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(54) **BLAST ABSORBING CLADDING**

(76) Inventors: **Tejav Dehghanyar**, Marina Del Rey, CA (US); **Michel Michno**, Minneapolis, MN (US)

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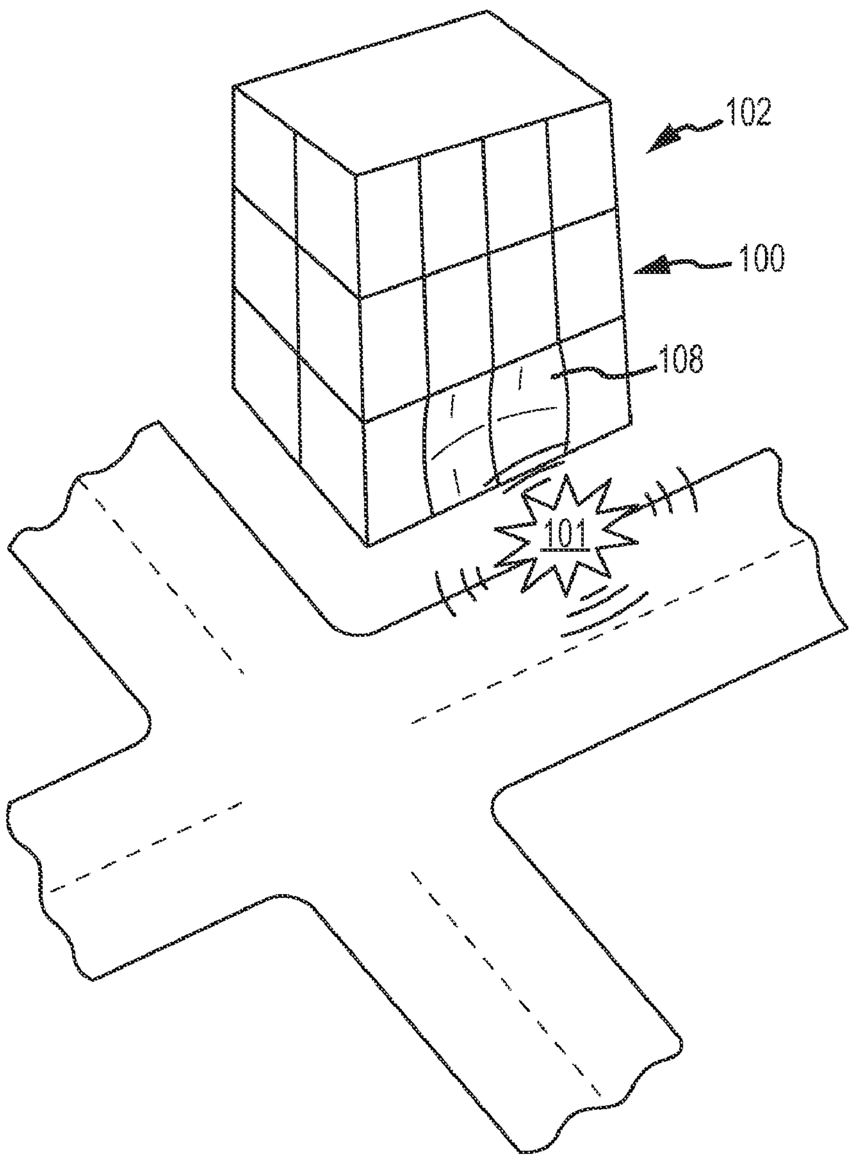
E04B 2/90 (2006.01)

(52) **U.S. Cl.** **89/36.02**; 89/36.04; 89/920

(57) **ABSTRACT**

A blast resistant cladding includes a curtainwall arranged on a structure and defines a load path for transferring loads imparted on the curtainwall to the structure and an absorbing system positioned along the load path and configured for absorbing blast-type loads imparted on the curtainwall.



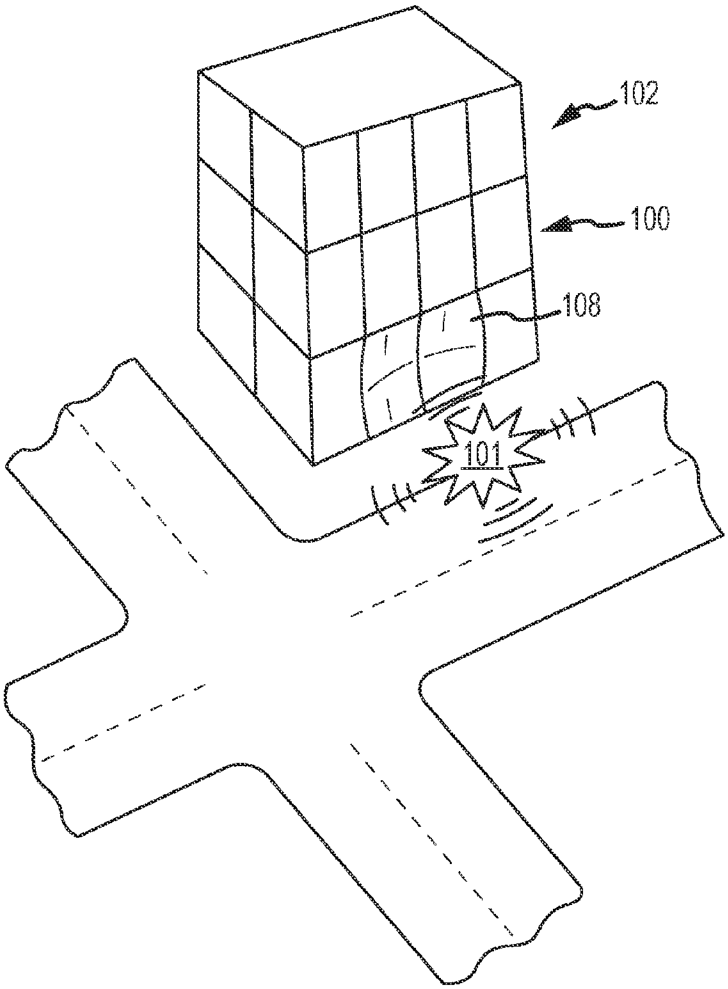


FIG.1

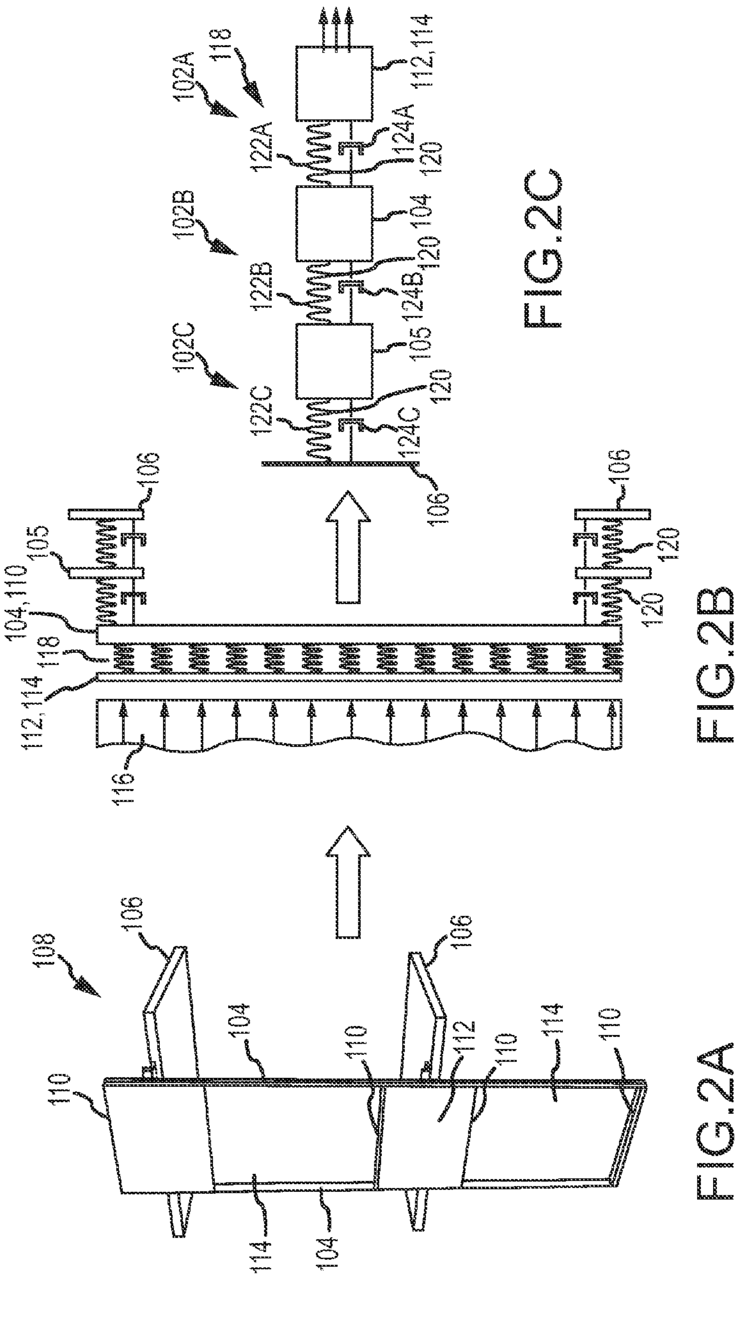


FIG.2A

FIG.2B

FIG.2C

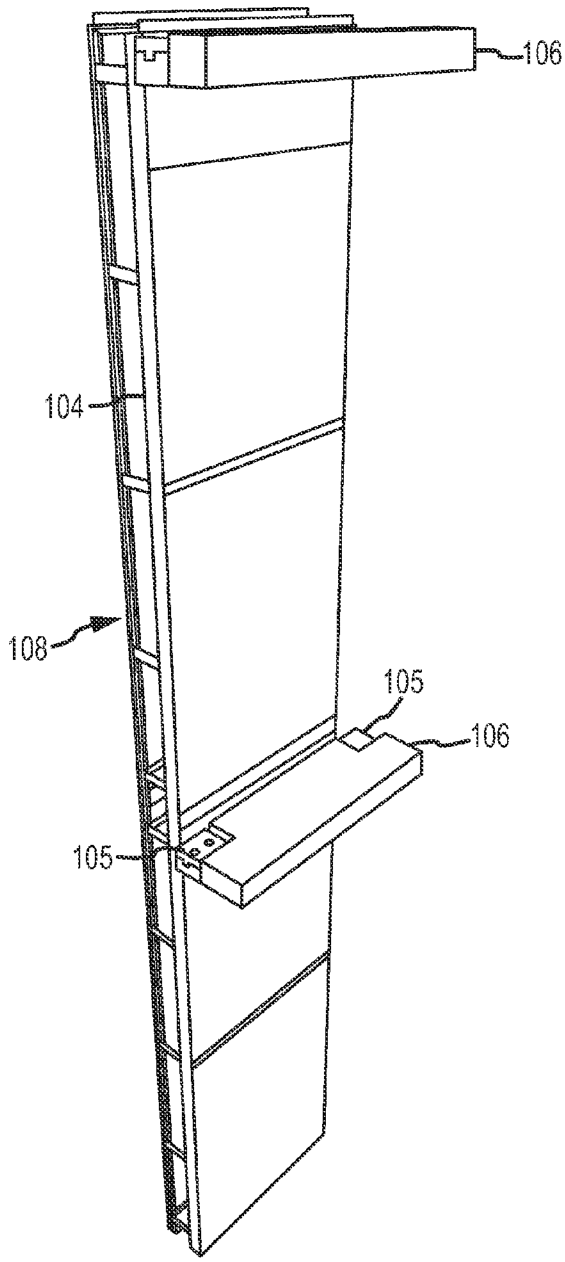
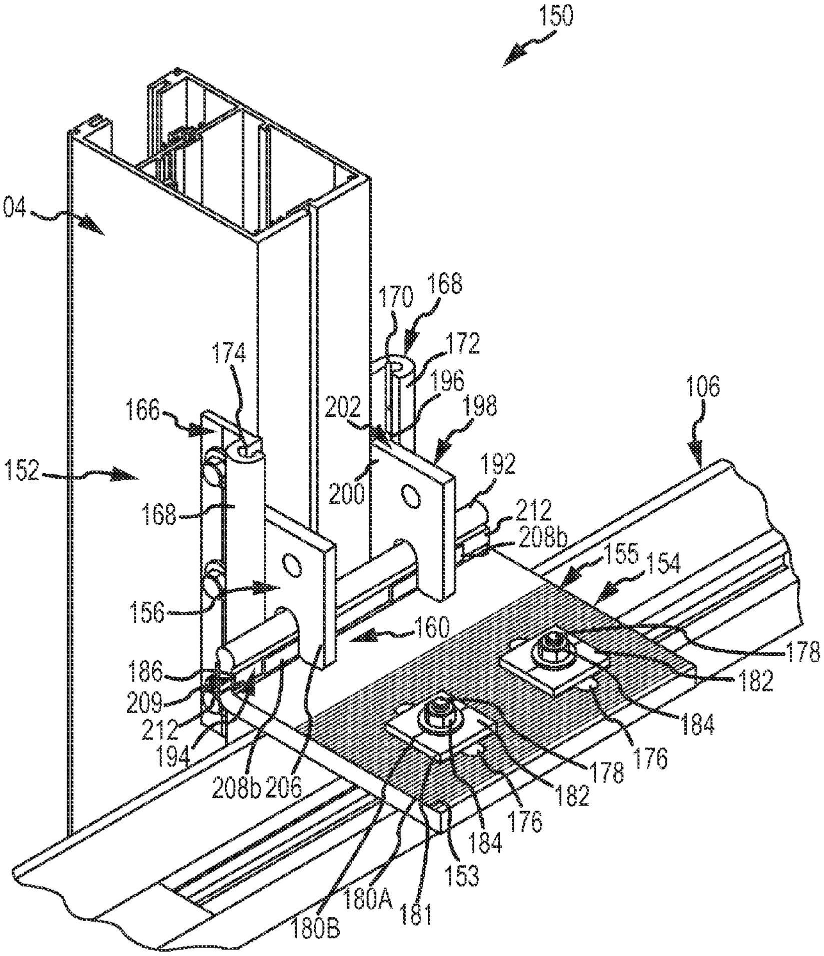


FIG.3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104
152
166
174
168
170
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202
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212
208b
106
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156
160
186
209
212
194
208b
206
178
182
184
176
178
182
184
176
153
180A
181
180B

FIG.4A

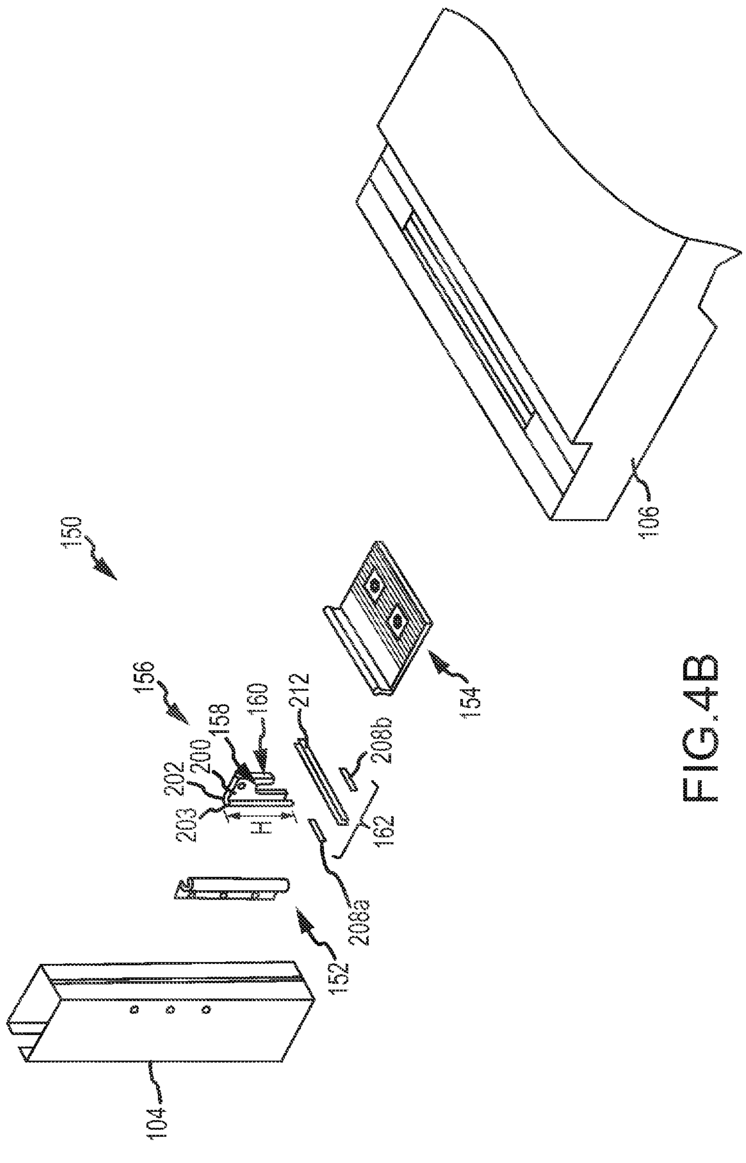
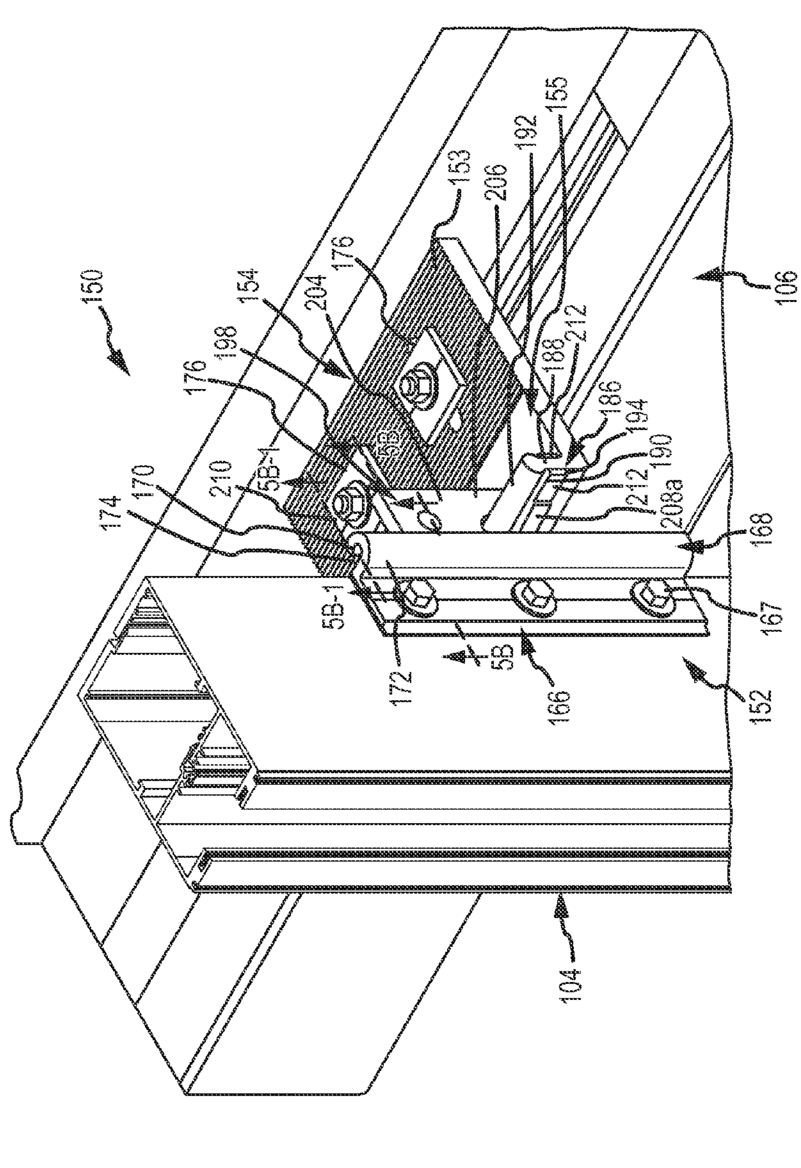


FIG.4B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154
176
204
198
176
5B-1
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208a
5B
5B-1
168
167
172
5B
166
152
106
104

FIG.5A

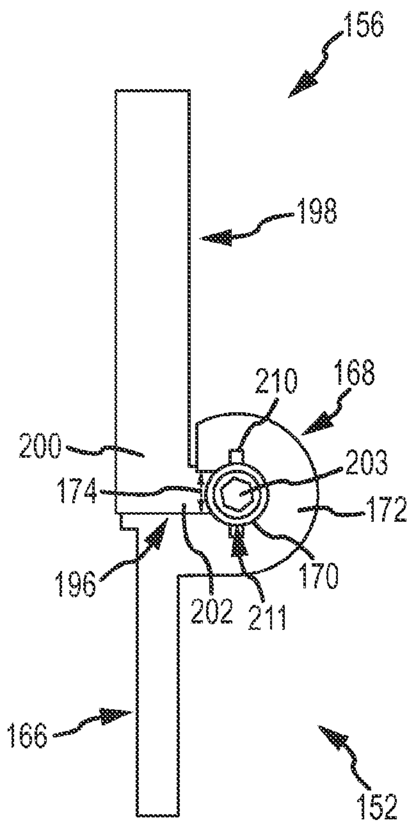


FIG.5B

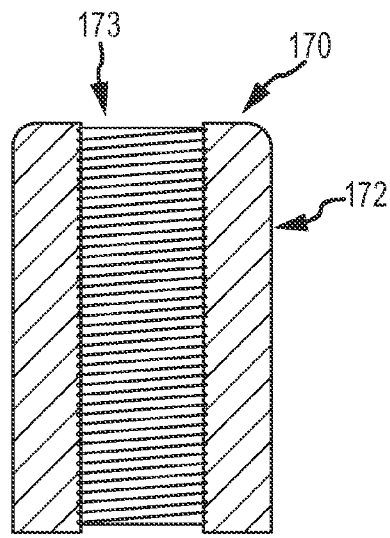


FIG.5B-1

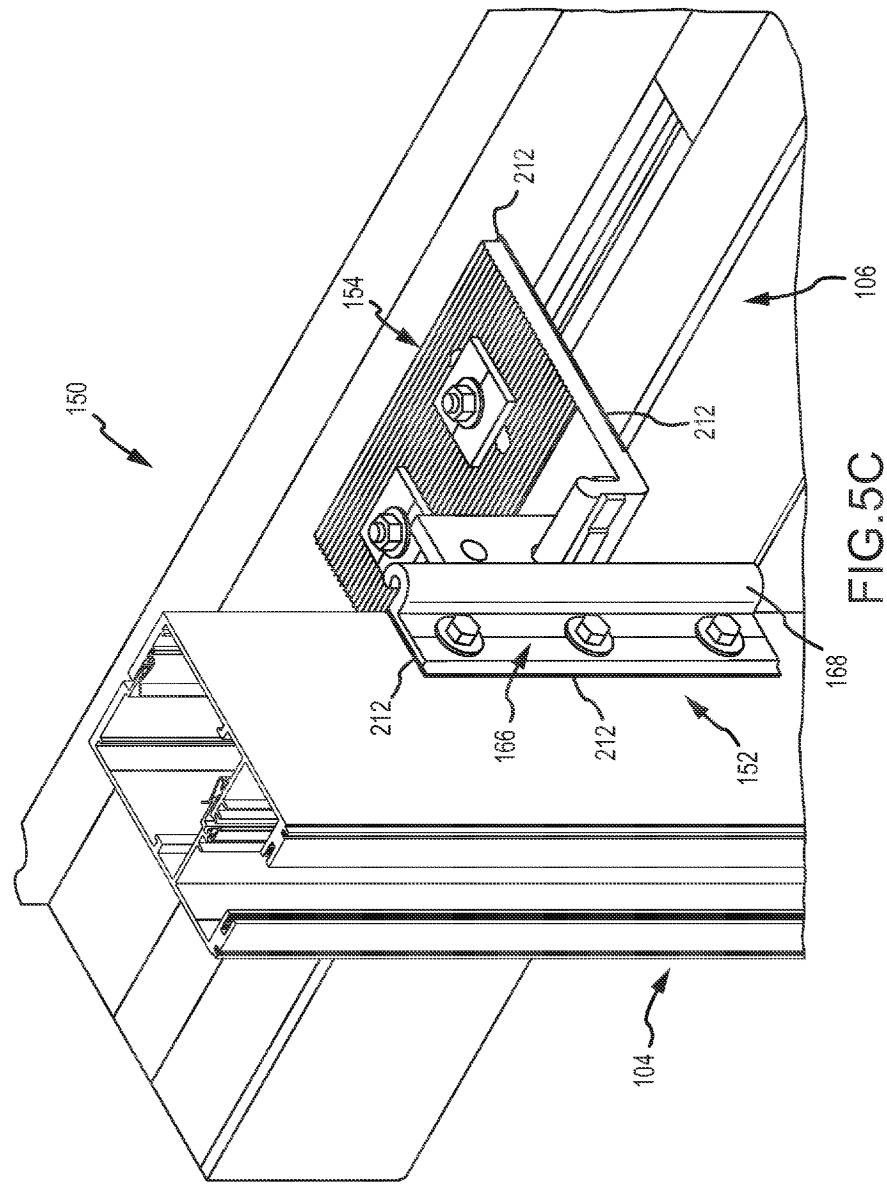


FIG.5C

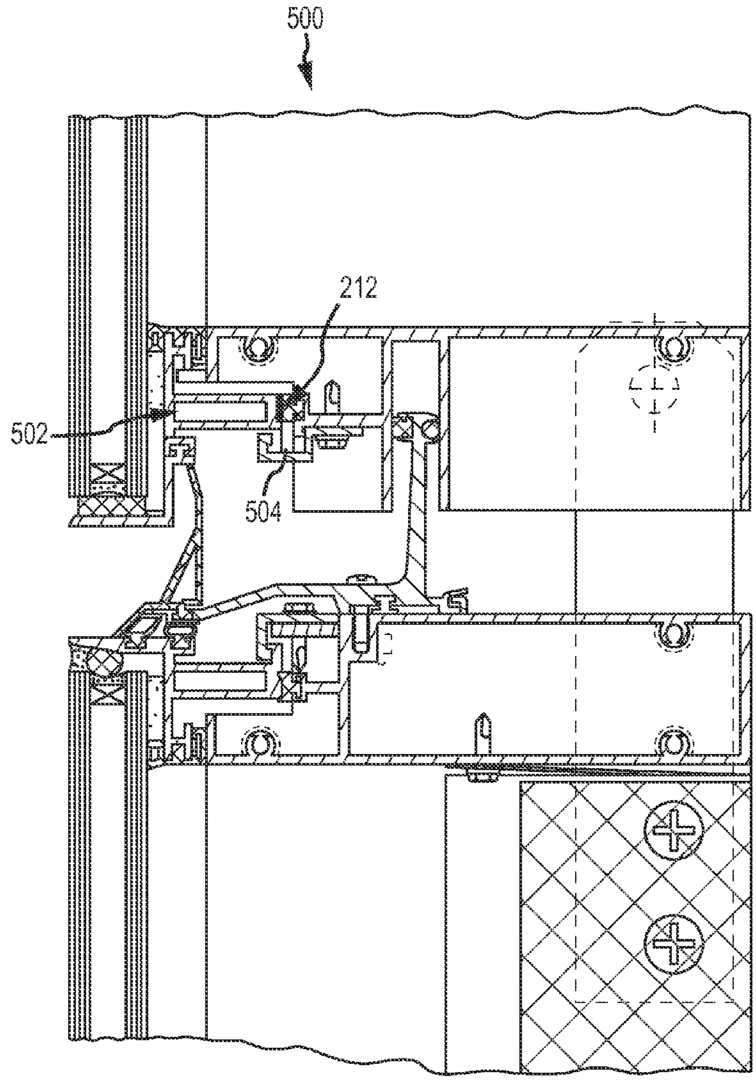
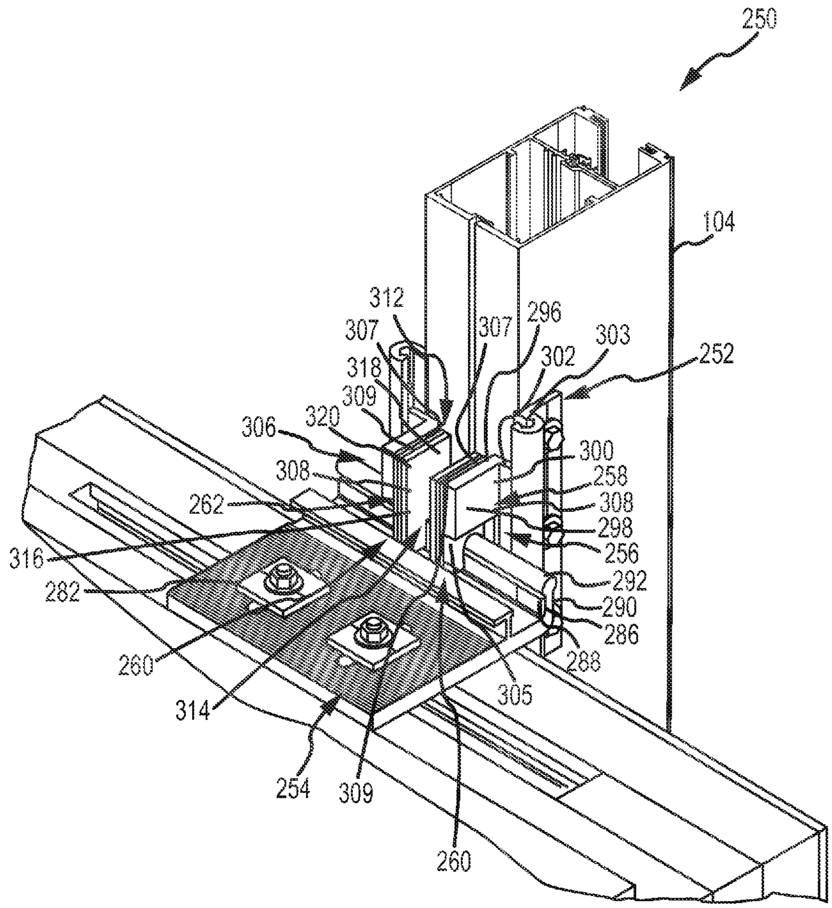


FIG.5D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318
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316
282
260
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286
288
305

FIG.6

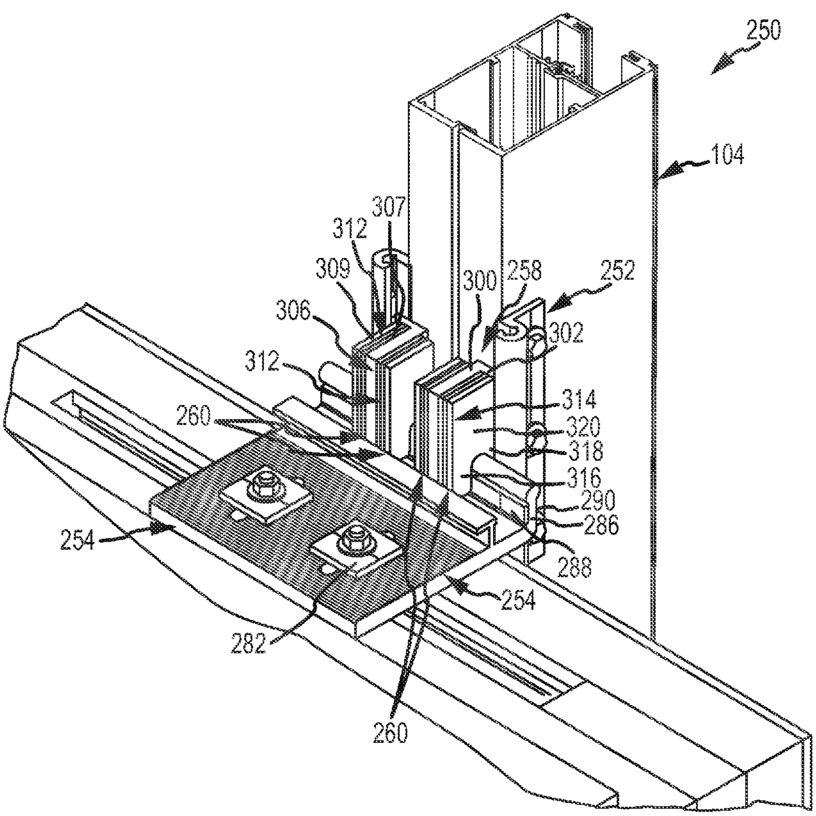
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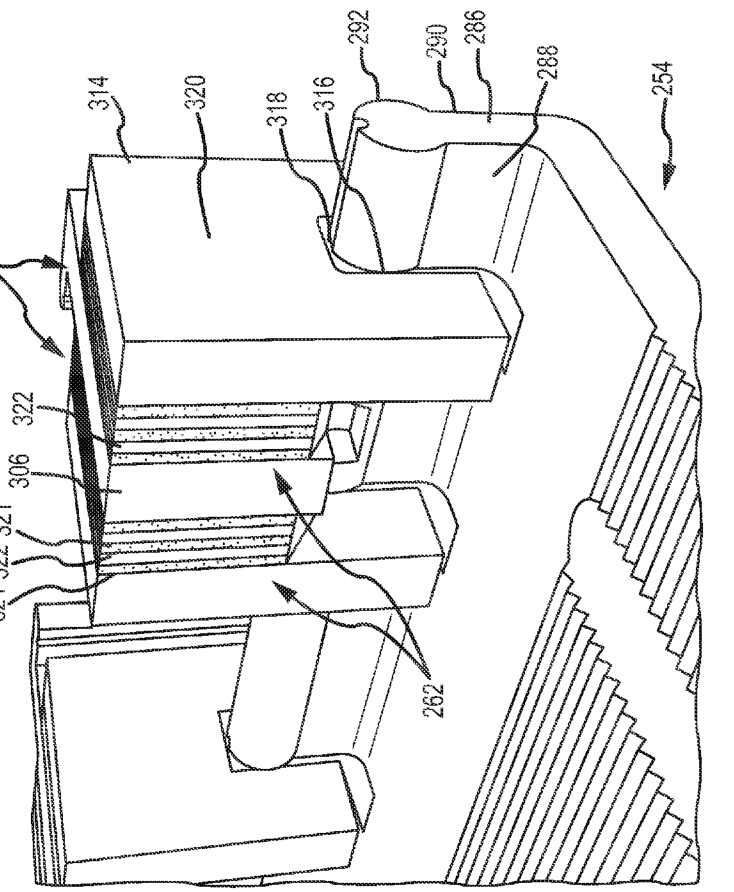
FIG.7



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321
262

FIG.8A

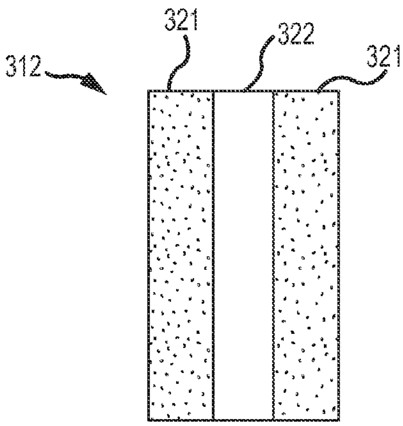


FIG.8B

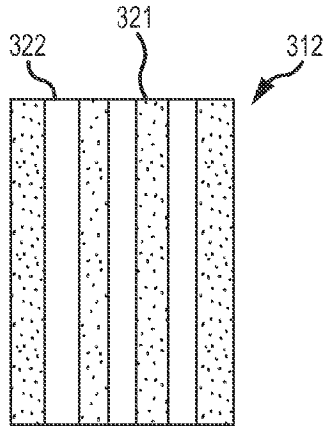


FIG.8C

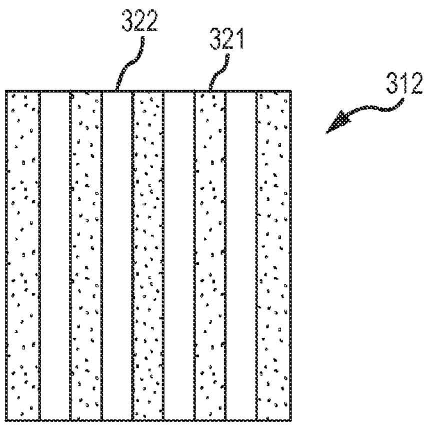


FIG.8D

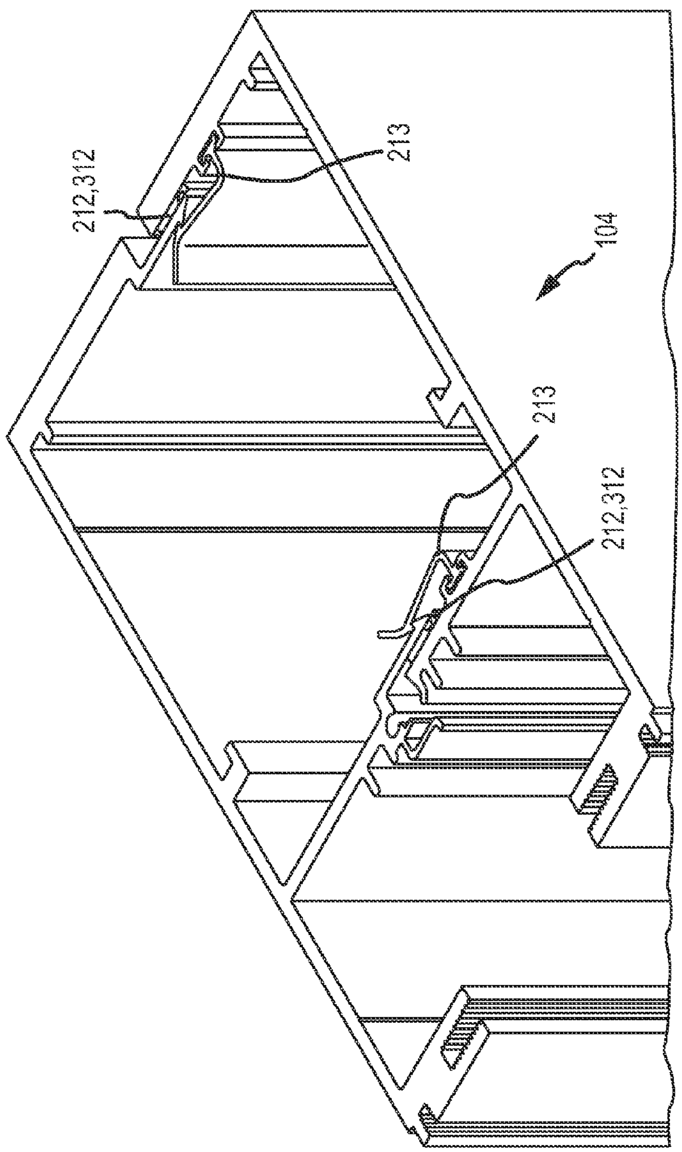


FIG.9A

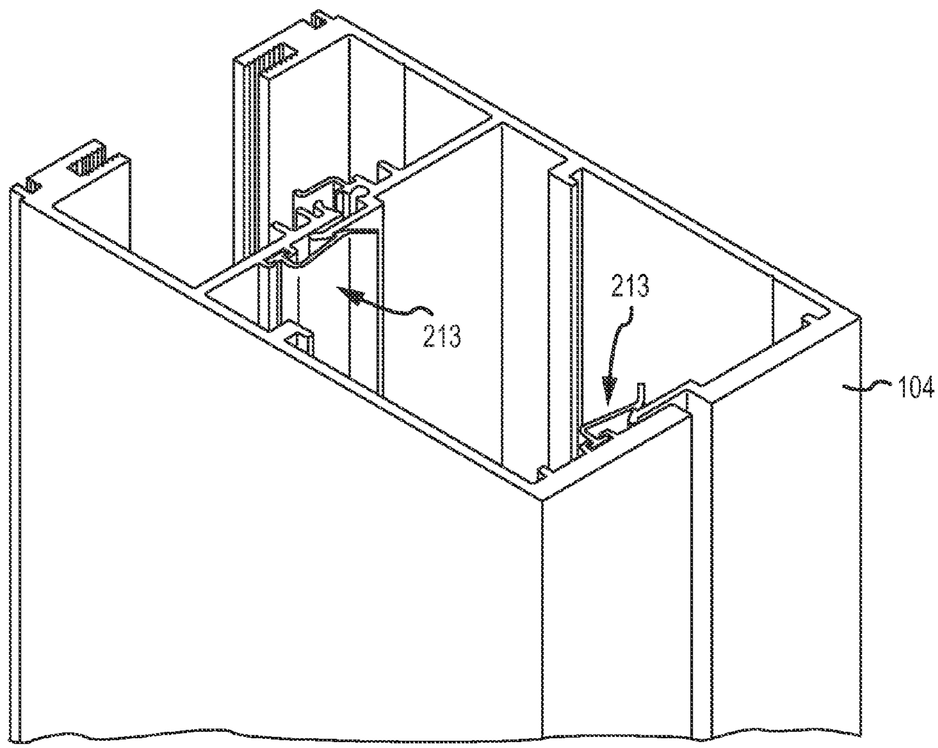


FIG.9B

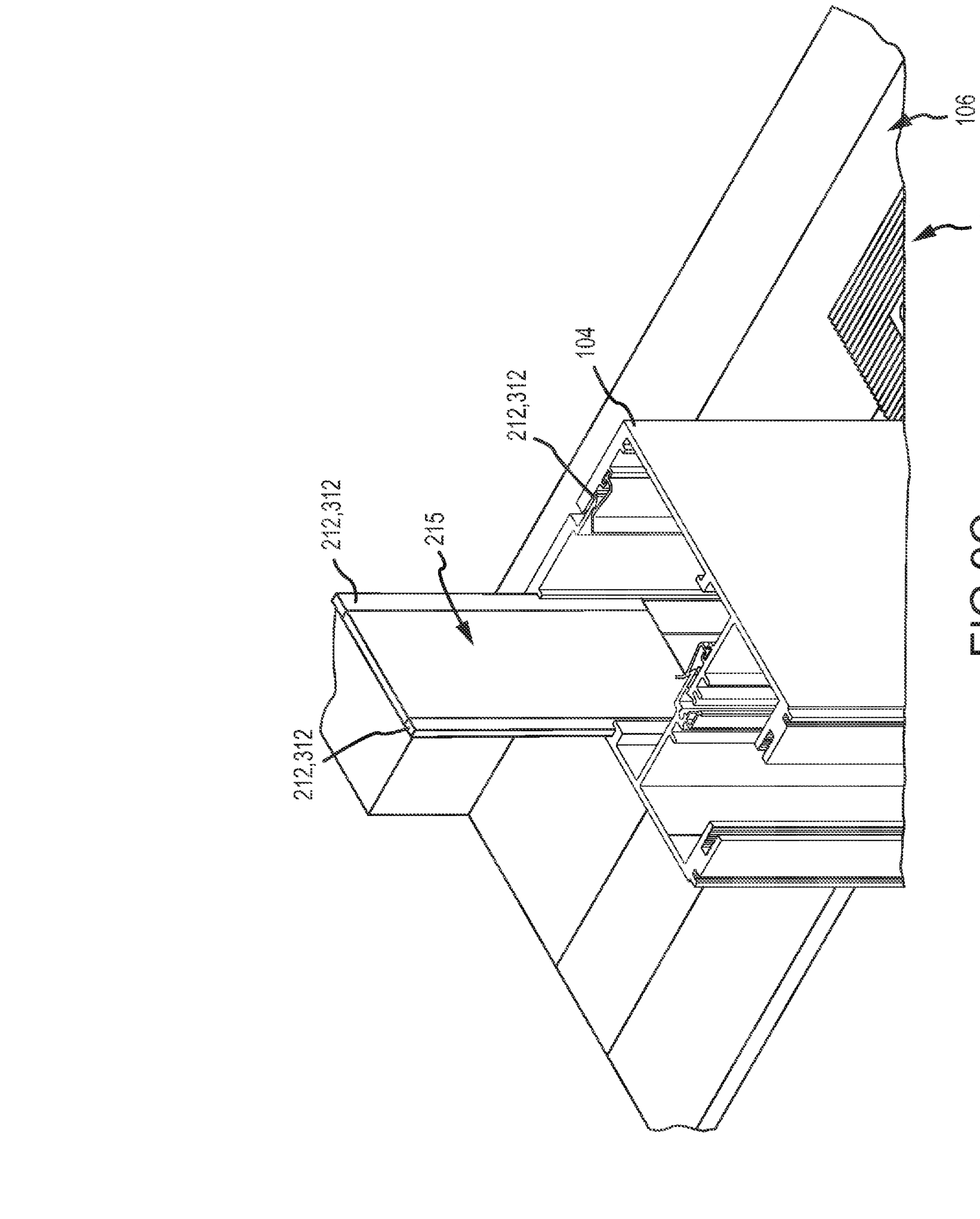
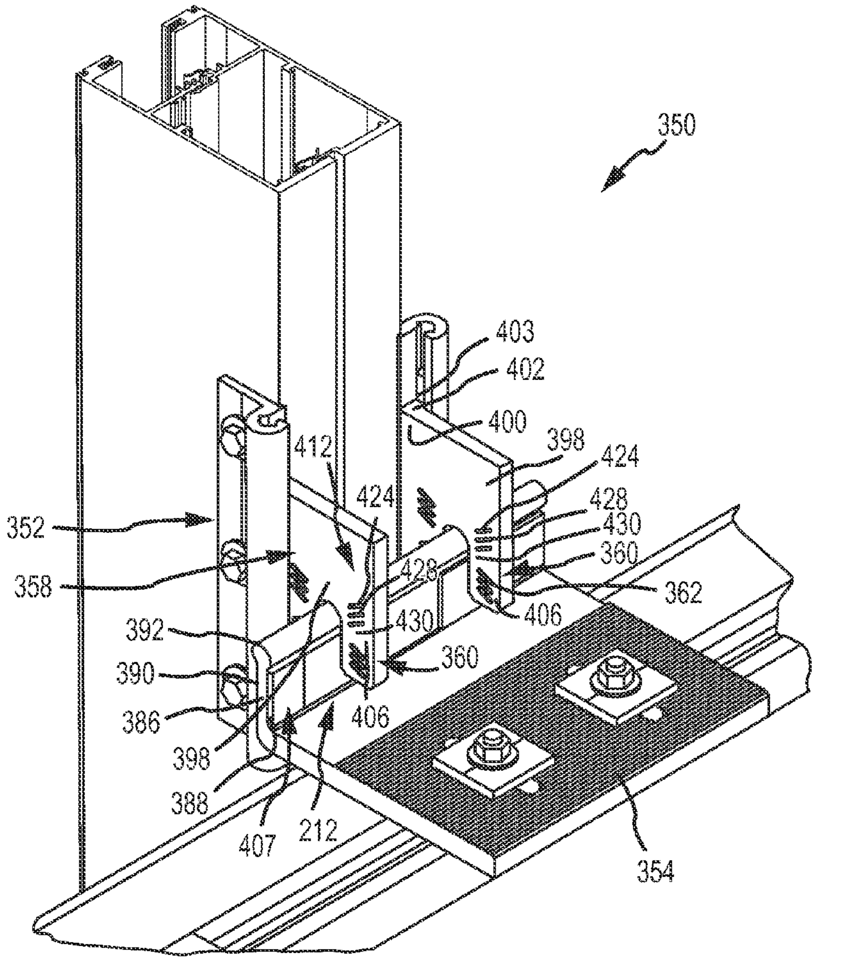


FIG.9C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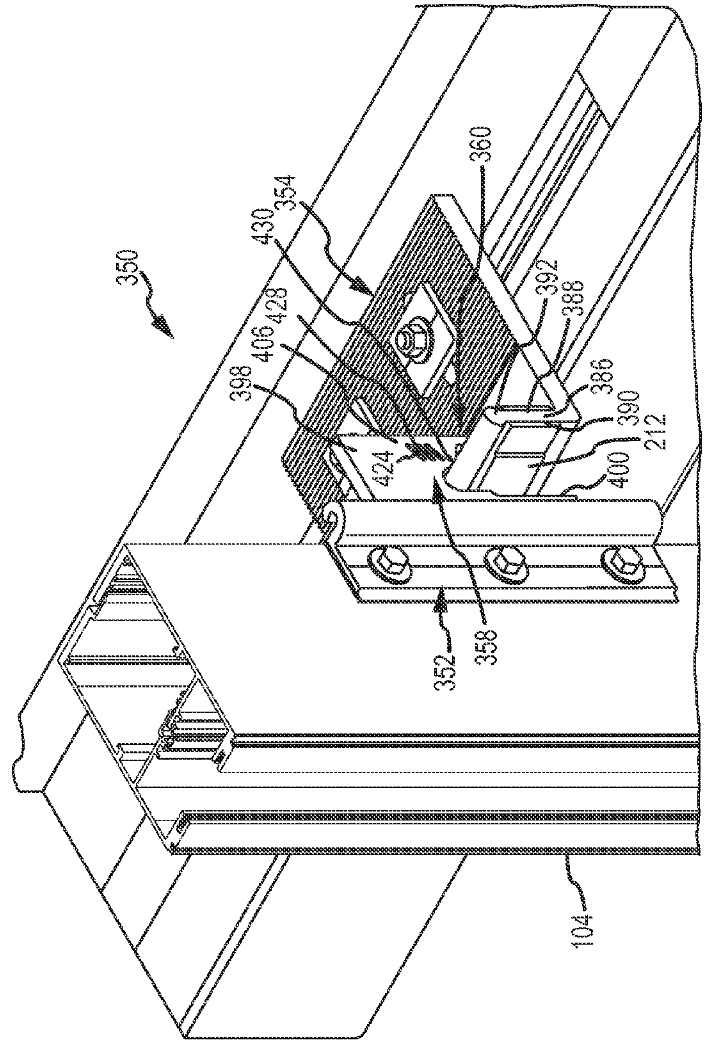
212
354

FIG.10A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390
212
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358
352
104

FIG.10B

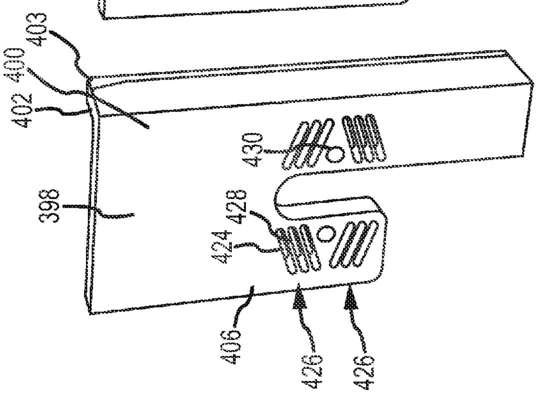

FIG.11A

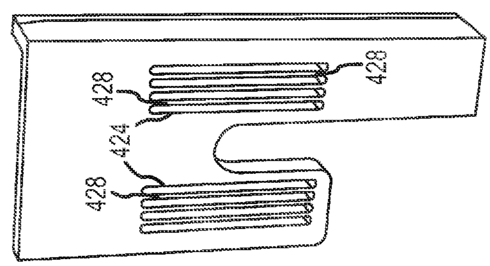

FIG.11B

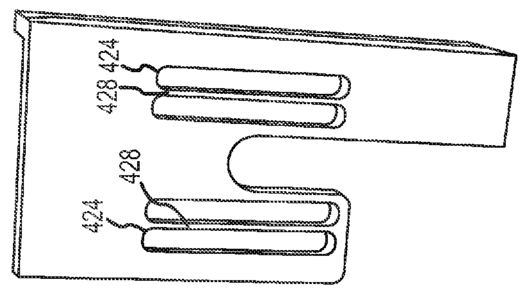

FIG.11C

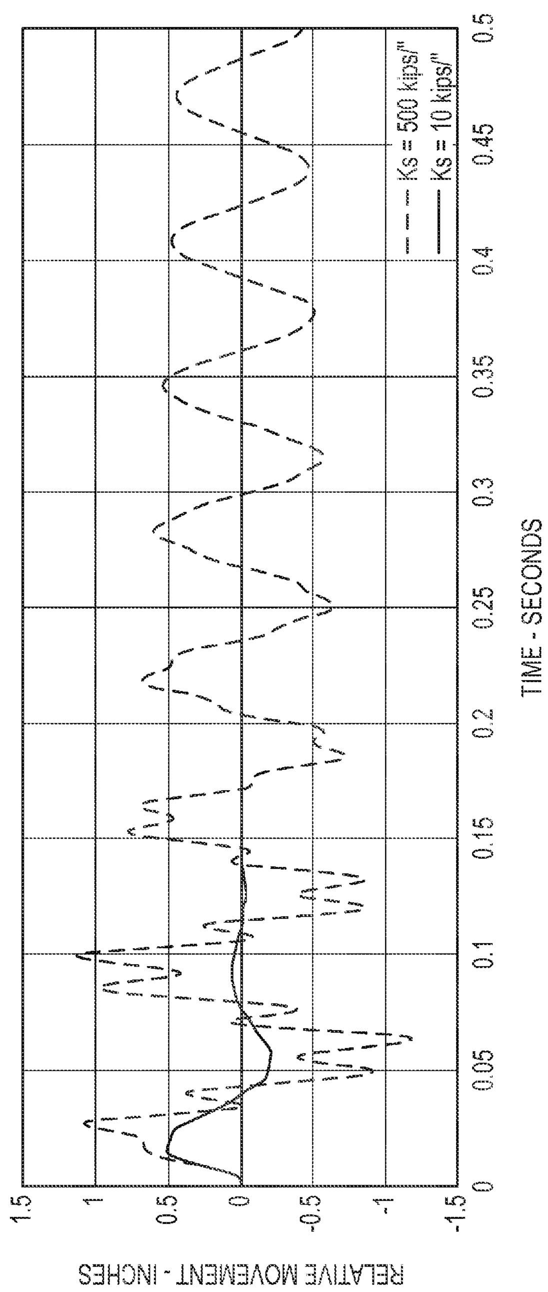
RELATIVE MOVEMENT - INCHES
TIME - SECONDS
1.5
1
0.5
0
-0.5
-1
-1.5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
Ks = 500 kips/"
Ks = 10 kips/"

FIG.12

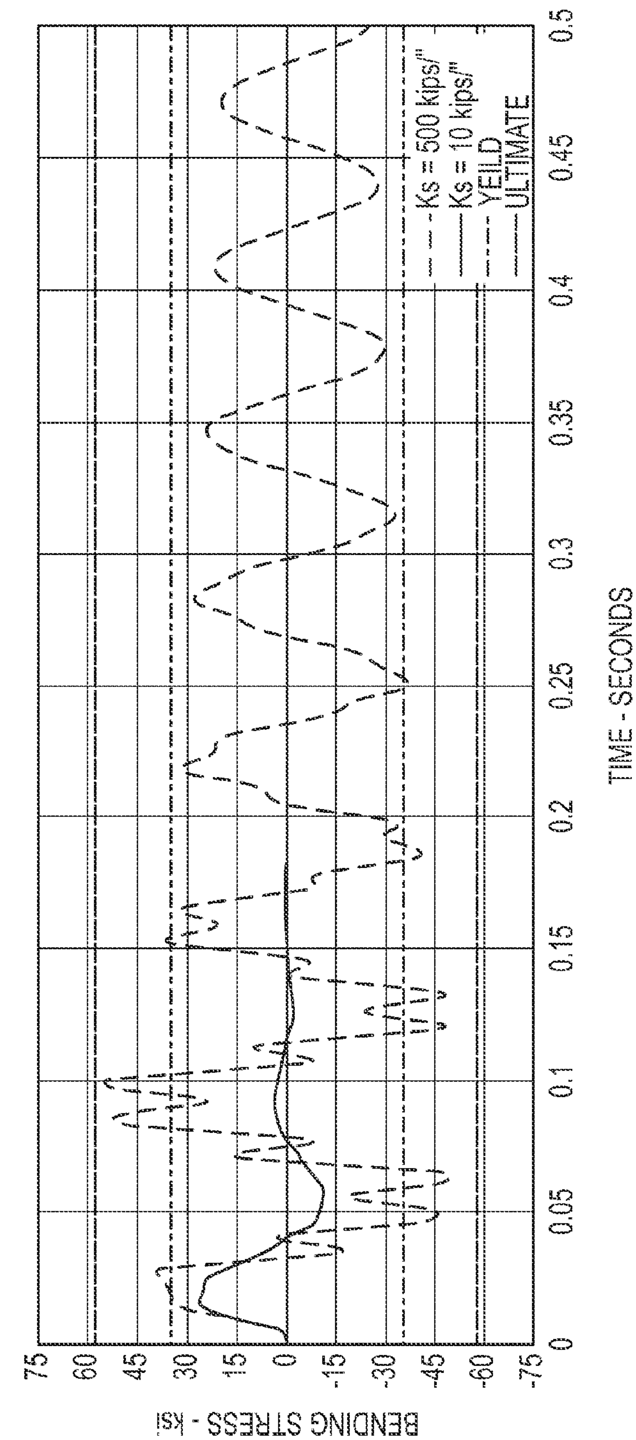
BENDING STRESS - ksi
TIME - SECONDS
Ks = 500 kips/"
Ks = 10 kips/"
YEILD
ULTIMATE
75
60
45
30
15
0
-15
-30
-45
-60
-75
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

FIG.13

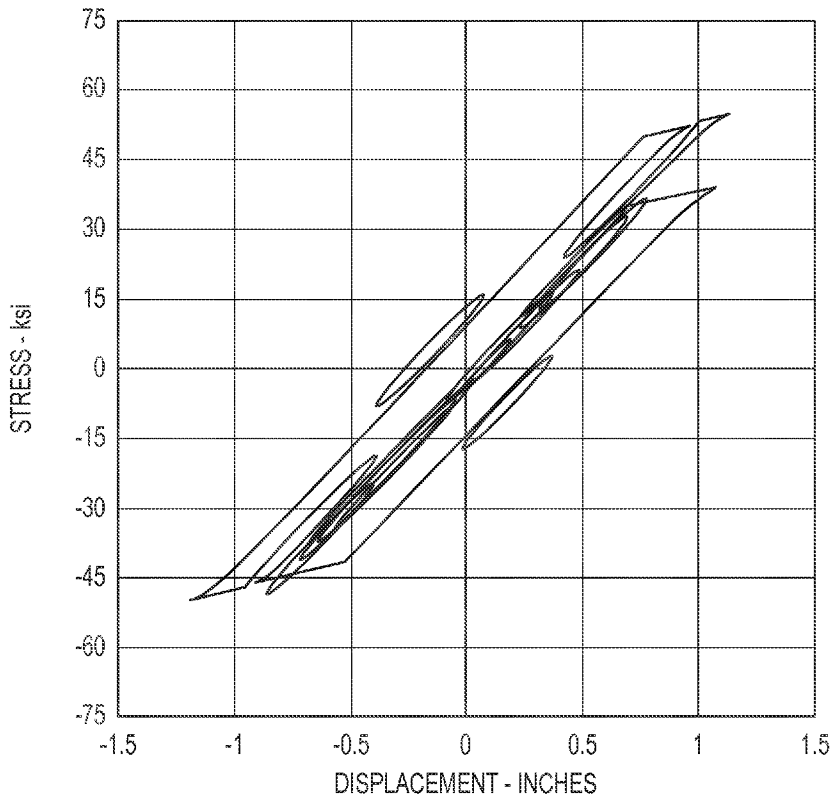
75
60
45
30
15
0
-15
-30
-45
-60
-75
STRESS - ksi
-1.5
-1
-0.5
0
0.5
1
1.5
DISPLACEMENT - INCHES

FIG.14

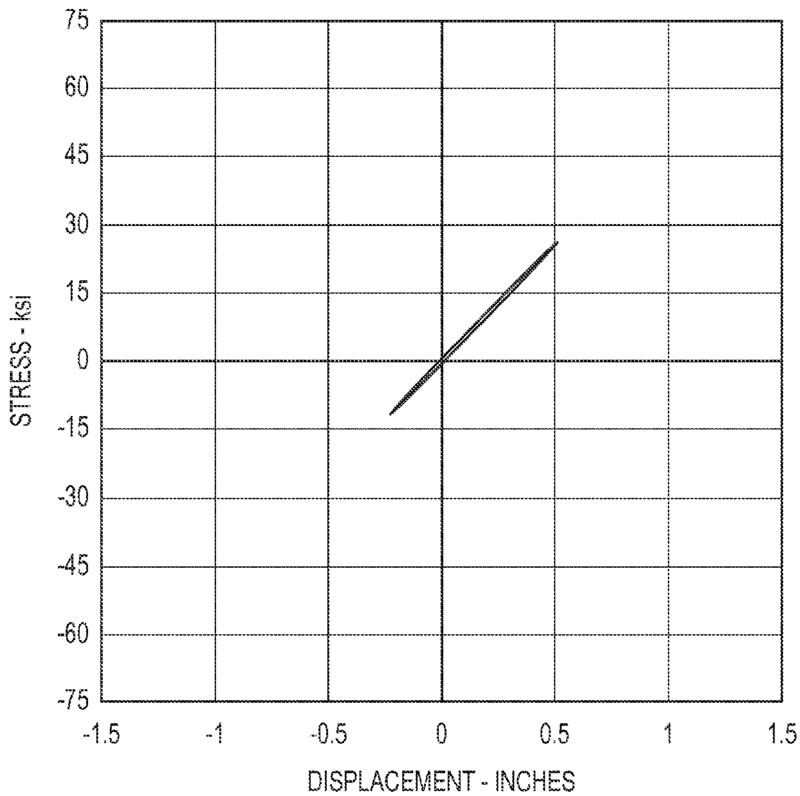
75
60
45
30
15
0
-15
-30
-45
-60
-75
STRESS - ksi
-1.5
-1
-0.5
0
0.5
1
1.5
DISPLACEMENT - INCHES

FIG.15

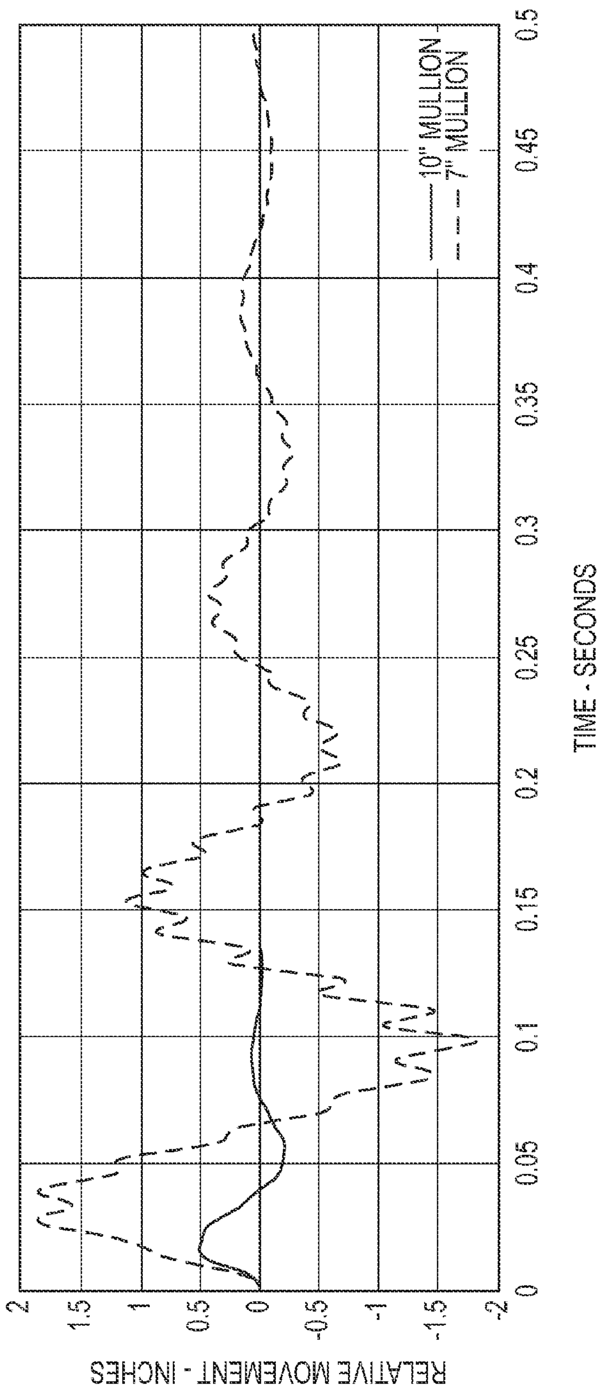
10" MULLION
7" MULLION
RELATIVE MOVEMENT - INCHES
TIME - SECONDS
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

FIG. 16

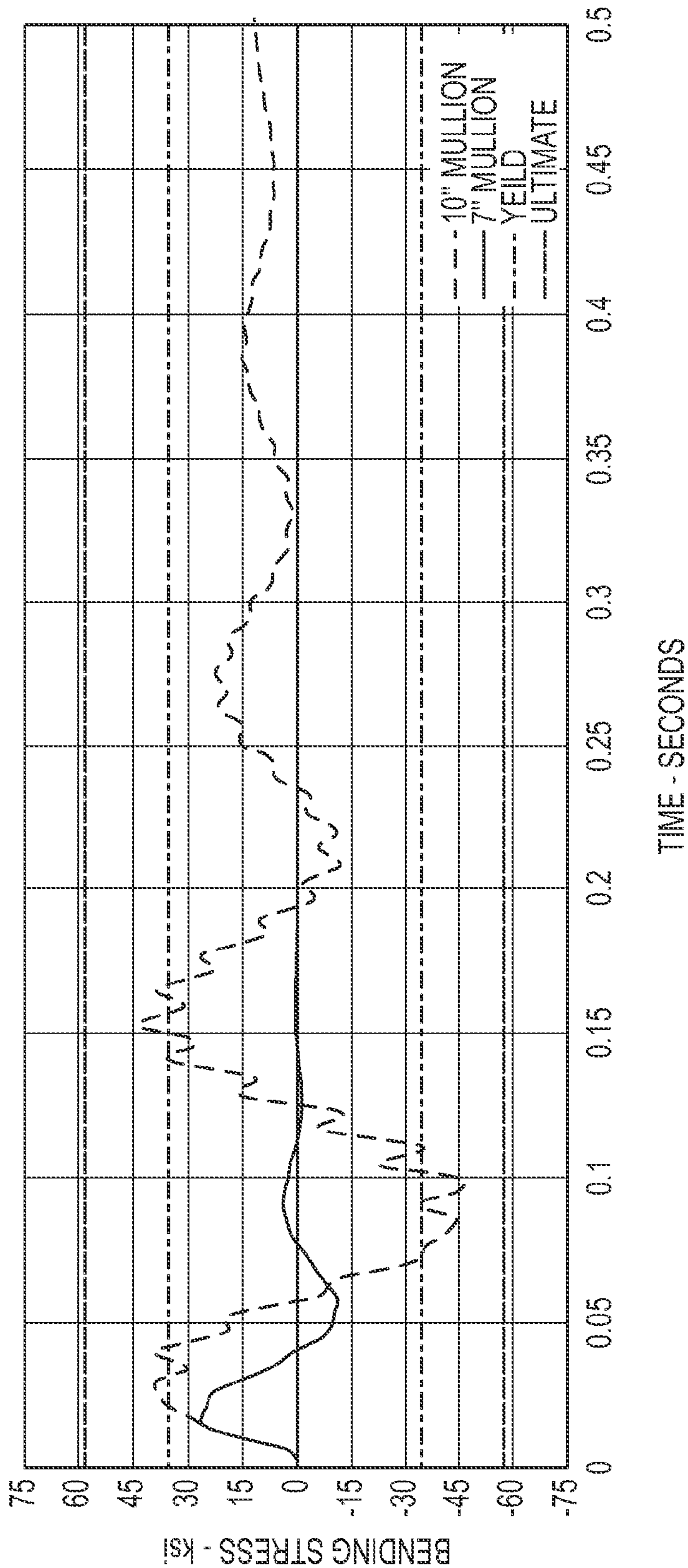
BENDING STRESS - ksi
75
60
45
30
15
0
-15
-30
-45
-60
-75
TIME - SECONDS
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
10" MULLION
7" MULLION
YEILD
ULTIMATE

FIG. 17

BLAST ABSORBING CLADDING

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit under 35 USC §119(e) to U.S. Patent Application No. 61/505,610 filed Jul. 8, 2011 entitled "Blast Absorbing Cladding" which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present disclosure relates to mitigating blast loads imparted on building cladding. More particularly, the present disclosure relates to an absorbing system for mitigating blast loads on cladding thereby reducing the effect of the loads on the cladding as well as the building structure. Still more particularly, the present disclosure relates to an absorbing system incorporated into a curtainwall anchor for mitigating blast loads.

BACKGROUND

[0003] In the wake of several terrorist attacks within the U.S. there has been a heightened level of protection provided by Federal, State, and Local law enforcement agencies. These efforts have included increased security measures and increased numbers of security personnel, particularly at highly attended and/or particularly vulnerable events. These efforts have also included putting additional thought into and conducting studies on how to minimize vulnerabilities when constructing new facilities and structures. Some of this additional thought and study relates to restricting access and providing more control over logistics of public and private entrances and exits to and from facilities. In some instances, where restricted access, separation, or other known techniques are not available or desirable, reinforcement of the vulnerable portion of the facility may be another solution.

[0004] In a building structure, the building façade is often the first line of defense against an attack on a structure. Where explosives, projectiles, or other dangerous systems are used near or directed toward a building, the building façade is likely the first portion of the building that will be contacted. The building façade, often formed of a curtainwall type structure, can be reinforced in an effort to better resist, for example, blast forces. However, the strength required to resist such forces is often balanced with the increased costs associated with it. In some cases, the increased costs may be justifiable and affordable, but in other cases, safety may be compromised due to costs, an aesthetic desire of the facility owner, or other limitations on reinforcement of the curtainwall system.

[0005] The information included in this Background section of the specification, including any references cited herein and any description or discussion thereof, is included for technical reference purposes only and is not to be regarded subject matter by which the scope of invention is to be bound.

SUMMARY

[0006] In one embodiment, a blast resistant cladding may include a curtainwall arranged on a structure defining a load path for transferring loads imparted on the curtainwall to the structure. The cladding may include an absorbing system positioned along the load path configured for absorbing blast-type loads imparted on the curtainwall.

[0007] In another embodiment, a system for supporting exterior cladding and resisting blast forces imparted thereon may include a cladding interface for fixedly engaging the cladding, a structure interface for fixedly engaging the structure, and an engagement system positioned between the cladding interface and structure interface. The engagement interface may include a hanger system for vertically supporting the cladding and a bracing system for laterally supporting the cladding. The bracing system may include an absorbing system for absorbing the blast forces.

[0008] In still another embodiment, a blast resistant cladding may include a curtainwall arranged on a structure defining a load path for transferring blast-type loads imparted on the curtainwall to the structure and a means for absorbing blast-type loads imparted on the curtainwall.

[0009] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter. Other features, details, utilities, and advantages of the present invention will be apparent from the following more particular written description of various embodiments of the invention as further illustrated in the accompanying drawings and defined in the appended claims.

BRIEF DESCRIPTION OF FIGURES

[0010] FIG. **1** is an exterior perspective view of a building clad with a curtainwall system according to the present disclosure and subject to an external blast.

[0011] FIG. **2**A is a perspective view of a curtainwall unit of the system of FIG. **1**.

[0012] FIG. **2**B is a schematic diagram of the blast load of FIG. **1** passing through the curtainwall unit of FIG. **2**A.

[0013] FIG. **2**C is a dynamic model of the blast load of FIG. **1** passing through the curtainwall unit of FIG. **2**B.

[0014] FIG. **3** is an interior perspective view of the curtainwall unit of FIG. **2**A showing an anchor system securing the curtainwall unit to a floor of the building.

[0015] FIG. **4**A is an interior perspective view of an anchor system according to one embodiment.

[0016] FIG. **4**B is a partial exploded perspective view of the anchor system of FIG. **4**A.

[0017] FIG. **5**A is an exterior perspective view of the anchor system of FIG. **4**A.

[0018] FIG. **5**B is a cross-sectional top view of a portion of the anchor system of FIG. **5**A taken about line **5**B-**5**B.

[0019] FIG. **5**B-**1** is a cross section of a portion of the anchor system of FIG. **5**A taken about line **5**B**1**-**5**B**1**

[0020] FIG. **5**C illustrates an embodiment of the anchor system of FIG. **4**A wherein a damping device is used in other locations within the system.

[0021] FIG. **5**D depicts a side view of an embodiment of the anchor system that may be used with a wall system according to aspects of the present disclosure.

[0022] FIG. **6** is an interior perspective view of an anchor system according to another embodiment.

[0023] FIG. **7** is an interior perspective view of an anchor system similar to FIG. **6** and including an additional bracing system.

[0024] FIG. **8**A is a close-up view of the bracing system of the anchor system of FIG. **7**.

[0025] FIGS. **8**B-**8**D illustrate various embodiments of a damping device that may be used in the bracing system of FIG. **8**A.

[0026] FIGS. **9**A-**9**B depict clips that may be used with an anchor system according to aspects of the present disclosure.

[0027] FIG. **9**C illustrates an embodiment of the anchor system of FIG. **9**A wherein a damping device is used in other locations within the system.

[0028] FIG. **10**A is an interior perspective view of an anchor system according to another embodiment.

[0029] FIG. **10**B is an exterior perspective view of the anchor system of FIG. **10**A.

[0030] FIGS. **11**A-**11**C are perspective views of several engagement systems for use with the anchor system of FIG. **10**A.

[0031] FIG. **12** is a comparative displacement diagram showing the displacement of a curtainwall mullion with a rigid support condition compared to that of a flexible support condition.

[0032] FIG. **13** is a comparative stress diagram showing the stress of a curtainwall mullion with a rigid support condition compared to that of a flexible support condition.

[0033] FIG. **14** is a hysteresis diagram showing the stress v. displacement of a curtainwall mullion with a rigid support condition.

[0034] FIG. **15** is a hysteresis diagram showing the stress v. displacement of a curtainwall mullion with a flexible support condition.

[0035] FIG. **16** is a comparative displacement diagram showing the displacement of a 10" mullion with a flexible support as compared to that of a 7" mullion with a flexible support.

[0036] FIG. **17** is a comparative displacement diagram showing the stress of a 10" mullion with a flexible support as compared to that of a 7" mullion with a flexible support.

DETAILED DESCRIPTION

[0037] The present disclosure relates to an absorbing system for mitigating blast loads imparted on the cladding of a building. The absorbing system may be positioned at any point along the blast load path and may be configured to transfer some of the blast load and absorb the remaining portion of the blast load. Accordingly, when passing through the absorbing system, the blast load may be at least partially absorbed thereby reducing the effect of the load on the components of the cladding and the building structure.

[0038] The absorbing system may include one or a combination of several devices configured for absorbing and transferring loads. In some embodiments, the absorbing system may include damping pads positioned along the blast load path and oriented substantially orthogonally to the path. The damping pads may be configured to absorb the load much like a combined spring and shock absorber or imperfect spring. In other embodiments, the absorbing system may include damping pads oriented substantially parallel to the load path. The damping pads, in this embodiment, may be configured to absorb the load similar to the system above, but by way of shear deformation rather than compressive or tensile deformation. In still other embodiments, the absorbing system may include elements adapted for inelastic deformation, sliding friction, or other energy absorbing mechanisms or devices. Advantageously, the dampening approaches described herein may improve the performance of the system not only under initial load but also by diminishing or reducing damage caused during rebound of the system.

[0039] With reference to FIG. **1**, one form of cladding, for which the absorbing system may be used, may include a curtainwall system **100** that is supported by hanging from the structure of a building **102**. For purposes of understanding the load path, at least one example of a curtainwall **100** will be described. As shown in FIG. **2**A, the curtainwall **100** may include a series of curtainwall units **108** with vertically extending mullions **104** positioned on each side of the unit **108**. The curtainwall unit **108** may also include horizontally extending transoms **110** at one or more locations throughout the height of the unit **108**. In addition, the unit **108** may have portions of spandrel glass **112** or other material at or near the floor locations **106** and may have transparent or semi-transparent glass **114** arranged in between the floors **106**. The curtainwall unit **108**, as best shown in FIG. **3**, may be supported off of the floor **106** with anchors **105** adjustably connected to the floor **106** and the curtainwall mullions **104**. It is noted that FIG. **3** shows an interior finish system without openings and has been provided primarily to show the anchor system location.

[0040] Other cladding systems may also be provided. For example other curtainwall systems such as that described in U.S. patent application Ser. No. 11/532,360 filed on Sep. 15, 2006 and entitled Curtainwall System, the contents of which are hereby incorporated by reference herein in their entirety, may be provided. In addition, the curtainwall described in U.S. Patent Application No. 60/867,341 filed on Nov. 27, 2006 and entitled Dual Wall System, the contents of which are hereby incorporated by reference herein in their entirety, may also be provided. Other curtainwall types may also be provided. Still other cladding systems may include, for example, stone on truss type cladding, cladding applied to studs, precast panels, window walls, and other cladding systems suspended from a structure. More particularly, the systems described herein may be applied to pre-cast panels, stick wall systems and to studs on sheathing supporting rain screen systems such as panels, stone and terra cotta.

[0041] With reference again to FIG. **1**, the curtainwall **100** may encounter loads emanating from a blast **101** occurring near or around the building **102**. Having described a typical curtainwall **100** structure, the load path of a blast load, for example, may be described with reference to FIG. **2**B. The load path may begin on an outer surface of the curtainwall **100** and travel inward toward the building structure. The load may be distributed by the glass **112** or other material **114** making up the surface of the curtainwall **100** and may be transferred through a sealant **118** to the supporting transoms **110** and mullions **104**. The load in the transoms **110** may be collected by the mullions **104** and transferred to the structure through an anchor **105** to the support structure of the building **102**. As best shown in FIG. **2**A, the mullions **104** of the curtainwall **100** may transfer this load by being designed to span between adjacent floor systems **106** of the building **102**. The blast may be resisted by the mullions **104** in flexure and shear as depicted by the deflected shape of the curtainwall in FIG. **1**. That is, under loads imparted by the blast force, the curtainwall **100** may have a bending and shear capacity configured to resist these loads while spanning the distance between the floors **106**. The loads resisted by the curtainwall **100** may then be transferred into the floor systems **106** by the anchors **105** that are positioned on the edge of the floor system **106** to support the curtainwall **100**.

[0042] Aside from the absorbing system being provided and described herein, a curtainwall system **100** may have some ability to absorb load. As shown in FIG. **2**C, each of the transitions between a given part or element of the curtainwall unit **108** and an adjoining or adjacent part or element may provide a dynamic resisting element **120**. Each dynamic resisting element **120** may function to transfer and absorb a portion of the force passing between the parts of the curtainwall unit **108** based on its stiffness and damping characteristics. Accordingly, each of the dynamic resisting elements **120** can define a spring constant **122** and a viscous damping constant **124**. That is, for example, the sealant **118** between the glass **112**, **114** and the mullion **104** may have a stiffness or spring constant Ks **122**A and a viscous damping constant Cs **124**A. The connection between the mullion **104** and the anchor **105** may have a spring constant of Km **122**B and a viscous damping constant Cm **124**B. Additionally, the connection of the anchor system **105** to the building or floor **106** may have a spring constant Ka **122**C and a viscous damping constant Ka **124**C. As the load passes through each of these dynamic resisting elements **120**, the energy of the imparted load may be partially transmitted and partially stored based on the stiffness of the particular element **120**. The stored energy may then be released, but damped according to the viscous damping constant. As the element **120** continues to store and release energy in an oscillating manner, the damping characteristics of the materials may eventually dissipate all of the oscillation. A typical curtainwall system **100** as described may have a stiffness, when considering all of the dynamic resisting elements, on the order of 500 kips/inch. Other stiffnesses may also be provided depending on the materials and connections selected for the system.

[0043] With the context provided above, several embodiments of an absorbing system may be described. It is noted that the embodiments disclosed herein include an absorbing system associated with the connection of the mullions **104** of the curtainwall **100** to the building structure. This particular location for the absorbing system can be advantageous because it reflects a logical break in the load path relating to the assembly and installation of the cladding. However, as mentioned, it is within the scope of the present disclosure to position the absorbing system anywhere along the load path.

[0044] The embodiments disclosed herein include a securing device for securing exterior cladding to a building. The securing device can be an anchor system **105** configured to support a curtainwall **100** relative to a building structure. The anchor system **105** can include several elements adapted to suspend the curtainwall **100** from the building and allow for adjustment during installation. Moreover, the anchor system **105** may include a bracing system for bracing the curtainwall laterally relative to the supporting structure thereby accommodating wind loads, internal building pressures differentials, blast loads or other lateral acting loads imparted on a curtainwall system. The absorbing system may be incorporated into the bracing system allowing the anchor to more effectively absorb blast forces imparted on the exterior or interior of the curtainwall **100**. Accordingly, the absorbing system may reduce the effect of forces imparted on the curtainwall **100** thereby allowing for a more economical and safe solution. That is, the absorbing system may allow the curtainwall **100** and the building structure to be more resistant to imparted loading without needing to be unduly reinforced.

[0045] With reference to FIGS. **4**A-**5**B, a first embodiment of an anchor system **150** may be described. As shown in FIGS. **4**A-**4**B, the anchor system **150** may include a curtainwall anchor with a curtainwall interface **152** configured for secured connection to a mullion **104** of the curtainwall unit **108**. The system **150** may further include a structure interface **154** configured for secured connection to a base. For example, the structure interface **154** may be configured for connection to a floor slab **106** of a building **102**. The curtainwall interface **152** and the structure interface **154** may each be configured to both vertically and laterally support the curtainwall **100** and an engagement system **156** may be provided to connect the two. The engagement system **156** may include a hanger system **158** for transferring vertical support loads between the two interfaces **152**, **154** and a bracing system **160** for transferring lateral acting support loads between the two interfaces **152**, **154**. The bracing system **160** may include an absorbing system **162**. It is noted that, while a single curtainwall interface element **152** is shown, two or more may be provided as shown in FIGS. **4**A-**5**B. Similarly, while a single engagement system **156** has been shown and a single set pads in the absorbing system **162** are shown, two or more of these elements may also be provided.

[0046] With continued reference to FIGS. **4**A-**5**B, each of the elements of the anchor system **150** may be described in more detail. The curtainwall interface **152** may generally be a device providing for engagement of the mullion **104** or other portion of the curtainwall **100**. As such, the curtainwall interface **152** may be a lip, ledge, loop, rib, pin, rod, hole, or other feature allowing for engagement of the curtainwall **100**. The curtainwall interface **152** may be attached to or integral with mullion **104** or other portion of the curtainwall **100**. With reference to FIGS. **4**A and **5**A-**5**B, the curtainwall interface **152** may take the form of a pair of mullion brackets or fists. For purposes of further discussion, the curtainwall interface **152** will be referred to as a fist **152**. In some embodiments, the mullion **104** and fist **152** may be made of steel, stainless steel, or other appropriate material.

[0047] The fist **152** may include a securing portion **166** and an adjustment portion **168**. The securing portion **166** may be adapted for positioning adjacent to and securing to the mullion **104**. Where the mullion **104** is a rectangular element, with relatively flat sides, the securing portion **166** may also be flat in the form of a plate and may be positioned on or coupled to the surface of the mullion **104**. The securing portion **166** may be constructed of steel, aluminum, other metals, an alloy, or a composite material. Other materials may also be used. In the case of a steel securing portion **166** in the form of a plate, the plate may have a thickness ranging from approximately ⅛" to approximately ¾". In other embodiments, the plate may have a thickness ranging from approximately 3/16" to approximately ⅝". In still other embodiments, the plate may be approximately ¼" thick. Thicker or thinner plate thicknesses may also be provided. The securing portion **166** of the fist **152** may be fastened to the mullion **104** with a plurality of fasteners **167** such as screws, bolts, self-tapping screws, self-drilling screws, or other fasteners. In other embodiments, the securing portion **166** may be welded or otherwise secured to the mullion **104** or may be an integral portion of the mullion **104**. For example, the securing portion **166** may be extruded together with the mullion **104**.

[0048] As mentioned, in addition to the securing portion **166**, the fist **152** may include an adjustment portion **168** and the adjustment portion **168** permits adjustment of the mullion **104** relative to the support structure or building **102** in one of a lateral and horizontal direction or both. In the embodiment shown, the adjustment portion **168** is configured for vertical adjustment. The adjustment portion **168**, as seen in FIGS. **5**B and **5**B-**1**, may include a hollow shaft structure **170** formed by a shaft wall **172** extending along the vertical length of the securing portion **166**. The shaft structure **170** may be configured to allow an adjustment element **203** to translate vertically along the length of the shaft **170**. As shown, the shaft wall **172** may be generally cylindrical and may extend fully along the length of the securing portion **166**. In other embodiments, the shaft wall **172** may extend partially along the securing portion **166** or beyond the securing portion **166**. The shaft wall **172** may have a longitudinal adjustment control **173** in the form of a helical thread **173** on an inner surface providing for screw-like propagation of an adjustment screw, for example, that, in turn, adjusts the position of the adjustment element **203** along the length of the shaft **170**. Other longitudinal adjustment controls **173** can also be used such as, for example, ratchet features and pin and socket features. The shaft **170** may also include an elongate opening **174** extending fully or partially along its length allowing elements to extend through the shaft wall **172** into the shaft **170** and, for example, connect to the adjustment element positioned in the shaft **170**. The elongate opening **174** may have a width at least slightly smaller than the corresponding shaft dimension to prevent escape of the adjustment element **203** laterally through the shaft wall **172**. For example, where the shaft **170** has a circular cross-section, the width of the elongate opening **174** may be at least slightly smaller than the diameter of the shaft **170**. The adjustment portion **168** may be made from the same material as the securing portion **166** and they may be extruded or molded as a single piece after which the helical threads may be cut into the shaft **170**.

[0049] As mentioned, the anchor system **150** may include a structure interface **154** in addition to the curtainwall interface or fist **152**. The structure interface **154** may be coupled to or configured for connection to the surface of a concrete slab **106** near an edge, for example. In other embodiments, the structure interface **154** may be positioned in or coupled to an embed and secured to the embed. For example, the structure interface **154** may be provided as shown and described in any or all of U.S. patent application Ser. No. 11/208,444 filed on Aug. 19, 2005, Ser. No. 12/422,754 filed on Apr. 13, 2009, and Ser. No. 12/422,799 filed on Apr. 13, 2009, each entitled Adjustable Attachment System. The contents of each of these applications are hereby incorporated by reference herein in their entireties. In still other embodiments, the structure interface **154** itself may be in the form of an embed. In any or all of the above cases, the structure interface **154** may be configured to be secured directly or indirectly to a base element in the form of a floor system **106** of a building **102** thereby transferring vertical and lateral acting loads imparted on the curtainwall **100** to the building **102**. As such, the structure interface **154** may be a bracket, plate, pin, rod, hole, or other feature allowing floor system **106** or other portion of the building **102** to be engaged with the structure interface. Similar to the curtainwall interface or fist **152**, the structure interface **154** may be separate from or integral with the floor system **106** or other portion of the building **102**. In some embodiments, the structure interface or bracket **154** may be made of steel, stainless steel, or other appropriate material.

[0050] In the embodiment shown in FIGS. **4**A-**5**B, the structure interface **154** may be in the form of a bracket, floor bracket, or attachment plate. For purposes of further discussion, the structure interface **154** will be referred to as a bracket or floor bracket **154**. The bracket **154** may include a generally flat or planar surface or portion **155** arranged in a horizontal orientation. The bracket **154** may include a slotted hole **176** having a longitudinal axis extending along its length. The bracket **154** may be arranged such that the longitudinal axis of the slotted hole is directed at an angle to the edge of the base or slab **106**. In some embodiments, the bracket **154** may be arranged with the longitudinal axis of the slotted hole **176** extending generally perpendicularly to the edge. The slotted hole **176** may receive and slide along a bolt or other anchoring element **178** extending from the base thereby coupling the bracket **154** to the base **106**. The slotted hole **176** and anchoring element **178** may allow some use slippage and friction. That is, the slotted hole **176** and anchoring element **178** may allow minimal to no movement of the system under wind load but may allow some movement of the system (within acceptable limits) to dissipate a blast load

[0051] As shown, a top surface **153** of the bracket **154** may include a gripping feature or surface **180**A such as, for example, a roughened or toothed surface. A washer **182** may also be coupled to the bolt or anchoring element **178** and a bottom surface **181** of the washer **182** may also include a gripping feature or surface **180**B such as, for example, a roughed or toothed surface for engaging the roughened or toothed surface of the bracket **154**. A nut or other fastening element **184** couples or causes engagement of the opposing gripping features **180**A/B of the washer **182** and bracket **154** thereby fixing the position of the bracket **154** relative to the bolt or anchoring element **178**, and thus fixing the bracket **154** position relative to the edge of the base **106**. Multiple slotted holes **176** and anchor bolts **178** may be provided to prevent twisting of the bracket **154** about the bolt or anchoring element **178** or to provide more strength. As shown, where more than one slotted holes **176** are provided, the slotted holes **176** may be arranged generally parallel to one another to facilitate an adjustable position of the bracket **154** by sliding the bracket **154** relative to the anchor bolts **178** prior to installing the washer **182** and nut **184**.

[0052] In addition to the flat surface or portion **155**, the bracket **154** may include an upturned leg **186** arranged generally perpendicular to the flat surface **155** and extending laterally from the edge of the bracket **154**. The upturned leg **186** may include an inboard surface **188** facing the building or structure **102** and an outboard surface **190** facing away from the building or structure **102**. The upturned leg **186** may also include a cap bearing element **192** positioned on the top edge of the leg **186** and extending along the length of the leg **186**. In cross-section, the cap bearing element **192** may have a relatively flat top surface and may have arcuate upper corners transitioning into relatively vertical sides and a relatively flat bottom surface. In other embodiments, the cap bearing element **192** may have a circular or other cross-section. The cap bearing element **192** may have a width or circumference slightly larger than the width or thickness of the upturned leg **186** of the bracket **154** and it may be centered on the upturned leg **186** causing the cap bearing element **192** to overhang the upturned leg **186** on each of the outboard and inboard faces **188**, **190** creating leg cavities **194**. The bracket **154** may have a width, measured along the edge of the floor **106**, larger than a width of a mullion **104** allowing the fists **152** secured to the sides of the mullion **104** to be connected to the bracket **154** with an engagement system **156**.

[0053] As mentioned, and as indicated in FIG. **4**B, the curtainwall interface or fist **152** and the structure interface or floor bracket **154** may be connected or coupled together by an engagement system **156** and the engagement system may include one of a hanger system **158** and a bracing system **160** or both. The hanger system **158** may vertically support the curtainwall **100** relative to the base **106**. Accordingly, the hanger system **158** may engage the fist **152** and the floor bracket **154** in a manner that prevents or controls vertical displacement therebetween. The bracing system **160**, on the other hand, may be configured to laterally support the curtainwall **100** relative to the base **106**. Accordingly, the bracing system **160** may engage the fist **152** and the floor bracket **154** in a manner that prevents or controls horizontal displacement therebetween. The engagement system **156** including the hanger system **158** and bracing system **160** may include a single integral piece of material with several parts or the systems may be separate parts that are coupled together. In the embodiments shown herein, the engagement system **156** includes a hook that both vertically supports and laterally braces the curtainwall relative to the base **106**. In some embodiments, the engagement system **156** may also be fixedly secured to the structure interface **154**.

[0054] Turning first to the hanger system **158**, it may include a device, a portion of a device, or system of devices adapted for engaging the fist **152** and the floor bracket **154** and hanging the curtainwall **100**. As such, it may include a hook, lip, ledge, tab, pin, rod, or portion thereof configured to connect the fist **152** to the floor bracket **154**. With reference to FIGS. **4**A-**5**B, in one embodiment, the hanger system **158** is provided as a portion of a hook. That is, the portions of the hook that function to provide vertical support are included in the hanger system **158**.

[0055] As indicated in FIGS. **4**A and **5**B and others, the hanger system **158** may include a fist engaging portion **196** and a floor bracket engaging portion **198**. The fist engaging portion **196** may include a main body portion **200**, a tab element **202**, and an adjustment element **203**. The main body portion **200** may be positioned adjacent or inline with the shaft **170** of the fist **152** and may be configured for movement along the length of and parallel to the shaft **170**. The main body portion **200** may be a generally flat plate-like element or another shape may be provided. The tab element **202** may extend from the main body portion **200** through the elongated slot **174** in the shaft wall **172** of the fist **152** and may be connected to the adjustment element **203** previously described as being positioned in the shaft **170** of the fist **152**. The fist **152** may include piston adjusters or screws that control the vertical position of the adjustment element **203** within the shaft **170** and as such also control the vertical position of the hanger system **158**. For example, the piston adjusters may be threaded elements that move vertically within the shaft **170** through a screw-type engagement with the inner surface of the shaft **170**.

[0056] In some embodiments, the floor bracket engaging portion **198** may be a tab, lip, rod, or other element which extends from the main body **200**, bears on or otherwise engages the floor bracket **154**, and prevent relative vertical displacement between the fist engaging portion **196** of the hanger system **158** and the floor bracket **154**. One embodiment of the floor bracket engaging portion **198** shown in FIGS. **4**A, **4**B and others, is in the form of a boom type structure extending from the main body **200** of the fist engaging portion **196**. For purposes of discussion, the floor bracket engaging portion **198** will be referred to as a boom **198**.

[0057] The boom portion **198** may be fixedly secured to the main body **200** to prevent displacement and rotation therebetween. For example, the boom **198**, like the main body **200**, may be a plate-like element and may be formed together with the main body portion **200** from a single piece of material. The boom **198** may extend substantially horizontally from the main body **200** and may bear on top of the upturned leg **186** of the floor bracket **154**. More particularly, the boom **198** may bear on the top surface of the cap bearing element **192** positioned on the top of the upturned leg **186**.

[0058] As described, the hanger system **158** may provide vertical support to the curtainwall **100** by way of the adjustment element **203** engaging the shaft **170**. The adjustment element **203** may be rigidly connected or coupled to the tab element **202**, which may be rigidly connected or coupled to the main body **200**, which may be rigidly connected or coupled to the boom **198** and the boom **198** may bear on the floor bracket **154**. It is noted that the offset nature of the support of the curtainwall **100** at the fist **152** relative to the bearing point on the floor bracket **154** may induce a moment in the hanger system **158**. In other embodiments, the support of the curtainwall **100** at the fist **152** relative to the bearing point on the floor bracket **154** may be in-line rather than off set. The main body **200** together with the tab element **202** and adjustment element **203** positioned in the shaft **170** may have a height H, measured along the fist **152**, adapted to resist the induced moment. In one embodiment, the main body **200** may have a height between approximately ½ inch and approximately 4 inches. In another embodiment, the main body **200** may have a height up to and including approximately 2 feet. In another embodiment, the main body **200** may have a height between approximately 1 inch and approximately 3 inches. In still other embodiments, the main body **200** may have a height of approximately ½ inches. In still other embodiments, the main body **200** may be longer than approximately 4 inches or shorter than approximately ½ inch and may have a length similar to the spandrel height of the associated curtainwall, for example. Suitable heights may be selected to resist the imparted loads and also accommodate desires to keep the portions of the anchor secluded and out of sight. Other heights may also be provided.

[0059] As mentioned, the engagement system **156** for connecting or engaging the curtainwall interface or fist **152** and the structure interface or floor bracket **154** may include a bracing system **160** in addition to the hanger system **158** just described. The bracing system **160** may be separate from or partially integral with the hanger system **158**. In the embodiment shown in FIGS. **4**A to **5**B, the bracing system **160** may be said to be partially integral with the hanger system **158** since it extends from the hanger system **158** and relies on the main body **200**, tab element **202**, and adjustment element **203** to prevent horizontal displacement relative to the fist **152**. The bracing system **160** further includes elements secured to and extending from the hanger system **158** to provide lateral bracing relative to the floor bracket **154**. As shown, the bracing system **160** may include an inboard hook leg **206** extending vertically downward from the boom **198** along the inboard face **190** of the upturned leg **186** of the floor bracket **154**. The inboard hook leg **206** may be fixedly secured or otherwise coupled to the boom **198** to prevent displacement and rotation therebetween. For example, the hook leg **206** may also be part of the same material as the main body **200** and boom **198**. The boom **198** and inboard hook leg **206** may form a generally L-shaped member and may together be referred to as a hook. In addition, the main body **200** may also form a portion of the hook and the hook may be generally U-shaped. The term hook may also be used to refer to the element including the main body **200**, the tab element **202**, the adjustment element **203**, the boom **198**, and the vertical hook leg **206**. In some embodiments, the elements of the hook may be made of steel, stainless steel, or other appropriate material.

[0060] Accordingly, as mentioned, the engagement system **156** may include a hanger system **158** and a bracing system **160**, each of which may be separate parts or may be formed by a portion of a single part. In the embodiment described, the hanger system **158** and bracing system **160** are partially integral in that they each include portions of the hook which connects the fist **152** to the floor bracket **154**. In some embodiments, as mentioned, the engagement system **156** may be further integral with the structure interface **154** by being fixedly or slidingly secured or otherwise coupled thereto.

[0061] As can be understood from FIGS. **4**A, **4**B, **5**A and others, the bracing system **160** may further include an absorbing system **162** including distribution elements **208** and damping devices **212**. With respect to distribution elements **208**, first or outboard distribution element **208***a* may be secured to the main body **200** of the hanger system **158** and a second or inboard distribution element **208***b* may be secured to the vertical hook leg **206**. The distribution elements **208** may be configured for handling lateral acting forces by being positioned normal to the force direction and, thus, the absorbing system **162** shown may be referred to as a normal force-type absorbing system **162**. Accordingly, and as can be seen in at least FIG. **5**A, the distribution elements **208** may include a generally planar or damping surface oriented in a plane adjacent and parallel to the plane defined by the corresponding inboard or outboard face **188**, **190** of the upturned leg **186** of the floor bracket **154**. The planar surfaces of the distribution elements **208** may be separated from the respective faces **188**, **190** of the upturned leg **186** defining a space **209** therebetween. As explained in more detail below, the damping devices **212** are received in the space **209**. The distribution elements **208** may be plate elements as shown or may have some other shape adapted to more readily distribute loads. For example, the distribution element **208** may have a triangular cross-section when viewed from above, from the side, or both. In this embodiment, for the outboard distribution element **208***a,* for example, the apex of the triangle may abut the main body **200** and the base of the triangle may form the planar surface adjacent the outboard face **190** of the upturned leg **186**. In other embodiments, rather than modifying the shape of the distribution element **208**, the thickness, measured perpendicular to the planar surface, may be increased or selected to suitably distribute lateral acting loads. Generally, a thicker distribution element **208** may provide for more load distribution.

[0062] The damping device **212** may be configured for absorbing and damping loads passing through the bracing system **160**. In some embodiments, the damping device **212** may include a energy storing and releasing device such as a spring, for example, and a shock absorber using fluids such as a dash pot device, for example. In some embodiments, the energy storing/releasing function and dash pot or damping function may be provided by a single device. In the present embodiment, as shown in FIGS. **4**A, **5**B and others, the damping device **212** may be provided in the form of a damping pad or pads **212**. In the embodiment shown, the damping pads may be normal force-type damping pads and may be particularly adapted to transfer and dissipate loads imparted normal to the surface of the pad. The damping pads **212** may be positioned in the space **209** between the distribution elements **208** and respective inboard and outboard faces **188**, **190** of the upturned leg **186** of the floor bracket **154**. In this position and orientation, the damping pads may transfer and dissipate lateral acting loads through compressing and stretching. The pads may be adhered or otherwise secured to the distribution elements **208** or the inboard and outboard faces **188**, **190** of the upturned leg **186** of the floor bracket **154** or both. The damping pads may include an elastomeric material such as for example, rubber, neoprene, ethylene propylene rubber (EPM), or ethylene propylene diene rubber (EPDM). Other materials, including other elastomeric materials, can also be used. In some embodiments, the damping pad may include lead or other internal materials for increasing the internal friction of the material to further damp lateral acting forces or may include layers of material such as lead or brass to further damp lateral acting forces. In some embodiments, the pads **212** may be replaceable. In some embodiments, the damping device is made of a "crushable" material such as sand, stone, plaster board. cement board or other appropriate material that could absorb a blast. A device **212** made of such crushable material may be configured as a replaceable insert.

[0063] While the distribution element **208** has been described as being arranged on the hook and not on the floor bracket **154**, the upturned leg **186** of the floor bracket **154** may form an opposing distribution element for positioning of the damping device **212** therebetween. In other embodiments, distribution element **208** may be arranged on the floor bracket **154** and a natural surface of the hook may oppose the distribution for placement of a damping device **212** therebetween. In other embodiments, the absorbing system **162**, or elements of the absorbing system **162**, are placed in other locations along the load path. For example, in one embodiment shown in FIG. **5**C, the damping pads **212** may be positioned between the mullion **104** and the fist **152**. In this position and orientation, the damping pads may transfer and dissipate lateral acting loads by shear deformation or compressive deformation of the pad. Additionally or alternatively, the damping pads **212** may be positioned or coupled between the floor bracket **154** and the slab floor **106**. In this position and orientation, the damping pads may transfer and dissipate lateral acting loads by compressive or tensile deformation of the pad. In other embodiments, such as a system shown in FIG. **5**D, where the system is a wall system **500** comprised of cassettes **502** applied to support framing **504**, the damping pads **212** may be positioned between the cassettes **502** and the frame **504**. It can be appreciated that any of the above-described systems can also use the damping pads described elsewhere herein, such as the layered damping pads **312** discussed with reference to FIGS. **6-8**.

[0064] The damping pads may have a neutral (i.e., unstressed) thickness substantially equal to the space between the distribution elements **208** and the faces **188**, **190** of the upturned leg **186**. In some embodiments, the thickness of the damping pads may be between approximately 1⁄16 inch and approximately 1 inch. In other embodiments, the thickness may be between approximately ⅛ inch and approximately ½ inch. In still other embodiments, the thickness may be approximately 3⁄16 inch. Multiple layers of damping material may be provided and adhesives may be provided between the layers. The layers of damping material may all be the same material or several types of material may be provided in the several layers. The thickness of the damping pads may be selected to accommodate the space available within the wall in addition to other load considerations. That is, for wind loads, for example, limitations for allowable deflections must be met, so highly flexible and low resistant materials may not satisfy these requirements.

[0065] The distribution elements **208** in conjunction with the damping device **212** may allow the absorbing system **162** to distribute lateral acting loads to a relatively larger area of the upturned leg **186** of the floor bracket **154**. The distribution of the force over a larger area may reduce the force per unit area that is being transferred and dissipated thereby increasing the efficacy of the system. In some embodiments, the surface area of the planar surface for each distribution element **208** and the size of the damping pads may be between approximately ¼ square inches and 9 square inches. In other embodiments, the area may be between approximately ½ square inches and 4 square inches. In still other embodiments, the area may be approximately 1 ½ square inches. Larger or smaller areas may also be provided.

[0066] It is noted that under lateral acting loads, the horizontally offset nature of the position of the bracing system **160** and corresponding absorbing system **162** relative to the longitudinal axis of the shaft **170** of the fist **152** may induce horizontal rotation of the bracing system **160** about the longitudinal axis of the fist shaft **170**. As shown in FIGS. **5**A-**5**B, a keyway **210** may be provided extending longitudinally along the internal surface of the shaft **170** and a corresponding key **211** may be provided on the adjustment element **203** positioned in the shaft. In one embodiment, the key **211** may be two tabs extending from or integral with the cylindrical adjustment element **203** that correspond and engage with the keyway **210**. In other embodiments, the shape or number of adjustment elements, key and keyways may be different but the key and keyway will correspond in number and shape with each other. As such, the adjustment element **203**, tab element **202**, and main body **200** of the hanger system **158** may be prevented from twisting relative to the fist **152**.

[0067] With reference to FIGS. **6**-**8**, a second embodiment of an anchor system **250** may be described. The anchor system **250** shown may be similar to the anchor system **150** described with respect to FIGS. **4**A-**5**B. That is, the anchor system **250** may include a curtainwall interface in the form of a bracket or fist **252** and may also include a structure interface in the form of a bracket, floor bracket, or plate **254**. Still further, the engagement system **256** may include a hanger system **258** with a fist engaging portion **296** having a main body **300**, a tab element **302** and an adjustment element **303** in addition to a floor bracket engaging portion or boom **298** in bearing relationship on the top edge of the upturned leg **286** of the floor bracket **254**. In contrast to the anchor system **150** described with respect to FIGS. **4**A-**5**B, the present anchor system **250** may include a shear force-type bracing system **260** and corresponding absorbing system **262** rather than a normal force-type bracing system **160** and absorbing system **162**. In further contrast to the bracing system **150**, the absorbing system **262** of the bracing system **260** may be positioned to isolate the bracing system **260** from the hanger system **258**.

[0068] Accordingly, the bracing system **260** shown may be partially integral with the hanger system **258** like the bracing system **160** of FIGS. **4**A-**5**B. That is, the bracing system **260** may extend from the hanger system **258** and thus rely on some lateral force transfer through the hanger system **258**. However, the damping device **312** may be positioned between the hanger system **258** and the bracing system **260** rather than between the bracing system **260** and the floor bracket **254**. Like the bracing system **160** previously described, the bracing system **260** may be configured to transfer and dissipate lateral acting loads between the curtainwall interface or fist **252** and the structure interface or floor bracket **254**.

[0069] The bracing system **260** shown may include a U-shaped hook **314** having an inboard vertical leg **316** and an outboard vertical leg **318** connected to one another by a distribution body **320**. It is noted that the boom **298** of the present embodiment may include a planar surface **307** arranged generally parallel to a lateral acting force direction. Other orientations of the planar surface **307** may be provided including oblique orientations. It is noted that while the planar surface **307** shown is oriented substantially vertically, the planar surface **307** can be horizontal or at some angle between vertical and horizontal. The distribution body **320** of the hook **314** may be positioned adjacent the boom **298** of the hanger system **258** and may include a planar surface **309** positioned in a plane adjacent to and parallel to the planar surface **307** of the boom **298**. The damping or planar surface **309** of the distribution body **320** may be separated from the planar surface **307** of the boom **298** defining a space therebetween. In this embodiment, the distribution body **320** and the boom **298** may function as distribution elements **308**. The vertical legs **316**, **318** of the hook portion **314** may fixedly extend from the distribution body **320**. That is, the vertical legs **316**, **318** may be secured to the distribution body **320** to prevent relative displacement and relative rotation therebetween, for example, by being part of the same plate. Each vertical leg **316**, **318** may be positioned adjacent a respective inboard or outboard face **288**, **290** of the upturned leg **286** of the floor bracket **254** and, as such, may be spaced from one another a distance substantially equal to the width of the bearing cap element **292**. Where a bearing cap element **292** is not provided, the spacing of the vertical legs **316**, **318** may be substantially equal to the thickness of the upturned leg **286** of the floor bracket **264**. Clearances for installation of the hook **314** may be provided to avoid an overly tight fit of the hook **314** over the upturned leg **286** of the floor bracket **254**. That is, the hook **314** is receivingly engaged with the bearing cap element **292** or the upturned leg **286** to allow for some movement (vertical, lateral) between these elements of the system as needed. As previously described, all or a portion of the engagement system **256** may be secured to the floor bracket **254** or it may be separate therefrom.

[0070] As with the previous embodiment described with regard to FIGS. **4**A-**5**B, the present absorbing system **262** may include a damping device **312** in the form of damping pads **312** as part of the bracing system **260**. The damping pads of the present embodiment may be shear force-type damping pads adapted to transfer and dissipate loading imparted parallel to the surface of the pads. In one embodiment, as shown in FIG. **6**, shear force-type damping pads may be provided in the space between the distribution body **320** of the hook **314** and the boom **298** of the hanger system **358**. The pads may be adhered to both the damping or planar surface **309** of the distribution body **320** and the corresponding (planar) surface **307** of the boom portion **298**. For example, an acrylic adhesive may be used. Other adhesives may include epoxy, polyurethane, or polyisocyanate. Still other adhesives may also be used. In this position, and in contrast to the embodiment of FIGS. **4**A-**5**B, the damping pads **312** may transfer and dissipate lateral acting loads through shearing deformation of the pad rather than compressive and tensile deformation.

[0071] The damping pads **312** and the corresponding planar surfaces **307**, **309** may be configured to distribute the lateral acting loads over a relatively large area. Accordingly, the planar surfaces **307**, **309** and damping pads **312** may have a surface area between approximately ¼ square inches and 9 square inches. In other embodiments, the area may be between approximately ½ square inches and 4 square inches. In still other embodiments, the area of the planar surface **307**, **309** may be approximately 1 ½ square inches. The pad or plurality of pads may have a thickness measured between the planar surfaces **307**, **309** between approximately 1/16 inch and approximately 1 inch. In other embodiments, the thickness may be between approximately ⅛ inch and approximately ½ inch. In still other embodiments, the thickness may be approximately 3/16 inch. Other sizes and thicknesses may also be used and may be selected to suitably damp loads imparted on the system.

[0072] Multiple layers of damping material may be provided and adhesives may be provided between the layers. The layers of damping material may all be the same material or several types of material may be provided in the several layers. Where multiple layers are used, the several damping pads may be adhered to one another with epoxy, polyurethane, or polyisocyanate adhesive. Other adhesives may also be used.

[0073] As with the embodiment of FIGS. **4**A-**5**B, the damping pads may include an elastomeric material of the types listed above. In this embodiment, however, the elastomeric material may include lead or other internal friction inducing materials. The internal friction inducing materials may assist in the ability of the damping pads to dissipate loading by generating heat through internal friction as the damping pad experiences shear deformation.

[0074] In some embodiments, as may be shown best in FIGS. **8**A-**8**D, multiple layer damping pads may include warp resisting layers **322**. The warp resisting layers **322** may be constructed of a relatively rigid material and may be configured to prevent warping of the adjacent layers under shear loading. The warp resisting layers **322** may include a steel, aluminum, alloy, or other metallic layer. Other warp resisting materials may include plastics or composites. Other warp resisting materials may also be provided. In some embodiments, an adhesive used between the layers may dry or cure into a relatively rigid material providing a warp resisting layer **322**.

[0075] In the embodiment shown in FIGS. **6**-**8**A, the damping pad **312** includes three damping layers separated by two warp resisting layers **322**. In other embodiments, as shown in FIG. **8**B, two damping layers separated by a single warp resisting layer **322** may be provided. In still other embodiments, as shown in FIG. **8**C, four damping layers separated by three warp resisting layers **322** may be provided. In still further embodiments, as shown in FIG. **8**D, five damping layers separated by four warp resisting layers **322** may be provided. Any number of damping layers may be provided including those listed or more or fewer damping layers. The several layers may be separated by warp resisting layers **322** or warp resisting layers may not be provided. In some embodiments, warp resisting layers **322** may be provided between every other or every third damping layer and not between each damping layer. Other damping layer spacings and orders may be provided.

[0076] With further reference to FIG. **6**, each of the hanger systems **258** is shown associated with a single bracing system **260**. That is, a single hook **314** is shown connected to the boom **298** of the hanger system **358** with a plurality of damping pads. As shown in FIG. **7**, multiple bracing systems **260** can be provided for each hanger system **258** thereby providing additional absorbing systems **262**. As shown, two bracing systems **260** can be provided where one system is connected with damping pads to each side of the boom **298** of the hanger system **258**. In other embodiments, additional bracing systems **260** may be provided by attaching additional hooks **314** to the hooks **314** shown with additional damping pads. Any number of hooks **314** and damping pad assemblies may be provided.

[0077] It is also noted that a combination of shear and normal type systems may be provided. For example, the bearing type system described with respect to FIGS. **4**A-**5**B may be used in conjunction with the shear type system described with respect to FIGS. **6**-**8**D. In addition, the normal type system may be used with the deformation type system to be described with respect to FIGS. **9**-**11**. Any combination of the systems may be used to add additional layers of damping. In other embodiments, as shown in FIG. **5**C, damping may be introduced between the fist **152**, **252**, **352**, and the mullion **104**, for example. In some embodiments, as also shown in FIG. **5**C, damping may be introduced between the structure interface, floor bracket or plate **154**, **254**, **354** and the floor slab **106**. A deformation type system as described with reference to FIGS. **9**-**11** may be used to reduce at least some of the sideways load transfer between curtainwall units through ductile failure of clips **213**, such as anti-buckling clips, used in the system, as shown in FIGS. **9**A-**9**B. For example, the clips **213**, such as anti-buckling clips **213**, are made of a ductile material or include a ductility feature or are connected to a component with a ductility feature to dissipate some of the sideways load on the system. One or more of the systems disclosed herein may also be used to reduce the vertical load transfer between curtainwall units through application of one of the described systems at the vertical mullion splice joints **215**. That is, and as shown in FIG. 9C, a damping device **212** such as a damping pad **212** or **312** is positioned between two vertical mullions **104** at the joint to dissipate some of the vertical load on the system (the second vertical mullion **104** is not shown in FIG. **9**C so that the damping pad **212** or **312** can be seen clearly). Still other combinations of the systems described may be provided.

[0078] With reference to FIGS. **9**-**11**, a third embodiment of an anchor system **350** is described. The anchor system **350** may be similar to the anchor systems **150**, **250** previously described. That is, and as shown in FIG. **10**A, the anchor system **350** may include a curtainwall interface in the form of a bracket or fist **352** and may also include a structure interface in the form of a bracket, floor bracket, or plate **354**. Still further, the hanger system **358** of the embodiment shown may include a main body **400**, a tab element **402**, and an adjustment element **403** in addition to a boom **398** in bearing relationship on the top edge of the upturned leg **386** of the floor bracket **354**. In addition, a vertical hook leg **406** may extend vertically from the boom **398** along the inboard face **388** of the upturned leg **386** of the floor bracket **354**. In contrast to the anchor system **150** described with respect to FIGS. **4**A-**5**B, the present anchor system **350** may include a bracing system **360** whose absorbing system is a material ductility-type absorbing system **362** rather than a normal force-type absorbing system **162**.

[0079] As best shown in FIG. **10**B, the main body **400** of the hanger system **358** may extend beyond the bottom edge of the fist **352** and may extend substantially further above the upper edge of the upturned leg **386** of the floor bracket **354** when compared to the main body portion **200** of FIGS. **4**A-**5**B. For example, the main body **400** may extend approximately ½ inch to approximately 4 inches beyond the bottom of the fist **352** and the top edge of the main body **400** may be positioned between approximately ½ inch and 4 inches above the top edge of the upturned leg **386** of the floor bracket **354**. As a result of the higher upper edge of the main body **400**, the boom **398** of the hanger system **358** that extends across the top edge of the upturned leg **386** of the floor bracket **354** may be substantially deeper than that shown in FIGS. **4**A-**5**B. For example, the depth of the boom **398** may also be between ½ inch and 4 inches corresponding to the distance that the upper edge of the main body **400** extends above the top edge of the upturned leg **386**.

[0080] The bracing system **360** shown, may be partially integral with the hanger system **358** like the bracing system **160** of FIGS. **4**A-**5**B. That is, the bracing system **360** may extend from the hanger system **358**. For example, the vertically extending hook leg **406** extends from the boom **398**. As a result of extending from the hanger system **358**, the bracing system **360** may rely on some lateral force transfer through the hanger system **358**. In contrast to previously described embodiments, the absorbing system of bracing system **360** may be built into the main body portion **400** and the vertical hook leg **406**.

[0081] As shown, in FIGS. **10**A and **10**B, the bracing system **360** may be provided by the positioning of the main body **400** and the vertical hook leg **406** against opposite sides of the cap bearing element **392** extending along the top edge of the upturned leg **386** of the floor bracket **354**. That is, unlike FIGS. **4**A-**5**B, where particular distribution elements **208** were provided, the current embodiment may rely on the edges of the main body **400** and vertical hook leg **406** bearing against either side of the cap bearing element **392**. In some embodiments, as shown, damping material or spacing material, like damping system **212**, for example, may be positioned in the leg cavity **407** below the cap bearing element **392** to fill the space between the edge of the main body **400** and the edge of the hook leg **406** and the inboard and outboard faces **388**, **390** of the upturned leg **386** of the floor bracket **364**.

[0082] The absorbing system **362** of the bracing system **360** of this embodiment may be provided by material ductility. That is, the hanger system **358** and bracing system **360** may be constructed of a ductile material such as steel, steel alloy, or other substantially ductile material. Other ductile materials may also be used. In this embodiment, the damping device **412** of the absorbing system may be in the form of a ductility feature which may help to make the main body **400** and hook leg **406** prone to ductile failure. The ductility features may be any notch, perforation, break line, or other shaped feature that may lessen the cross-sectional area available to resist the lateral acting loads. As shown best in FIG. **11**, ductility features in the form of perforation patterns may be used to cause the main body **400** and hook leg **406** to be prone to ductile failure. Under a given lateral acting load, the ductile features may deform beyond the elastic limit of the material. That is, the deformation may cause the material to begin plastic deformation causing the deformation to dissipate the load rather than return the load to the system. In some embodiments, the components subject to ductile failure are replaceable. That is, the main body **400** and hook leg **406** may be replaceable within the system.

[0083] With particular reference to FIG. **11**A, the ductility features may include a plurality of slot-shaped perforations **424** arranged in a chevron pattern. Each leg **426** of the chevron pattern may include one or more slot-shaped perforations **424** separated by ductile partitions **428**. In the embodiment shown, three slot-shaped perforations **424** are provided. Other quantities of slots **424** can be provided. A circular perforation **430** may be positioned in the gap between the legs **426** of the chevron and may function to disperse loading directed therethrough so as to direct the loading through and generally across each leg **426** of the chevron.

[0084] With reference again to FIG. **10**, where an inward directed lateral acting load is imparted on the curtainwall **100**, the force may be transmitted through the fist **352** into the main body **400** of the hanger system **358** causing the edge of the main body **400** to bear against the outboard surface **390** of the leg **386** of the floor bracket **354**. The fixed position of the floor bracket **354** may create an equal and opposite force on the main body **400**. This equal and opposite force may spread through the chevron shaped ductility feature causing the failure of the edge of the main body **400** followed by successive failures of the partitions **428** between the slot-shaped perforations **424**. Each failure may dissipate some load and the successive failure may dissipate accumulating amounts of load. It is noted that an outwardly directed force imparted on the curtainwall **100** may be resisted and dissipated in a similar manner by the circle **430** and chevron ductility feature arranged on the hook leg **406** on the inboard side of the bracket leg **406**. In this case, a tensile force may be transmitted from the curtainwall mullion **104**, into the fist **352**, into the main body **400**, and through the boom **398** to the hook leg **406**. The tensile force may cause the edge of the hook leg **406** to bear against the inboard surface **388** of the upturned leg **386** of the floor bracket **354** activating the ductility feature and dissipating the load.

[0085] With reference to FIGS. **11**B and **11**C, a series of vertically extending slot-shaped perforations **424** are provided. The slot-shaped perforations **424** may be positioned adjacent to one another separated by ductile partitions **428**. In these embodiments, like the circle and chevron ductility feature, a load imparted normal to the edge of the main body **400** or the hook leg **406** may cause a single ductility failure or a succession of ductility failures thereby transmitting a portion of the load to the floor bracket **354** and dissipating a portion of the load. As shown in FIG. **11**B, a series of four slot-shaped perforations **424** may be provided. In FIG. **11**C, two slot-shaped perforations **424** are provided. Any number of slots **424** may be provided including 1 slot, 3 slots, 5 slots, or another number of slots.

[0086] Other ductility features may include a plurality of circular perforations arranged in a grid or arranged in a staggered or nested grid. In still other embodiments, combinations of slots and circular perforations may be provided. In still other embodiments, triangular, rectangular, square, diamond, or other shaped perforations may be provided. In other embodiments, the ductility features may be positioned to allow the main body **400** or vertical hook leg **406** to bend relative to the boom **398**.

[0087] While the absorbing system of the present disclosure has been described in detail with respect to at least three anchor embodiments, modifications or changes may be made and remain within the scope of the invention. For example, the location of the absorbing system may be modified. That is, for example, in the embodiment shown, the damping pads are positioned between the structure interface and the curtainwall interface. That is, when considering the path of the load from the curtainwall **100** to the structure **102**, the load passes through the curtainwall interface, then the damping pads, and then into the structure interface. In other embodiments, the damping pads may be located, for example between the curtainwall interface and the curtainwall. For example shear force-type and/or normal force-type bracing systems may include placing damping pads between the fist and the mullion. In other embodiments, the damping pads may be located, for example between the structure interface and the structure. For example, shear force-type and/or normal force-type bracing systems may include damping pads between the floor bracket and the floor or associated embed. In still other embodiments, the damping pads or ductility type devices may be positioned between the mullion and the structure apart from the anchor system. In this embodiment, the anchor system may be provided with some lateral play or freedom to move thereby isolating the anchor system from the lateral acting load path and allowing lateral acting forces to resisted by the absorbing system located along a load path not traveling through the anchor system. In still other embodiments, the absorbing system may be positioned at any location along the load path.

[0088] As another example of a modification within the scope of the invention, the curtainwall interface and the structure interface may be one in the same. That is, the curtainwall interface and structure interface may be one integral component, such as a steel angle or other bracket, that engages both the curtainwall and the structure. In these embodiments, the damping element may be provided internally, similar to FIGS. **6-8**D or FIGS. **9-11**, or on either boundary of the component.

[0089] As another example of a modification within the scope of the invention, combinations of the embodiments shown may be provided. In one embodiment, combinations of normal force-type and shear force-type systems can be used. For example, the ductility features of the embodiment shown in FIGS. **9-11** may be added to the embodiment shown in FIGS. **4**A-**5**B.

[0090] As another example of a modification within the scope of the invention, additional damping resistance or features may be added through duplication or otherwise. For example, in the embodiment shown in FIGS. **4**A-**5**B, a fist is shown secured to each side of the mullion. A hanger system and bracing system extends from each fist and receives the upturned leg of the floor bracket. In other embodiments, a single fist may be provided with a single hanger system and bracing system. In still other embodiments, multiple floor brackets may be provided. For example, one floor bracket may be provided at or near the top surface of the floor and another may be provided at or near the bottom surface of the floor. In these embodiments, four engagement systems may be provided. Floor brackets or other structural interfaces may be provided throughout the thickness of the floor and any number of engagement systems can be used.

[0091] As another example of a modification within the scope of the invention, the damping device may be constructed of alternative materials. For example, in one embodiment, the damping device is made of a "crushable" material such as sand, stone, plaster board. cement board or other appropriate material that could absorb a blast. A device made of such crushable material may be constructed as a replaceable insert for the system.

[0092] The embodiments disclosed, or variations or modifications thereof can be advantageous for several reasons. Particularly, damping, in lieu of, or in addition to strengthening, reduces the affect of the forces on the curtainwall and the building. As such, costs associated with reinforcing the curtainwall can be reduced while the safety of the structure can be maintained. To better explain this advantage, two exemplary models may be described.

[0093] Referring to FIGS. **12-15**, a comparative model analysis of two curtainwall systems with differing support stiffnesses is shown. In one curtainwall system, the support stiffness is assumed to be rigid or approximately 500 kips/inch. This system reflects an anchor system similar to that which has been described above, but without any damping pads, ductility features, or other damping devices, systems, or elements. In the other curtainwall system, the support stiffness is assumed to be flexible or approximately 10 kips/inch. This system reflects an anchor system as described above. Both of the curtainwall systems were then assumed to otherwise be the same. That is, the following assumptions were made:

[0094] Span=12'6"

[0095] Unit Width=5'0"

[0096] Impulse Pressure=6.5 psi

[0097] Impulse Duration=14 milliseconds

[0098] Allowable Ductility Factor=3

[0099] Allowable Rotation=3°

[0100] Section Profile=Rectangular H10"×W3"×T1/4"

[0101] Material=Aluminum 6061-T6 fy=35 ksi, fu=58 ksi

[0102] Wind Load=50 psf dmax=span/175

[0103] Based on these assumptions remaining constant between each of the curtainwall systems and only the support stiffnesses differing, the two systems were compared. As shown in FIG. **12**, the magnitude of the displacement of the mullion exceeds 1 inch in the rigid support condition as compared to approximately ½ inch for the flexible support condition. Moreover, the dissipation of the rigid support condition is minimal as evidenced by the magnitude of the displacement of the mullion reducing to approximately ½ inch and remaining there for an extended period of time. Comparatively, in the flexible support condition, the magnitude is reduced much quicker from ½ inch to approximately 0 in a period of 0.15 seconds. Accordingly, the initial deflection of mullion with a flexible support is less than approximately 50% of the deflection of a mullion with a rigid support thereby significantly reducing the effect of a blast force on the curtainwall unit and the building structure. In addition, once the blast occurs, the vibration of the system is dissipated much faster with the flexible support system thereby reducing damage due to lingering or ongoing vibration.

[0104] Similarly as shown in FIG. **13**, the mullion with the rigid support approaches a bending stress of 60 ksi, while the mullion with the flexible support sees a bending stress of approximately 30 ksi. Moreover, like the displacement diagram, the bending stress due to lingering vibration reduces to 0 ksi much faster in the flexible support condition than in the rigid support condition. Hysteresis diagrams in FIGS. **14** and **15** show the oscillating relationship between stress and strain of the mullions. As can be seen, FIG. **14** shows the hysteresis behavior of a rigidly supported mullion and FIG. **15** shows the hysteresis behavior of a flexibly supported mullion. The results shown in FIGS. **14** and **15** reflect similar results as those shown in FIGS. **12** and **13**. That is, the flexibly supported mullion experiences less stress and less strain and the effects of the blast are dissipated much faster.

[0105] Referring to FIGS. **16** and **17**, a comparative model analysis of two curtainwall systems with differing mullions is shown. In one curtainwall system, the curtainwall mullion depth is assumed to 7 inches and in the other system, the mullion depth is assumed to be 10 inches. Otherwise, both of the curtainwall systems were assumed to be the same. The following assumptions were made for each system:

[0106] Span=12'6"

[0107] Unit Width=5'0"

[0108] Impulse Pressure=6.5 psi

[0109] Impulse Duration=14 milliseconds

[0110] Allowable Ductility Factor=3

[0111] Allowable Rotation=3°

[0112] Section Profile=Rectangular H10"×W3"×T1/4"

[0113] Rectangular H7"×W3"×T1/4"

[0114] Material=Aluminum 6061-T6 fy=35 ksi, fu=58 ksi

[0115] Wind Load=50 psf dmax=span/175

[0116] Support Stiffness=10 kips/inch for flexible support.

[0117] As shown in FIGS. **16** and **17**, the displacement of the 7" mullion approached approximately 2 inches, while the displacement of the 10" mullion approached ½ inch. The stress in the 7" mullion exceeded 45 ksi, while the stress in the 10" mullion was approximately 30 ksi. Accordingly, depending on tolerances of a given structure and the strength of materials available, an optimum section profile may be a 10" deep mullion.

[0118] One having ordinary skill in the art should appreciate that there are numerous types, shapes, and sizes of cladding for which there can be a need or desire to damp blast loads according to an exemplary embodiment of the present invention. Additionally, one having ordinary skill in the art will appreciate that although the preferred embodiments illustrated herein reflect a generally flat and rectangular damping pad and generally slotted ductility features, these elements can have a variety of shapes and sizes.

[0119] All directional references (e.g., proximal, distal, upper, lower, upward, downward, left, right, lateral, front, back, top, bottom, above, below, vertical, horizontal, outboard, inboard, outer, inner, clockwise, and counterclockwise) are only used for identification purposes to aid the reader's understanding of the present invention, and do not create limitations, particularly as to the position, orientation, or use of the invention. Connection references (e.g., attached, coupled, connected, and joined) are to be construed broadly and may include intermediate members between a collection of elements and relative movement between elements unless otherwise indicated. As such, connection references do not necessarily infer that two elements are directly connected and in fixed relation to each other. The exemplary drawings are for purposes of illustration only and the dimensions, positions, order and relative sizes reflected in the drawings attached hereto may vary.

[0120] In addition, the term "about" or "approximately" should generally be understood to refer to both the corresponding number and a range of numbers. In addition, all numerical ranges herein should be understood to include each whole integer or fraction thereof within the range. The above specification, examples and data provide a complete description of the structure and use of exemplary embodiments of the invention as claimed below. Although various embodiments of the invention as claimed have been described above with a certain degree of particularity, or with reference to one or more individual embodiments, those skilled in the art could make numerous alterations to the disclosed embodiments without departing from the spirit or scope of this invention. Other embodiments are therefore contemplated. It is intended that all matter contained in the above description and shown in the accompanying drawings shall be interpreted as illustrative only of particular embodiments and not limiting. Changes in detail or structure may be made without departing from the basic elements of the invention as defined in the following claims.

What is claimed is:

1. A blast resistant cladding, comprising:

a curtainwall coupled to a structure by an anchor system and defining a load path for transferring loads imparted on the curtainwall to the structure; and

an absorbing system positioned along the load path to absorb blast-type loads imparted on the curtainwall.

2. The cladding of claim **1** wherein the absorbing system comprises a normal force-type device to absorb and damp the forces through compression and tension.

3. The cladding of claim **2**, wherein the absorbing system comprises a damping pad positioned between a pair of distribution elements, the distribution elements including damping surfaces and each surface of the distribution element coupled to a corresponding surface of the anchor system.

4. The cladding of claim **3**, wherein the damping surfaces of the distribution elements are planar and the corresponding surface of the anchor system is planar.

5. The cladding of claim **1**, wherein the absorbing system comprises a shear force-type device to absorb and damp the forces through shear deformation.

6. The cladding of claim **5**, wherein the absorbing system comprises a damping pad positioned between a pair of distribution elements, the distribution elements including damping surfaces and each damping surface of the distribution element coupled to a corresponding surface of the anchor system.

7. The cladding of claim **6**, wherein the damping surfaces of the distribution elements are planar and the corresponding surface of the anchor system is planar.

8. The cladding of claim **6**, wherein the damping pad includes a plurality of damping layers, each layer separated by warp resisting elements.

9. The cladding of claim **1**, wherein the absorbing system comprises a ductility feature to dissipate forces through ductile deformation.

10. The cladding of claim **9**, wherein the ductility feature comprises a perforation positioned near an edge of the absorbing system to allow the edge to fail in a ductile manner under loading.

11. A system for supporting exterior cladding on a structure and resisting blast forces imparted thereon, the system comprising:

a cladding interface for fixedly engaging the cladding;

a structure interface for fixedly engaging the structure; and

an engagement system positioned between the cladding interface and structure interface, comprising:

a hanger system for vertically supporting the cladding; and

a bracing system for laterally supporting the cladding, the bracing system having an absorbing system for absorbing the blast forces.

12. The system of claim **11**, wherein the absorbing system comprises a damping pad positioned between two opposing distribution elements, the distribution elements including damping surfaces and each damping surface of the distribution element coupled to a corresponding surface of the bracing system.

13. The system of claim **12** wherein the surfaces of the distribution elements are planar and the surface of the bracing system is planar.

14. The system of claim **12**, wherein each damping surface of the distribution element is in a plane generally adjacent to and parallel to a plane defined by a corresponding surface of the bracing system.

15. The system of claim **12**, wherein the bracing system is a shear force-type system.

16. The system of claim **15**, wherein the damping pad is oriented generally orthogonally to an exterior surface of the cladding.

17. The system of claim **16**, wherein the damping pad comprises two damping layers positioned between the distribution elements with a warp resisting element positioned between the two damping layers.

18. The system of claim **16**, wherein the damping pad comprises three damping layers with two warp resistant elements positioned therebetween.

19. The system of claim **11**, wherein the bracing system is a normal force-type system.

20. The system of claim **19**, wherein the damping pad is oriented generally parallel to an exterior surface of the cladding.

21. The system of claim **11**, wherein the absorbing system is a ductile failure-type system.

22. The system of claim **21**, wherein the absorbing system comprises a ductility feature.

23. The system of claim **22**, wherein the ductility feature includes a plurality of slots separated by ductile partitions and the slots fail in a ductile manner.

24. The system of claim **23**, wherein the plurality of slots are arranged in a chevron pattern, the chevron pattern comprising two legs.

25. The system of claim **24**, wherein the ductility feature includes a circular perforation arranged in the gap between the legs of the chevron pattern.

26. The system of claim **23**, wherein the plurality of slots are arranged adjacent to one another.

27. The system of claim **22**, wherein the ductility feature includes at least one circular perforation.

28. A blast resistant cladding, comprising:

a curtainwall arranged on a structure and defining a load path for transferring blast-type loads imparted on the curtainwall to the structure; and

a means for absorbing blast-type loads imparted on the curtainwall.

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