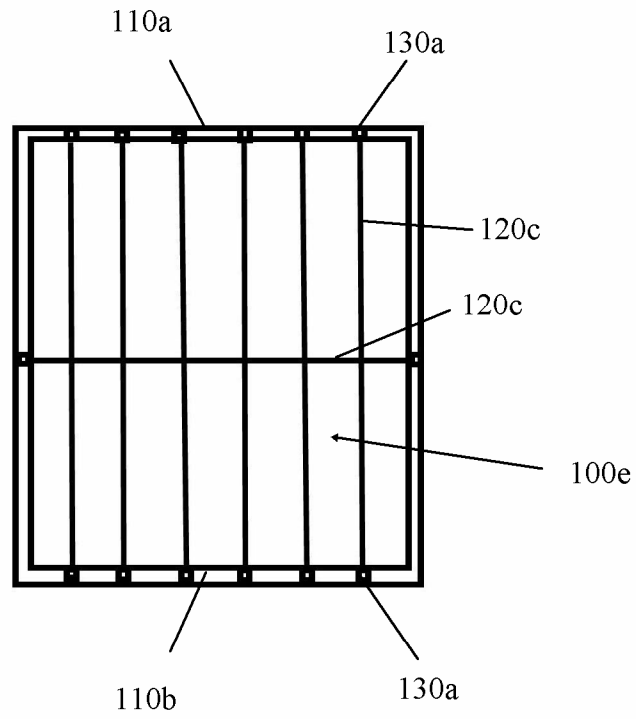


Figure 8

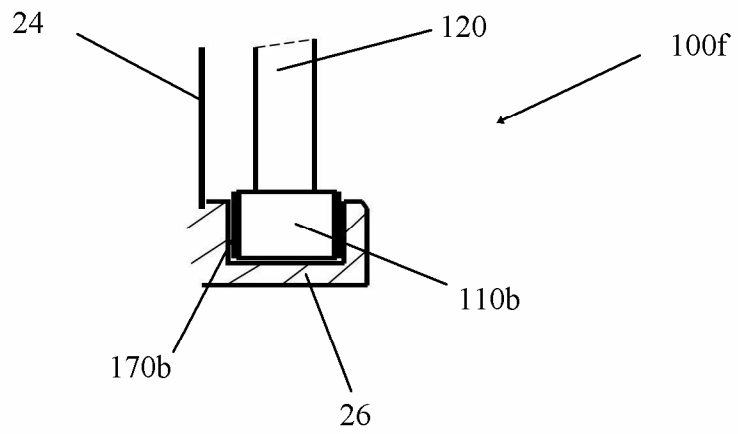


Figure 9