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Alberson et al.

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(54) **METHODS FOR THE MANUFACTURE OF A MODULE FOR USE IN A CRASH BARRIER AND ASSEMBLY OF THE CRASH BARRIER**

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(51) **Int. Cl.**

E01F 15/00	(2006.01)
E01F 15/08	(2006.01)
E01F 15/04	(2006.01)

(52) **U.S. Cl.**

CPC ***E01F 15/083*** (2013.01); ***E01F 15/0484*** (2013.01); ***E01F 15/08*** (2013.01);

(Continued)

(58) **Field of Classification Search**

CPC E01F 15/0484; E01F 15/08; E01F 15/083; E01F 15/085; E01F 15/086; E01F 15/088

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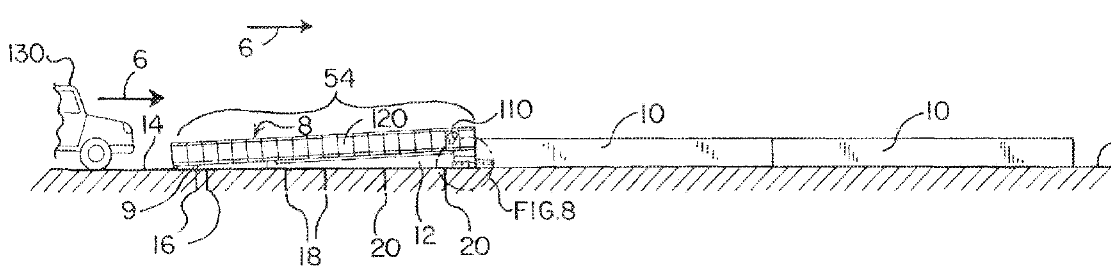
(57) **ABSTRACT**

A method of manufacturing a module suitable for use in a crash barrier includes adhering first and second cellular foam blocks to opposite sides of a diaphragm and wrapping a wrap layer around a periphery of the first and second cellular foam blocks. In one embodiment, the wrap layer is configured as a metal cover member. Methods of assembling a crash barrier include one or more of positioning a plurality of modules end to end, supporting the modules with a base, covering a junction between adjacent modules with a connector, and/or coupling a mounting portion to the base.

22 Claims, 7 Drawing Sheets



Related U.S. Application Data

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(52) **U.S. Cl.**
CPC ***E01F 15/085*** (2013.01); ***E01F 15/086*** (2013.01); ***E01F 15/088*** (2013.01)

(58) **Field of Classification Search**
USPC 404/6, 72
See application file for complete search history.

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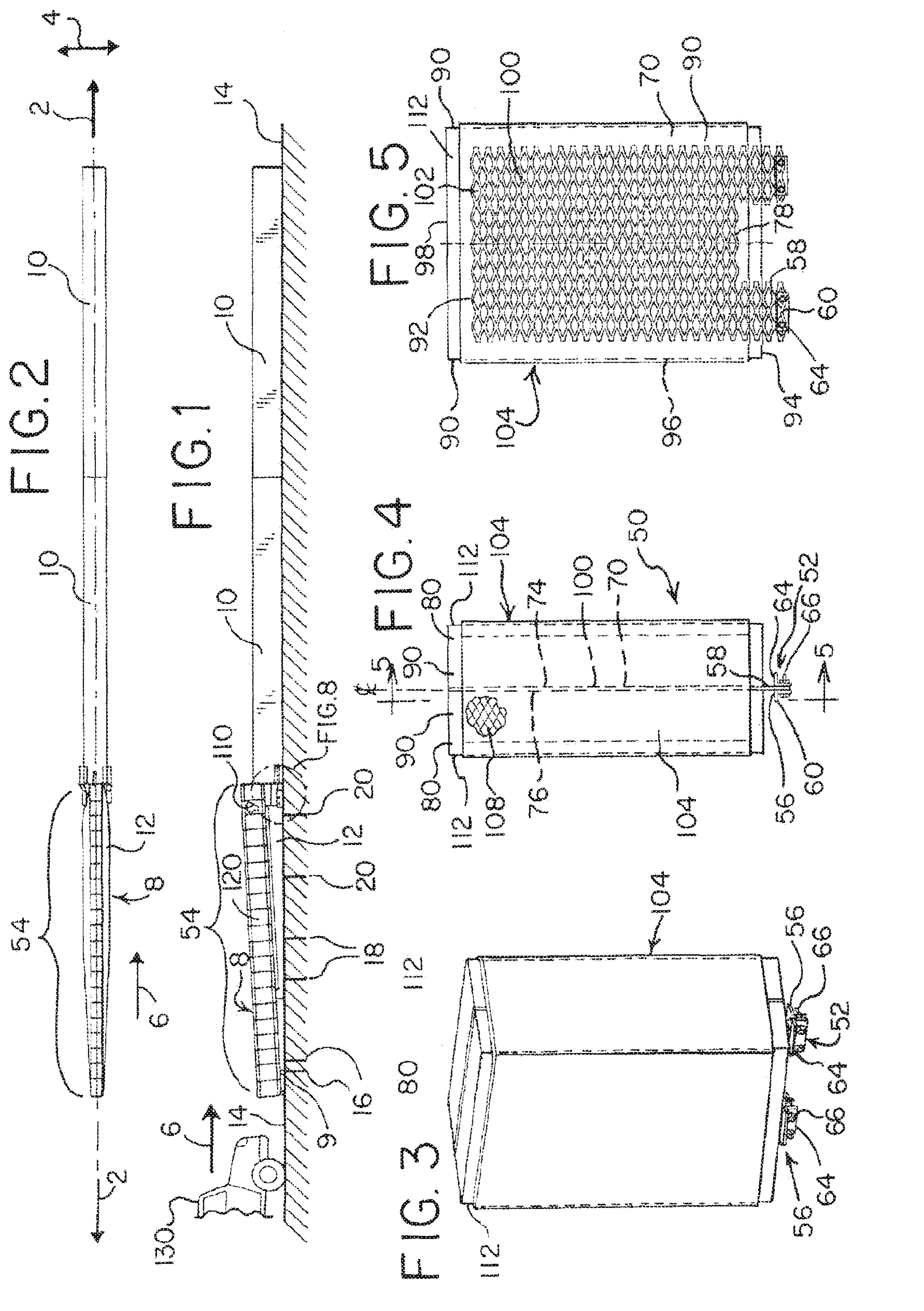
FIG. 1
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FIG. 6

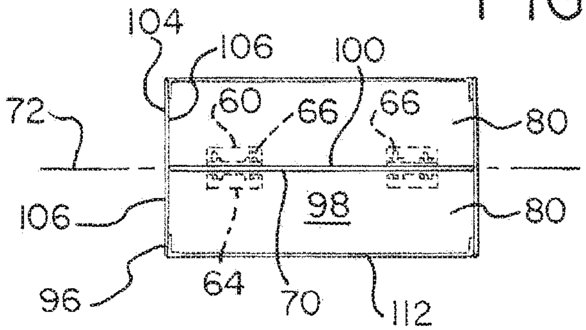


FIG. 7

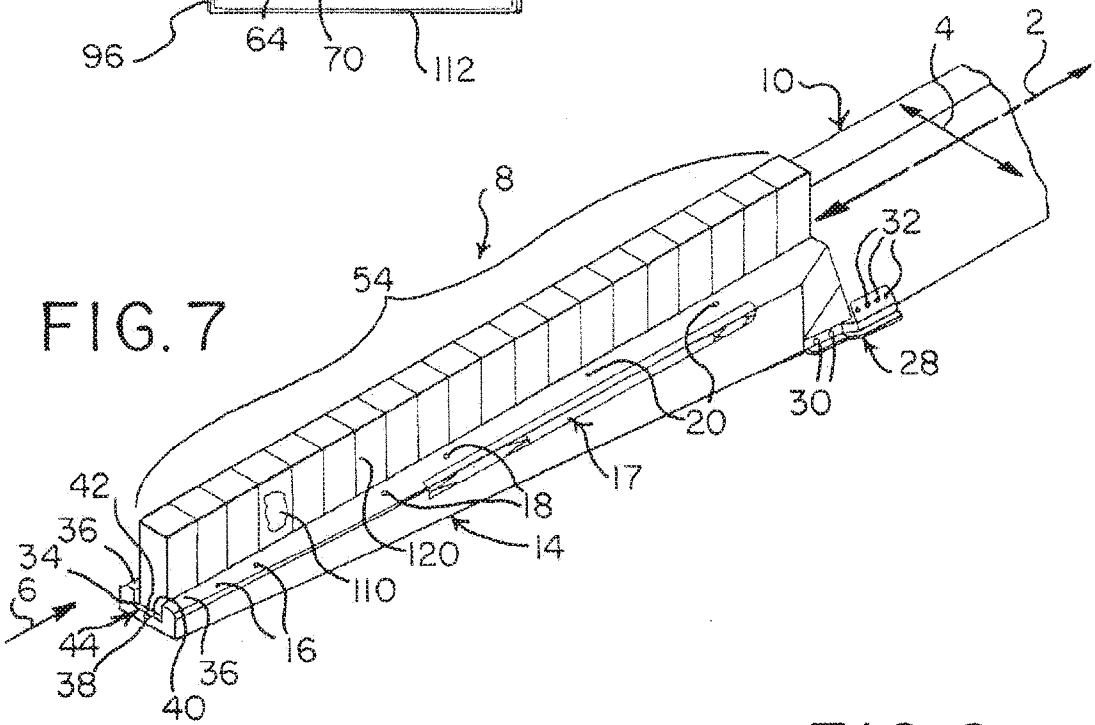


FIG. 8

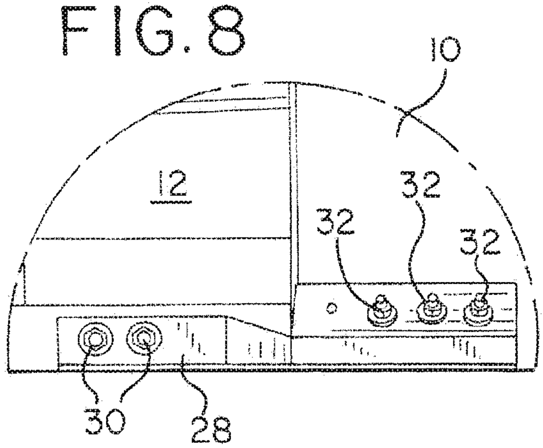
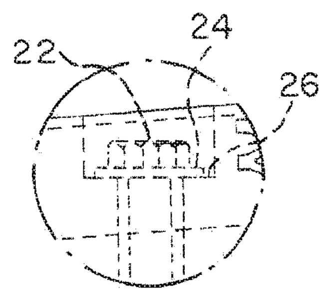


FIG. 9



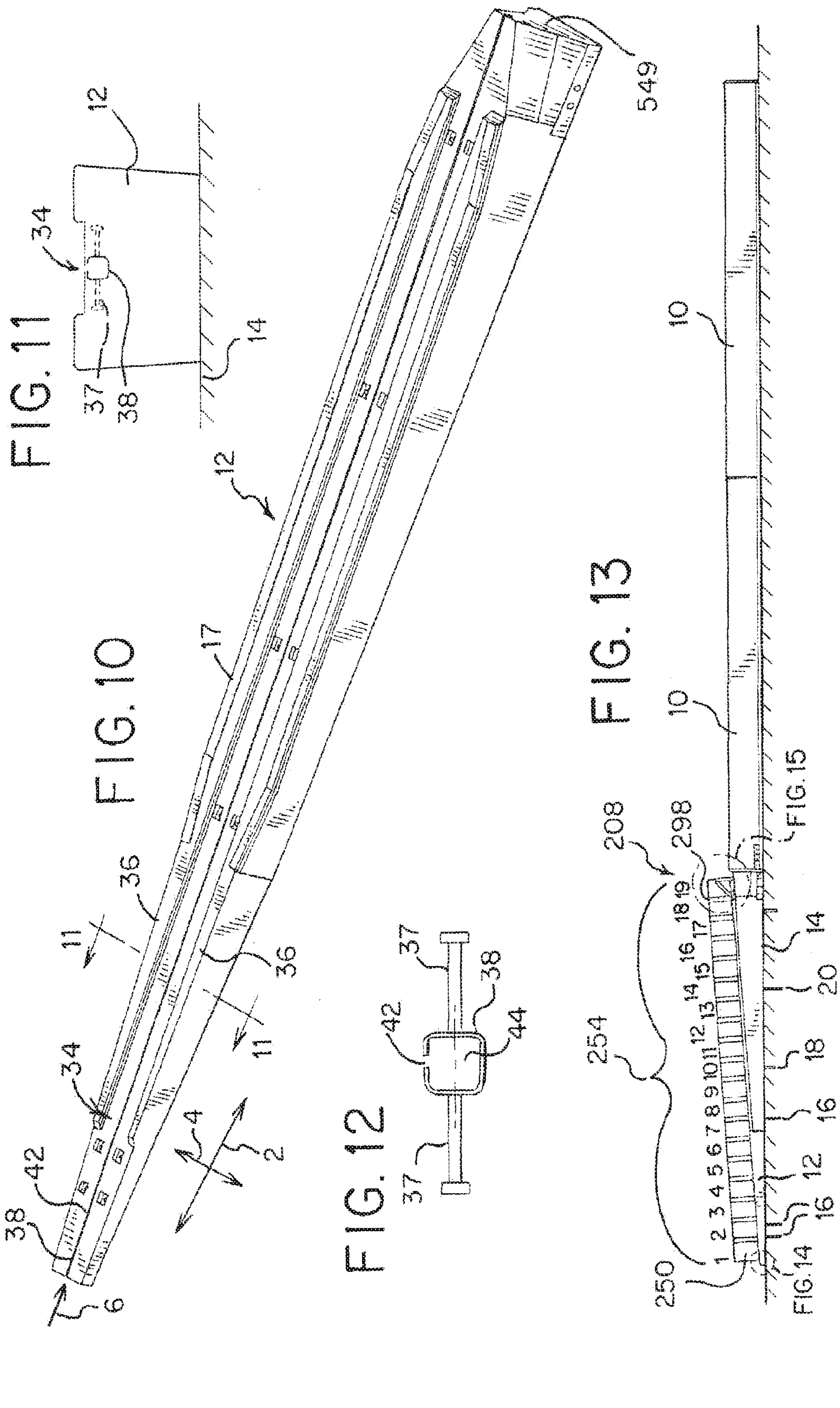


FIG. 11
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FIG.14

FIG. 14

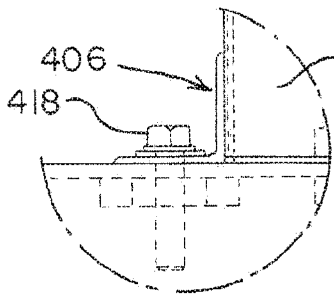


FIG. 16

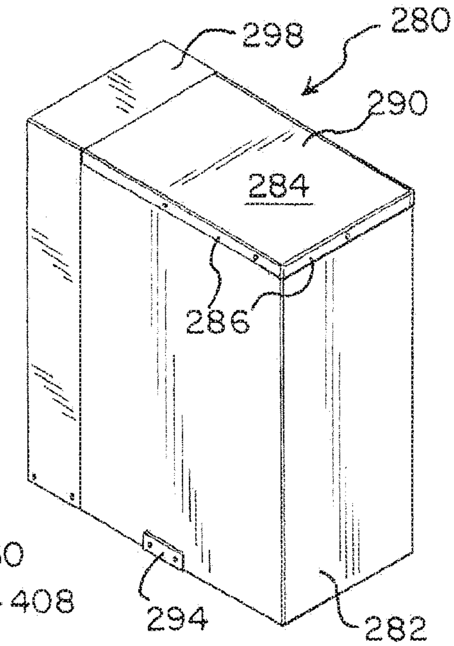
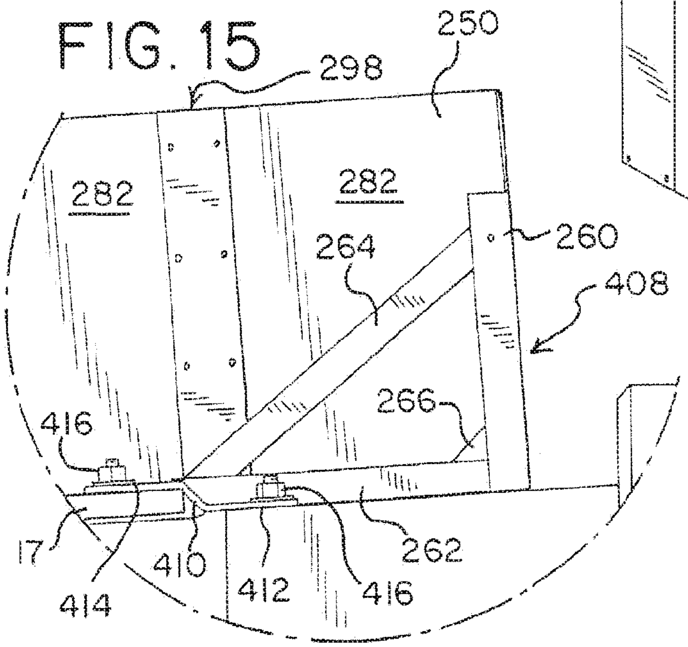
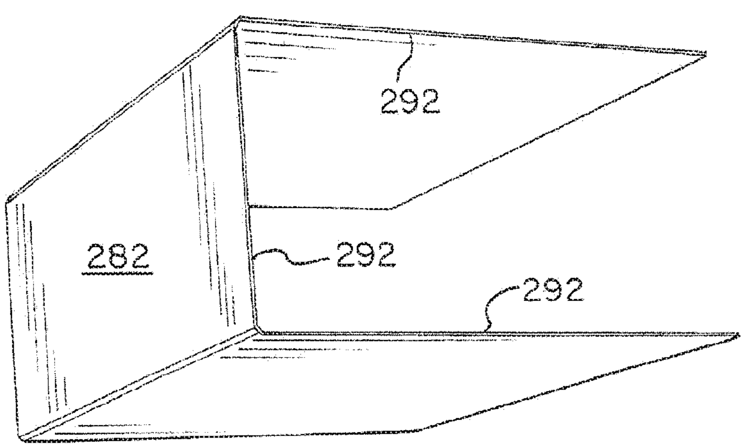


FIG. 15





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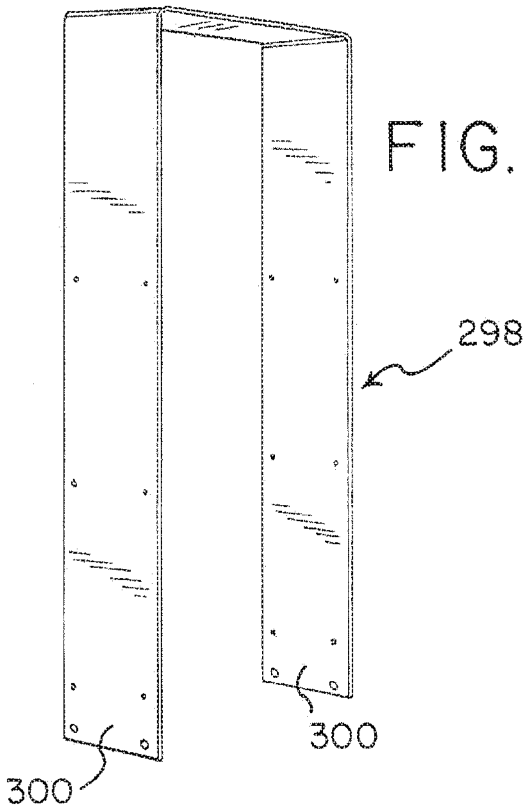


FIG. 19

FIG. 18

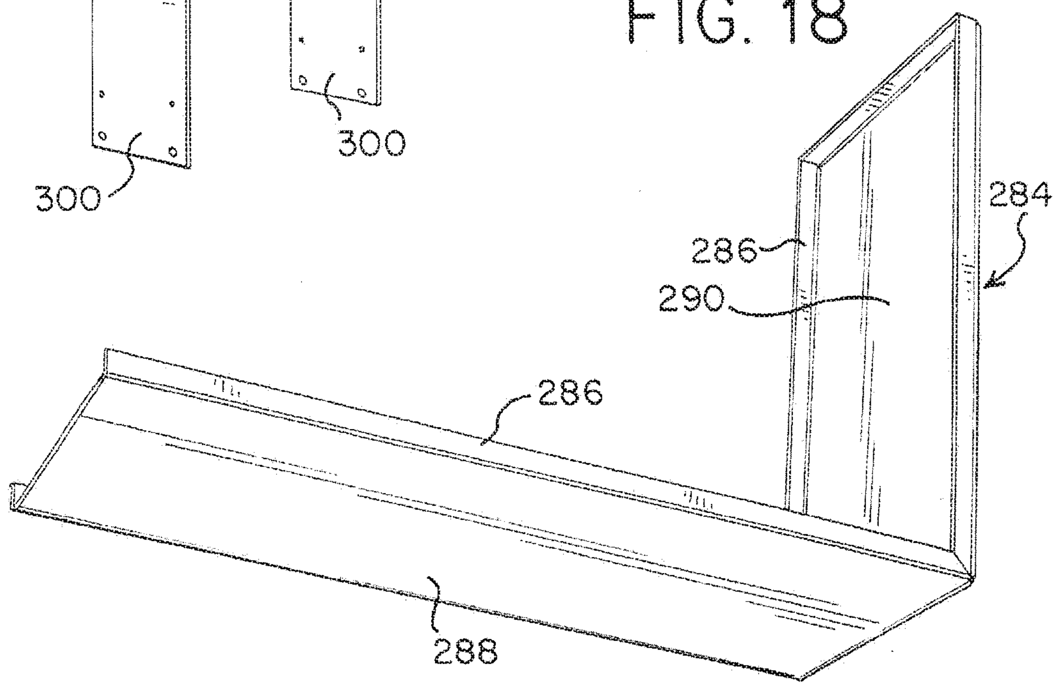
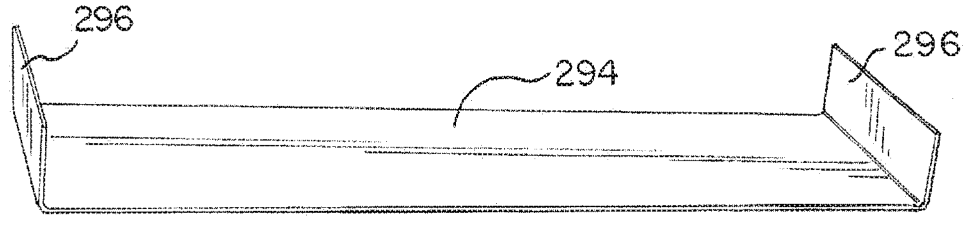


FIG. 20



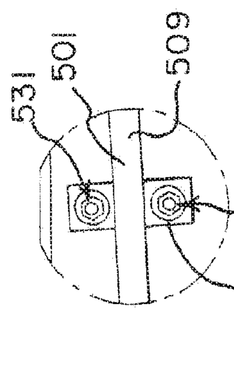


FIG. 23

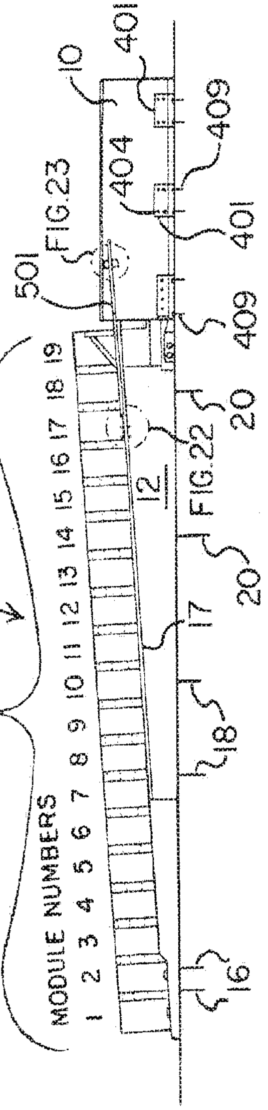
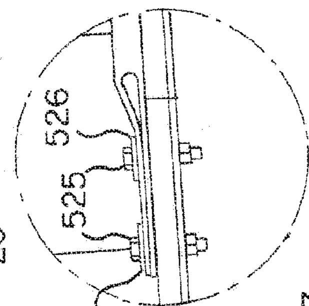


FIG. 21



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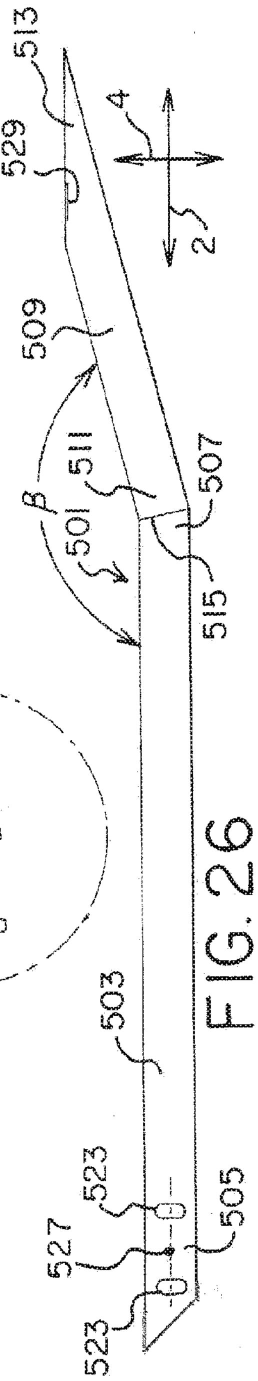

FIG. 26

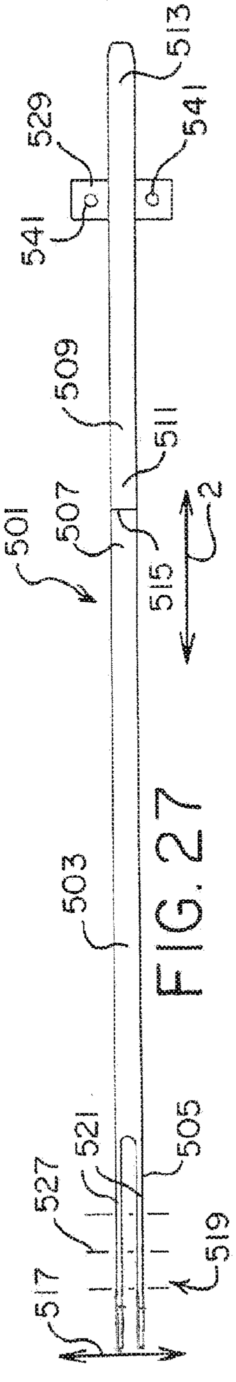

FIG. 27

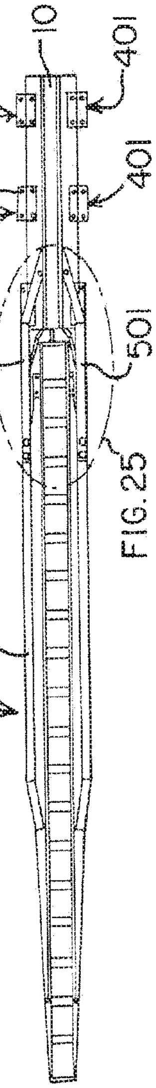

FIG. 24

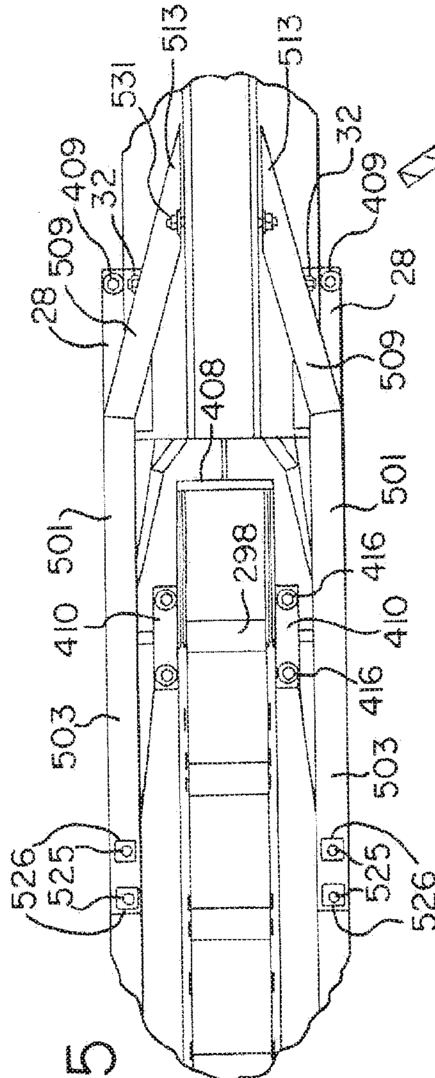

FIG. 25

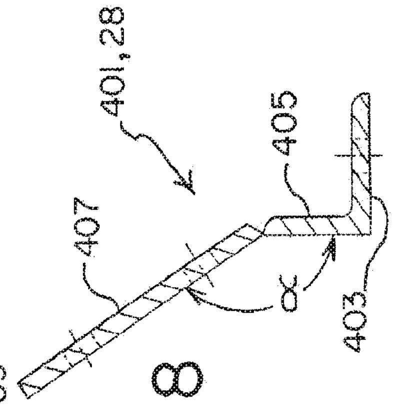

FIG. 28

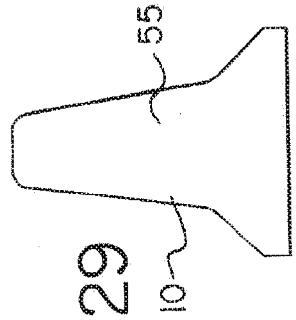

FIG. 29

METHODS FOR THE MANUFACTURE OF A MODULE FOR USE IN A CRASH BARRIER AND ASSEMBLY OF THE CRASH BARRIER

This application is a continuation of U.S. application Ser. No. 14/814,589, filed Jul. 31, 2015, which claims the benefit of U.S. Provisional Application No. 62/042,034, filed Aug. 26, 2014, the entire disclosures of which are hereby incorporated herein by reference.

TECHNICAL FIELD

The present application relates generally to a crash barrier module incorporating a cellular foam material, and to a crash barrier, transition rail and various methods for the manufacture and use thereof.

BACKGROUND

Concrete barrier walls are commonly used to redirect errant vehicles back onto a roadway. The terminal ends of such barrier walls, together with other hazards, such as trees, signs, culverts and bridge piers, may present a peril to oncoming traffic if left exposed. Accordingly, various crash barriers have been developed and used along highways to protect errant motorists from these types of hazards. Typically, such crash barriers are positioned in front of, or at the end of, the barrier wall or other hazard.

In one system, lightweight cellular concrete crash barriers have been developed for use with concrete barrier walls. Such end treatments, however, may be susceptible to water degradation due to their "open-cell" nature. Other systems have incorporated fiberglass and/or foamed polyurethane cartridges, which may be relatively expensive to manufacture and/or susceptible to ultraviolet radiation and water absorption. Moreover, many crash cushion systems using energy absorbing cartridges incorporate relatively complex and expensive containment systems, including for example collapsible frames, often made of metal. As such, the need remains for a low cost, weather resistant crash barrier, which is easy to manufacture, install and maintain.

SUMMARY

Briefly stated, in one aspect, one embodiment of a module suitable for use in a crash barrier has a diaphragm with opposite first and second sides. First and second cellular foam blocks are coupled to the first and second sides of the diaphragm respectively. In one embodiment, the cellular foam blocks are made of cellular glass foam. A wrap layer surrounds a periphery of the first and second cellular foam blocks. In one embodiment, a sealant layer may be applied to the wrap layer. In another embodiment, a coating may be applied over the sealant layer.

In another aspect, one embodiment of a crash barrier includes a module made at least in part of a cellular foam material. The module may have a bottom supported on a surface of a base. In one embodiment, the modules includes a diaphragm having a mounting portion extending downwardly from a bottom surface of first and second cellular foam blocks. The mounting portion may include a guide member, which is received in a longitudinal track formed in the base.

In another embodiment, the crash barrier includes first and second cellular foam blocks defining front and rear ends and opposite sides of the module. The wrap layer is configured as a cover member covering a top, the front and rear ends and the opposite sides of the module. In one embodiment, the cover member may be made of metal, for example and without limitation Aluminum, or other suitable materials such as fiberglass or plastic.

In one embodiment, the crash barrier may include a plurality of modules positioned end-to-end in a longitudinal array.

In another aspect, a method of manufacturing a module for use in a crash barrier includes adhering first and second cellular foam blocks to opposite sides of a diaphragm and wrapping a wrap layer around a periphery of the first and second cellular foam blocks. In one embodiment, the method may include applying a sealant layer to the wrap layer. In other embodiments, a coating may be applied over the sealant layer. In other embodiments, the wrap layer is configured as a cover member. In one embodiment, the method also includes securing adjacent modules with a connector.

In another aspect, a transition rail for a crash barrier includes a first elongated portion having a first end and a second end, with the first portion extending in a longitudinal direction. A second elongated portion also includes a first end and a second end, with the first end of the second portion being connected to the second end of the first portion. The second portion forms an obtuse angle relative to the first portion when viewed from a first direction orthogonal to the longitudinal direction. The first end of the first portion includes a first connector operable to permit movement of the first and second portions in a lateral direction. The second end of the second portion includes a second connector operable to limit lateral movement of the second end.

In yet another aspect, a crash barrier system includes a first crash barrier having spaced apart ends and a first cross-sectional profile, and a second crash barrier having spaced apart ends and a second cross-sectional profile. The second cross-sectional profile is different than the first cross-sectional profile. A transition rail has a first end connected to the first crash barrier with a first fastener extending in a first direction, and a second end connected to the second crash barrier with a second fastener extending in a second direction transverse to the first direction.

In another aspect, a method of assembling a crash barrier system includes orienting a first crash barrier along a longitudinal direction, positioning a second crash barrier adjacent to the first crash barrier and orienting the second crash barrier along the longitudinal direction. The first and second crash barriers have different cross-sectional profiles. The method further includes securing a first end of a transition rail to the first crash barrier with a connector, moving the transition rail about the connector until a second end of the transition rail abuts the second crash barrier, and securing the second end of the transition rail to the second crash barrier.

The various aspects and embodiments provide significant advantages over other modules, crash barriers and methods of manufacture and use. For example and without limitation, the cellular foam blocks are closed cell, meaning they are less susceptible to water penetration and degradation. Moreover, the modules are lightweight and portable, and relatively inexpensive to manufacture. The modules may be easily constructed with a mounting portion, making them adaptable to various support systems. The wrap and sealant layers, e.g. cover member, maximize the containment of the cellular foam material and ensure maximum performance.

The transition rail also provides significant advantages. The rail increases the height of the barrier, e.g. the base, so as to prevent a vehicle from riding up onto the adjacent

barrier. Conversely, the rail eliminates a snag point that may otherwise occur during a reverse direction impact where one of the barriers has a different profile than the other. In addition, the rails are symmetrical, meaning they can be secured on either side of the barriers and system. The configuration of the rails, and the connectors, also allows for lateral movement to accommodate varying width barriers.

The present embodiments, together with further advantages, will be best understood by reference to the following detailed description taken in conjunction with the accompanying drawings. Nothing in this section should be taken as defining or limiting the scope of the claims, or any term used therein, which claims are solely intended to define the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side view of one embodiment of a crash barrier positioned in front of a concrete barrier wall.

FIG. **2** is a top view of the crash barrier shown in FIG. **1**.

FIG. **3** is perspective view of a module suitable for use in a crash barrier without a sealant layer or coating applied thereto.

FIG. **4** is an end view of the module shown in FIG. **3**.

FIG. **5** is a cross-sectional side view of the module taken along line **5-5** of FIG. **4**.

FIG. **6** is a top view of the module shown in FIG. **3**.

FIG. **7** is a perspective view of the crash barrier shown in FIG. **1**.

FIG. **8** is an enlarged view of the connection between a base and a barrier wall taken along line **8** of FIG. **1**.

FIG. **9** is an enlarged view of an anchor pin positioned in a base taken along line **9** of FIG. **1**.

FIG. **10** is a perspective view of a base.

FIG. **11**. is a cross-sectional view of the base taken along line **11-11** of FIG. **10**.

FIG. **12** is an enlarged view of a track.

FIG. **13** is a side, elevation view of one embodiment of a crash barrier.

FIG. **14** is an enlarged view of a front stop take along line **14** of FIG. **13**.

FIG. **15** is a side view of a backstop assembly taken along line **15** of FIG. **13**.

FIG. **16** is a top, perspective view of an alternative embodiment of a module with a connector.

FIG. **17** is a perspective view of a side cover.

FIG. **18** is a perspective view of a top cover.

FIG. **19** is a perspective view of a connector.

FIG. **20** is a perspective view of a bottom bracket.

FIG. **21** is a side, elevation view of another embodiment of a crash barrier configured with a transition rail.

FIG. **22** is an enlarged, partial view of the transition rail taken along line **22** of FIG. **21**.

FIG. **23** is an enlarged, partial view of the transition rail taken along line **23** of FIG. **21**.

FIG. **24** is a top view of the crash cushion shown in FIG. **21**.

FIG. **25** is an enlarged partial view of the crash cushion and transition rail taken along line **25** of FIG. **24**.

FIG. **26** is a top view of one embodiment of a transition rail.

FIG. **27** is a side view of the transition rail shown in FIG. **26**.

FIG. **28** is a cross-sectional view of one embodiment of an anchor bracket.

FIG. **29** is a cross-sectional profile of one embodiment of a crash barrier.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

Referring to FIGS. **1** and **2**, it should be understood that the term "longitudinal," as used herein means of or relating to length or the lengthwise direction **2** of a crash barrier, which is parallel to and defines an "axial impact direction." The term "lateral," as used herein, means directed toward or running in a lateral direction **4** perpendicular to the side of the crash barrier. The term "transverse" means across, or non-parallel, and may include two features lying orthogonal to each other. The term "coupled" means connected to or engaged with, whether directly or indirectly, for example with an intervening member, and does not require the engagement to be fixed or permanent, although it may be fixed or permanent, and includes both mechanical and electrical connection. It should be understood that the use of numerical terms "first," "second" and "third" as used herein does not refer to any particular sequence or order of components; for example "first" and "second" blocks may refer to any sequence of such blocks, and is not limited to the order of blocks in an upstream or downstream direction unless otherwise specified. The term "yield" means to bend or deform, without breaking. The term "downstream," as used herein refers to the direction **6** with the flow of traffic that is approaching a front of the crash barrier and/or barrier wall, whereas the term "upstream" means in a direction against or opposite the downstream direction **6**, or the flow of traffic, when bi-directional, approaching a rear of the crash barrier. The term "plurality" means two or more, or more than one.

FIGS. **1**, **7**, **13**, **21** and **29** show embodiments of a crash barrier **8** positioned in front of a hazard, shown as a concrete barrier wall formed from a plurality of concrete barriers **10**. The concrete barriers **10** may be secured to the ground using a plurality of anchor brackets **401**. Referring to FIGS. **21**, **24** and **28**, the brackets **401** include a base flange **403**, an upright vertical flange **405**, and an angled flange **407** welded to and forming an obtuse angle α relative to the vertical flange **405**. In one embodiment, a is about 145°. The vertical and angled flanges are arranged so as to nest against a matching outer profile of the barrier **10**. Threaded anchor bolts **409**, for example and without limitation ¾ inch×6½ inch anchors, are then secured to the ground, e.g., pavement, and to the barrier, with epoxy.

Referring to FIGS. **1**, **7** and **10**, the crash barrier **8** includes a base **12** anchored to the ground **14**, and to the upstream end of the concrete barrier wall or adjacent concrete barrier **10**. One suitable base is an ADIEM® base available from Trinity Highway Products, Dallas, Tex. In one embodiment, the base **12** is secured to the ground with a plurality of pins **16**, **18**, **20**, which may have various exemplary lengths of 30 inches, 36 inches and 48 inches, or other lengths deemed appropriate. As shown in FIGS. **1** and **9**, the pins include a head **22** supported by a washer **24** engaging the base, for example in socket having a shoulder **26**. The pins extend vertically through the base **12** and penetrate the ground **14**. For example, in one embodiment, a plurality of front anchor pins **16** (shown as two pairs of two pins spaced apart on opposite sides of longitudinal axis **2**) may be 1 inch diameter, and from 18 to 30 inches in length depending on the type of ground material, which may be concrete or soil. In one embodiment, a plurality of middle pins **18** (shown as **4**) may be 1 inch diameter and between 24 and 36 inches in length, while a plurality of back pins **20** (shown as **4**) may be 1 inch diameter and between 36 and 49 inches in length. It should be understood that other numbers of pins of other dimensions and lengths may also be suitable.

As shown in FIGS. **1**, **7**, **8**, and **28** brackets **28** are secured to opposite sides of the base at the rear end thereof with a plurality of fasteners **30**. The brackets **28** each include a flange **407** secured to outwardly extending flanges of the upstream barrier wall **10** with a plurality of fasteners **32**, and to the ground with an anchor **409**. In one embodiment, the base **12** is 30 feet long, and has a support surface inclined at an angle of more than 2 degrees, and in one embodiment more than 3 degrees, and may be inclined at an angle of 3.18 degrees. It should be understood that different lengths and angles of pitch may be suitable for various uses. In one embodiment, the base **12** is made of concrete. It should be understood that the term "base" may simply refer to a ground surface, including a simple concrete pad, asphalt or soil.

As shown in FIGS. **7** and **10-12**, the base **12** has a central channel **34** formed by laterally spaced walls **36**, and a longitudinal track **38** formed along a bottom of the channel **34**, with the channel running the length of the base **12**. A bottom surface **40** of the channel defines a support surface. The track **38**, centrally located in the channel **34**, includes a slot **42** and a cavity **44** spaced below the support surface. The track **38**, with the slot and cavity, may be formed by a roll-formed metal rail, or by a pair of spaced apart rails (e.g., C-shaped or I-shaped), with the rails being embedded in the base and having embedded anchor members **37** extending laterally outwardly from the rail. The base **12** may also include side tube rails **17** cast into the base. One exemplary base is shown in U.S. Pat. No. 4,909,661, which is hereby incorporated herein by reference, and further includes the base incorporated in the ADIEM® crash barrier system made and sold by Trinity Highway Products, Dallas, Tex.

Referring to FIGS. **21-27**, barrier **8** may be further secured to the barrier **10** with one or more transition rails **501**, attached along one or both sides of the barriers **8**, **10**. In particular, the transition rail **501** has a first portion **503** extending in a longitudinal direction **2** and having first and second ends **505**, **507**, and a second portion **509** extending in longitudinal and lateral directions **2**, **4** and having first and second ends **511**, **513**. The second end **507** of the first portion **503** is connected to the first end **511** of the second portion **509**, for example with a weld **515**. The first and second portions may be made of steel tube, for example HSS 4×2×¼ A500 Grade B/C material. The second portion **509** forms an obtuse angle β relative to the first portion **503** when viewed from a first direction **517** orthogonal to the longitudinal and lateral directions, as shown in FIGS. **26** and **27**. In one embodiment, the angle β may be about 165°. The first end **505** of the first portion is formed as a clevis **519**, with a pair of flanges or plates **521** spaced apart in the first direction **517**. The first end **505** may have a taper, or be sloped, and comes to a point as shown in FIG. **26**, so as to eliminate or reduce the potential for snagging. Each plate has a pair of slotted openings **523** elongated in the lateral direction **4**, with the openings in the plates being aligned in the first direction **517**. The slotted openings **523** and fasteners **525**, e.g., bolts (see FIG. **22**), secured with a washer **526**, define an adjustable first connector, which permits lateral movement of the rail **502** in the lateral direction **4**, as well as rotational movement about an axis **527** extending in the first direction **517**. Rotational movement is achieved when the fasteners **525** are moved in opposite directions within the slotted openings **523**. In this way, the second portion **509** may be moved toward or away from a side of a barrier **10**. The second portion **509** includes a plate **529**, extending in the first direction **517** above and below the rail in one embodiment. The plate **529**, and fasteners **531** (see FIG. **23**) define a second connector, with the fasteners **531** extending in the lateral direction orthogonal to the first direction **517**. The plate **529** has a pair of openings **541** oriented in the lateral direction **4** transverse to the first direction **517**, and orthogonal thereto in one embodiment. The second connector, and in particular the plate **529** thereof, functions as a stop, and is operable to limit the lateral movement and/or rotation of the rail **501** relative to the barriers **8**, **10**. As shown in FIGS. **24-27**, the rails **501** are symmetrical, and may be attached to opposite sides of the barriers **8**, **10**.

During assembly, a first end **505** of the rail is secured to the barrier **8**, for example by securing fasteners **525** through the clevis **519** and into the base **12**, for example the base side rails **17**. The second end **513** of the second portion is then abutted against the side of the barrier **10**. The second end **513** is tapered and comes to a point so as to provide a smooth transition between the side of the barrier **10** and the rail **501**. The elongated slots **523** permit the rail **501** to be translated and rotated in a lateral direction so as to accommodate different width barriers **10**. Once the rail **501** is properly positioned, the anchor bolts **525** may be tightened so as to flatten the clevis **519** and draw the plates **519** together as shown In FIG. **22**. The fasteners **531** may also be installed so as to secure the second end of the rail **501** to the barrier **10**. The clevis **519** contributes to the symmetry of the rail, permitting either plate to be drawn downwardly, depending on which side the rail is position. The angle α of the second portion **509** relative to the first portion **503** provides a smooth transition between the barriers **8**, **10** so as to eliminate any snag points that may occur in reverse direction impacts where the adjacent, cross-sectional profiles **549**, **551** of the barriers **8**, **10** do not match. For example, the barrier **8**, and in particular the base **12** has a first cross-sectional profile **549**, taken along an end of the barrier **8** perpendicular to the longitudinal axis **2** as shown in FIG. **10**, while the barrier **10** has a second cross-sectional profile **551** taken along an adjacent end of the barrier **10** as shown in FIG. **29**. The profiles **549**, **551** may be the same or different. The rails **501** also prevent a vehicle **130** from riding up on the barrier **10** during an impact event.

Referring to FIGS. **1**, **2**, **7** and **13**, a plurality (shown in different embodiments as **20** or **19**) of modules **50**, **250** are disposed in the channel **34** and positioned in an array **54**, **254** and abutted end-to-end along the bottom support surface **40** of the base. Each module **50**, **250** includes at least one mounting portion **52**, configured in one embodiment as a T-shaped or I-shaped guide member **56**. As shown in FIGS. **3-6**, the module **50**, **250** is configured with a pair of guide members **56**, each having a leg portion **58** and a foot portion **60**. In one embodiment, the foot portions **60**, or feet, are defined by a pair or of L-shaped brackets **64** secured back-to-back on opposite sides of a diaphragm leg portion **58** extending downwardly from a bottom surface **62** of the module. The brackets **64** may be secured with a pair of fasteners **66** (bolts and nuts), welding, forming, or other known solutions or combinations thereof. Alternatively, the guide members, and feet portions in particular, may be integrally formed, for example by extrusion, or may assume other shapes suitable for engaging and being entrapped within, on or below a track. The brackets **64** have opposing flanges extending laterally outwardly from the diaphragm leg portion **58**. The leg portion **58** extends through the slot **42**, with the feet portions **60** disposed in the cavity **44** of the track. The feet portions **60** are trapped in the cavity, and engage the top of the cavity to retain the module **50** in the track **38**. The modules **50** are initially coupled to the base by sliding the guide members **56** of the modules along the track, from a front or back of the base, to a desired position, with the bottom of the module resting on the support surface **40**. The next module in the array is then similarly coupled to the base and moved into position adjacent the previously installed module. Alternatively, the modules **250** may be additionally coupled one to other with a connector strap as further explained below.

In one embodiment, and referring to FIGS. **13-15**, a front stop bracket **406** is abutted against a forwardmost module **50**, **250** to maintain the position of the array and secured to the base with a fastener **418**, while a backstop assembly **408** is abutted against the rearwardmost module **50**, **250** in the array. The backstop assembly **408** includes an upright backstop member **260** having a front surface engaging the modules, and a pair of forwardly extending supports **262** secured to the base **12**, for example with a flange **410** having a lower portion **412** and a stepped up upper portion **414** secured to the base with fasteners **416**. A plurality of support straps **264**, **266** secure the backstop **260** to the supports.

Referring to FIGS. **3-5**, a diaphragm **70** extends vertically along a centerline **72** of the module **50**, **250**, and includes in one embodiment a pair of leg portions **58** defining in part the guide members. It should be understood that the module, and diaphragm, may be configured with only one guide member, or more than two guide members. In other embodiments, the modules may be configured without any guide members, and may simply rest on a support surface, defined by a base or the ground. Or, the modules may be configured with mounting portions that are configured in other ways to engage and be coupled to the base, including various guide systems, or various release systems such as break-away fasteners. The modules also may or may not be restrained in a vertical and/or lateral direction by various retention devices such as tethers, anchors, guides, etc.

In one embodiment, the diaphragm **70** is made of an expanded metal panel. In an exemplary embodiment, the panel is made of ¾ #9 gauge carbon steel flattened, galvanized panel. Other materials, e.g., metal, plastic, fiberglass, wood, may also be suitable. The panel includes a plurality of apertures **102**, shown as diamond shaped openings, in the expanded metal embodiment of FIG. **5**. Other shapes and sizes of apertures may be suitable. In other embodiments, the panel may be configured without any apertures.

As shown in FIGS. **3-6**, first and second cellular foam blocks **80** are coupled to first and second sides **74**, **76** of the diaphragm. In one embodiment, the cellular foam blocks **80** are made of glass foam, for example a FOAMGLAS® HLB800 cellular glass foam material, and are configured as 18×24×5 (18 inches long by 24 inches tall by 5 inches wide) rectangular solid blocks. It should be understood that other shapes and dimensions may be suitable. The glass foam material has a closed cell structure, with the individual cells collapsing upon impact wherein energy is consumed. The glass foam material is inert, made of glass and silicon, non-combustible and is not susceptible to moisture intrusion. The glass foam material also is not susceptible to UV degradation. The glass foam blocks may be easily molded in any desired shape, and are easily cut or shaped after formation. The glass foam material provides an outer surface suitable and receptive to various adhesives. In one embodiment, the glass foam blocks **80** are wider and taller than the diaphragm panel **70**, such that the diaphragm bottom, top and side edges **78**, **90**, **92** are spaced inwardly from the outer bottom, top, and side **94**, **96**, **98** surfaces of the blocks (e.g., 1-3 inches), with the exception of the leg portions **58**, which extend downwardly from the bottom surface **94**. Other cellular foam structures may also be suitable for the blocks **80**, including without limitation cellular foams made of polyurethane and/or polyisocyanurate.

The first and second cellular foam blocks **80** are coupled to the first and second sides **74**, **76** of the diaphragm with an adhesive **100**. When the diaphragm includes apertures, the adhesive **100** permeates the diaphragm through the apertures **102**, bonding the first and second blocks **80** to each other, as well as to the first and second sides **74**, **76** of the diaphragm **70**. The adhesive **100** may be applied to the inner surfaces of the first and second cellular foam blocks, to the first and second sides of the diaphragm, or both. In one embodiment, the adhesive **100** is formed by a gypsum cement product, e.g., drywall mud. One suitable adhesive is a Hydrocal® B-11 gypsum cement, which is mixed with water to form an inorganic, noncombustible adhesive. The Hydrocal® adhesive is particularly well suited for bonding FoamGlas® cellular glass foam blocks. It should be understood that the cellular foam blocks may also be coupled to the diaphragm, or first and second sides thereof, and/or to each other with the diaphragm disposed therebetween, with mechanical fasteners, such as screws, bolts, rivets, rods, etc., alone or in combination with various adhesives. It should be understood that cellular foam blocks are "coupled" to the first and second sides of the diaphragm even when the mechanical fastener connect the foam blocks to each other with the diaphragm sandwiched therebetween.

Referring to one embodiment of the modules **50**, after the cellular foam blocks **80** are adhered or connected to the diaphragm **70**, or while the adhesive **100** is curing, a wrap layer **104** is wrapped around the periphery of the outer exposed surfaces (opposite ends and outermost side surfaces) of the first and second cellular foam blocks **80**. In one embodiment, the wrap layer is formed as a thin, resilient sheet of material, such as a 4.5 oz fiberglass mesh. The wrap layer **104** may be permeable, e.g., include a plurality of apertures **108** (shown as exaggerated in partial view of FIG. **4** for purposes of illustration). In other embodiments, the wrap layer may be devoid of apertures, and may be formed of metal, plastic sheeting, or other similar materials. In one embodiment, the wrap layer **104** is 22 inches tall, and surrounds the outer periphery of the first and second cellular foam blocks, with the ends **106** of the wrap layer overlapping as shown in FIG. **6**. In one embodiment, the cellular foam blocks have a greater height than the wrap layer, such that portions of the cellular foam blocks are exposed below and above the wrap layer **104**. In one embodiment, the ends **106** of the wrap layer overlap about 8 inches, with the opposite edges of the wrap layer being disposed inwardly from the opposite sides of the module about 1 inch on the each end of the module.

As shown in the partial cut-away of FIGS. **1** and **7**, a sealant layer **110** is applied over the wrap layer, and penetrates the apertures **108** of the wrap layer **104** in one embodiment, bonding the wrap layer to the outer surfaces **90**, **112** of the first and second cellular foam blocks and sealing the outer surface of the first and second cellular foam blocks. The sealant **110** may be applied over the entire surface of the module, including the exposed portions of the surfaces **90**, **112**, and the top and bottom surfaces **98**, **94**, of the first and second cellular foam blocks **80**. In one embodiment, the sealant layer **110** is formed by a quick-set joint compound, or drywall mud. One exemplary and suitable embodiment is the Hyrdocal® B-11 gypsum cement also described above as a suitable adhesive. The sealant layer **110** seals any gaps between the blocks and/or pin holes in the blocks, so as to prevent water penetration.

A coating **120** is then applied over the sealant layer **110**. The coating may include a plurality of separately applied coats of material. For example, the coating may include one coat of urethane primer, followed by two coats of a base. In an exemplary embodiment, the coating includes one coat of Garna-Thane® primer, or Garna-Prime® urethane primer adhesive, and two coats of Garna-Thane® base. Of course, it should be understood that the coating may include a single coating, or more than three coatings, whether of a primer or base. The coatings may be applied by spraying, or with a brush or roller applicator.

The coating **120** provides an additional weather barrier for the module **50**. The wrap, sealant and coating layers **104**, **110**, **120** ensure that cellular foam blocks **80** hold together for as long as possible during an impact event, and further provide protection against invasive weather elements.

Referring to FIGS. **13** and **15-20**, in an alternative embodiment of the modules **250**, the wrap layer is configured as a cover member **280** positioned around the front and rear ends and opposite sides of combined first and second cellular foam blocks **80**, which are coupled to the diaphragm **70**, for example with adhesive and/or mechanical fasteners. The cover member also covers the top of the cellular foam blocks **80**. In this embodiment, the cellular foam blocks **80** may or may not be provided with a wrap layer, sealant layer or coating. The cover member **280** includes a three sided side cover **282** that wraps around one end (front or rear) and two sides of the blocks **80**. A top cover **284**, including an inwardly extending flange **286** formed around the periphery thereof, has a side member **288** extending along an opposite end (rear or front) of the blocks and a top member **290** covering the top of the blocks. The flanges **286** overlap and lie outside peripheral edges **292** of the side cover **282** such that fluids are prevented from penetrating the cover. A U-shaped bottom bracket **294** extends underneath the modules and has a pair of upwardly extending flanges **296** secured to the outer surface of the side covers. Another U-shaped connector **298** is positioned over the junction of adjacent modules and covers the joint therebetween, with opposite bottom end portions **300** being secured to adjacent modules as shown in FIG. **16**. The cover member **280**, including the side cover **282**, top cover **284**, bottom bracket **294** and connector **298** may be made of a metal, such as Aluminum, including a 22 gauge or 0.032 AL Sheet. In other embodiments, the cover member may be made of other metals, including galvanized sheet metal, or various composite materials, such as fiberglass, or plastic. The cover members may be secured to the blocks and each other with rivets or sheet metal screws, alone or in combination with an adhesive.

During an impact event, and referring to FIG. **1**, a vehicle **130** impacts the array **54**, **254** of modules **50**, **250**, arranged end-to-end along the base **12**, in the downstream direction **6**. The modules **50**, **250** sequentially crush and absorb energy. It should be understood that the modules **50**, **250** in the array **54**, **254** may provide different energy absorbing capabilities, for example by varying the density of the cellular foam blocks, such that the energy absorbing capabilities increase as the impacting vehicle **130** travels in a downstream direction **6** along the array **54**. For example, in an nineteen (19) module array, the first nine (9) modules may be made of FoamGlas® cellular glass HLB 800 having a density of 7.5 lb/ft^3, while the back ten (10) modules may be made of a more dense FoamGlas® cellular glass HLB 1600, having a density of 10.0 lb/ft^3. Another suitable material may be a FoamGlas® cellular HLB 1200 having a density of 8.7 lb/ft^3. It should be understood that other cellular foams, including other cellular glass foams and cellular polyurethane and/or polyisocyanurate foam materials may also be suitable. In other embodiments, the modules **50** all have the same energy absorbing characteristics, and may be positioned at any location within the array **54**, which simplifies the installation of the crash barrier.

The installation involves setting the base **12**, for example by anchoring the base to the ground **14** and/or to the hazard, such as a concrete barrier wall **10**. The modules **50**, **250** are then disposed in the channel **34** and individually engaged with the track **38**, and slid or moved along the channel **34** to a desired location. After an impact even, damaged or crushed modules **50**, **250** may be removed and replaced. The modules **250** may further be connected one to the other with the connectors.

Although the present invention has been described with reference to preferred embodiments, those skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention. As such, it is intended that the foregoing detailed description be regarded as illustrative rather than limiting and that it is the appended claims, including all equivalents thereof, which are intended to define the scope of the invention.

What is claimed is:

1. A method of manufacturing a module for use in a crash barrier, the method comprising:

coupling first and second cellular foam blocks to opposite sides of a diaphragm; and

applying a wrap layer around a periphery of said first and second cellular foam blocks.

2. The method of claim **1** further comprising applying a sealant layer to said wrap layer.

3. The method of claim **2** wherein said sealant layer comprises a joint compound.

4. The method of claim **2** further comprising applying a coating over said sealant layer.

5. The method of claim **4** wherein said coating comprises a urethane primer.

6. The method of claim **1** wherein said diaphragm comprises a mounting portion extending downwardly from a bottom surface of said first and second cellular foam blocks.

7. The method of claim **1** wherein said wrap layer comprises a permeable material.

8. The method of claim **7** wherein said wrap layer comprises a plurality of apertures, and wherein said applying said sealant layer comprises permeating said plurality of apertures with said sealant layer and adhering said sealant layer to said first and second glass cellular blocks.

9. The method of claim **8** wherein said wrap layer comprises a fiberglass mesh.

10. The method of claim **1** wherein said diaphragm comprises a plurality of apertures, and wherein said coupling said first and second cellular foam blocks to opposite sides of a diaphragm further comprises permeating said plurality of apertures with an adhesive and adhering said first and second cellular foam blocks to said opposite sides of said diaphragm.

11. The method of claim **10** wherein said diaphragm comprises an expanded metal sheet.

12. The method of claim **11** wherein said adhesive comprises a gypsum cement product.

13. The method of claim **1** wherein said first and second cellular foam blocks define front and rear ends and opposite sides of said module, and wherein said wrap layer covers a top, said front and rear ends and said opposite sides of said module.

14. The method of claim **13** wherein said wrap layer comprises a cover member made of metal.

15. The method of claim **14** wherein said cover member is made of aluminum.

16. The method of claim **14** wherein said cover member comprises a side cover and a top cover separate from said side cover, and covering one of said front and rear ends and said opposite sides of said module with said side cover, and covering said top and the other of said front and rear ends with said top cover.

17. The method of claim **16** wherein said top cover comprises a flange extending from a periphery thereof and overlapping portions of said side cover with said flange.

18. The method of claim **16** further comprising positioning a bottom bracket comprising a pair of flanges underneath said module and connecting said pair of flanges to said opposite sides of said module.

19. A method of assembling a crash barrier comprising positioning a plurality of modules made in accordance with claim **1** end to end, supporting said plurality of said modules with a base, covering a junction between adjacent modules with a connector, and connecting said connector to said adjacent modules.

20. A method of assembling a crash barrier comprising supporting a module made in accordance with claim **6** on a base, and coupling said mounting portion to said base.

21. The method of claim **20** wherein said mounting portion comprises a guide member, and wherein said base comprises a support surface supporting a bottom of said module and a longitudinal track, wherein said guide member is received in said track.

22. The method of claim **21** wherein said track comprises a cavity and a slot opening upwardly from said cavity, and said guide member comprises a leg portion extending through said slot and a foot portion received in said cavity, wherein said foot portion is shaped so as to not be removable through said slot.

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