US007325789B2

# (12) United States Patent
Buth et al.

(10) Patent No.: US 7,325,789 B2
(45) Date of Patent: Feb. 5, 2008

(54) **BOX BEAM TERMINALS**

(75) Inventors: **C. Eugene Buth**, Wellborn, TX (US); **Roger P. Bligh**, Bryan, TX (US); **Dean C. Alberson**, Bryan, TX (US); **D. Lance Bullard, Jr.**, College Station, TX (US); **Hayes E. Ross, Jr.**, College Station, TX (US); **Akram Abu-Odeh**, College Station, TX (US)

(73) Assignee: **The Texas A&M University System**, College Station, TX (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **11/682,442**

(22) Filed: **Mar. 6, 2007**

(65) **Prior Publication Data**

US 2007/0147957 A1 Jun. 28, 2007

**Related U.S. Application Data**

(63) Continuation of application No. 10/199,540, filed on Jul. 19, 2002, now Pat. No. 7,185,882.

(60) Provisional application No. 60/306,970, filed on Jul. 20, 2001.

(51) **Int. Cl.**
***E01F 15/00*** (2006.01)
***E04H 17/14*** (2006.01)

(52) **U.S. Cl.** ........................................ **256/13.1**; 256/19

(58) **Field of Classification Search** ................ 256/13.1
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 4,928,928 | A | 5/1990 | Buth et al. | 256/13.1 |
| 5,078,366 | A | 1/1992 | Sicking et al. | 256/13.1 |
| 5,391,016 | A | 2/1995 | Ivey et al. | 404/6 |
| 6,109,597 | A | 8/2000 | Sicking et al. | 256/13.1 |
| 6,505,820 | B2 | 1/2003 | Sicking et al. | 256/13.1 |
| 6,554,256 | B2 | 4/2003 | Ochoa | 256/13.1 |
| 6,561,492 | B1 | 5/2003 | Hubbell | 256/13.1 |

FOREIGN PATENT DOCUMENTS

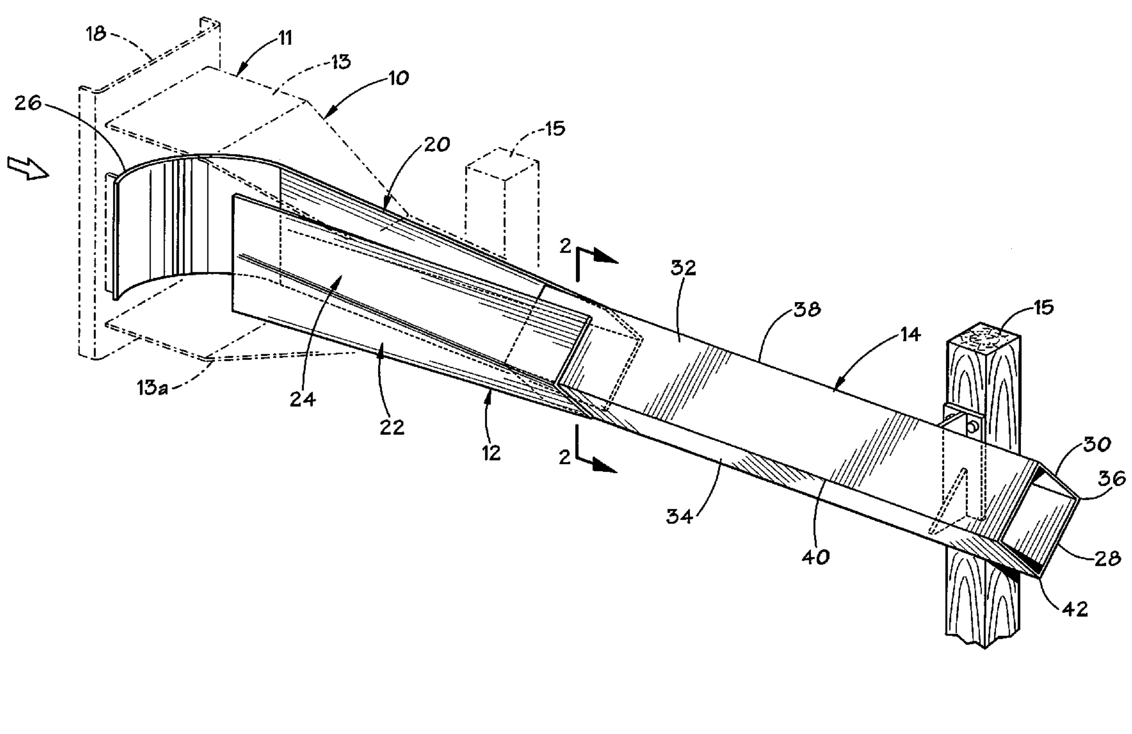
GB 2294489 A 5/1996

*Primary Examiner*—Rehana Perveen
*Assistant Examiner*—Stefan Stoynov
(74) *Attorney, Agent, or Firm*—Baker Botts L.L.P.

(57) **ABSTRACT**

Guardrail installation designs are described that incorporate a box beam rail as the structural rail member. The box beam rail member may have an open cross-section or a closed cross-section. An impact head is provided to bend and deflect the rail member during an end-on collision, allowing the rail member to be deflected away from the roadway and out of the path of an end-on impacting vehicle. The impact head includes a striking face and a chute portion that receives the box beam rail member therewithin. In addition to bending and deflecting the rail member, the impact head may also include a flattening section for flattening the rail member.

**24 Claims, 11 Drawing Sheets**



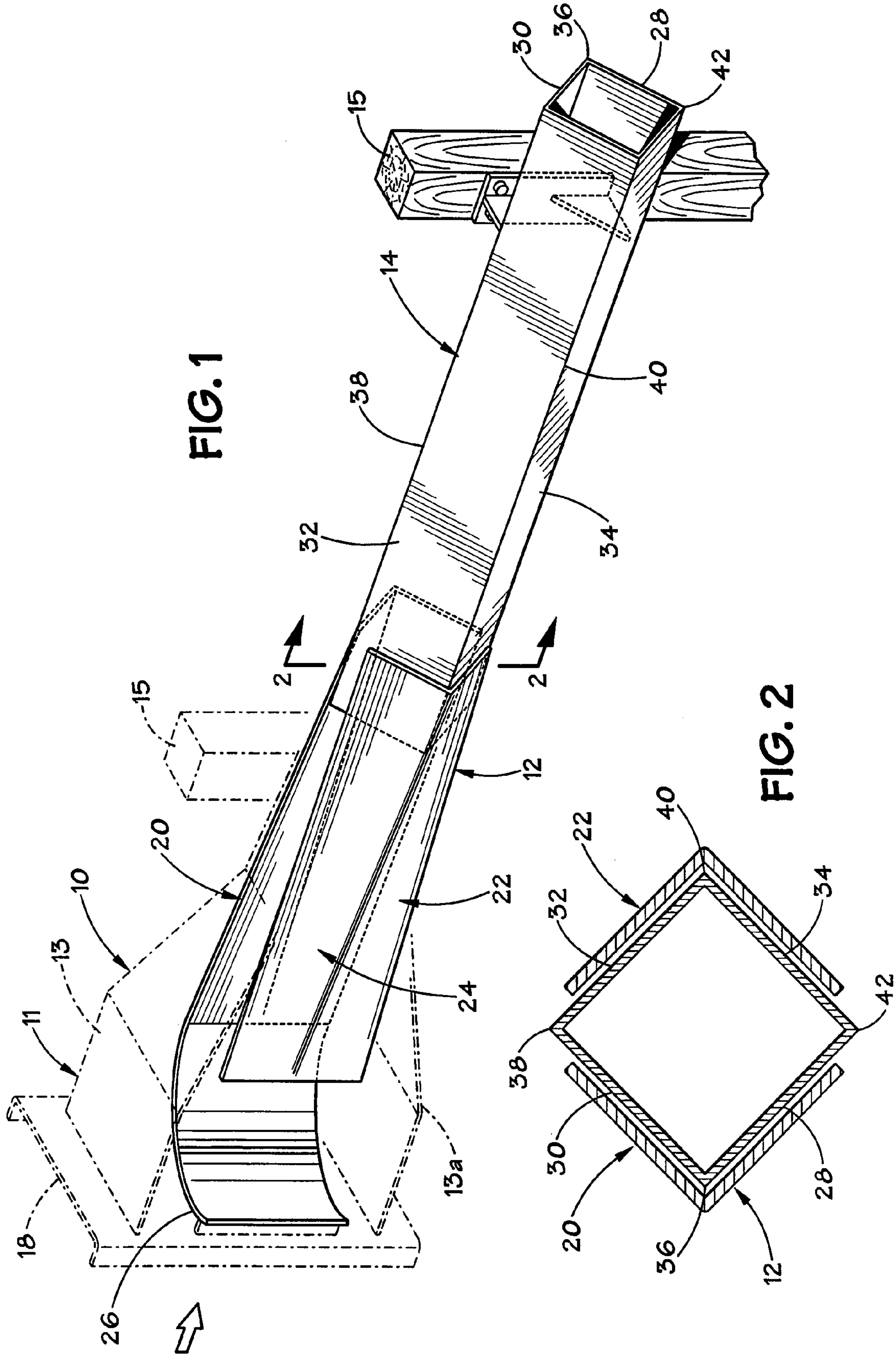



FIG. 1

FIG. 2

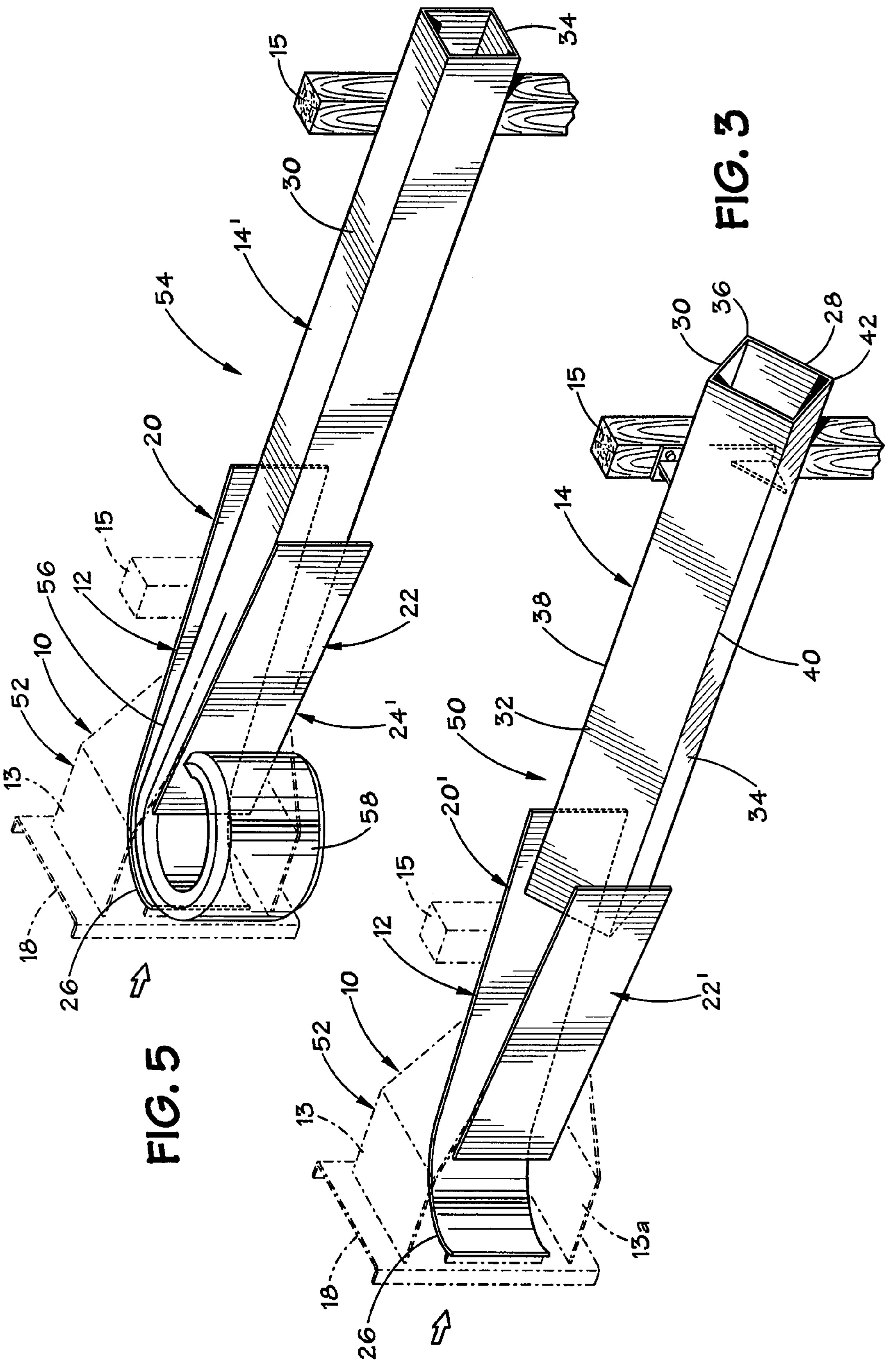

34
15
30
14'
54
20
15
56
12
22
10
52
24'
13
58
18
26
30
36
28
42
15
14
38
40
50
32
34
20'
15
12
22'
10
52
13
13a
18
26

FIG. 3

FIG. 5

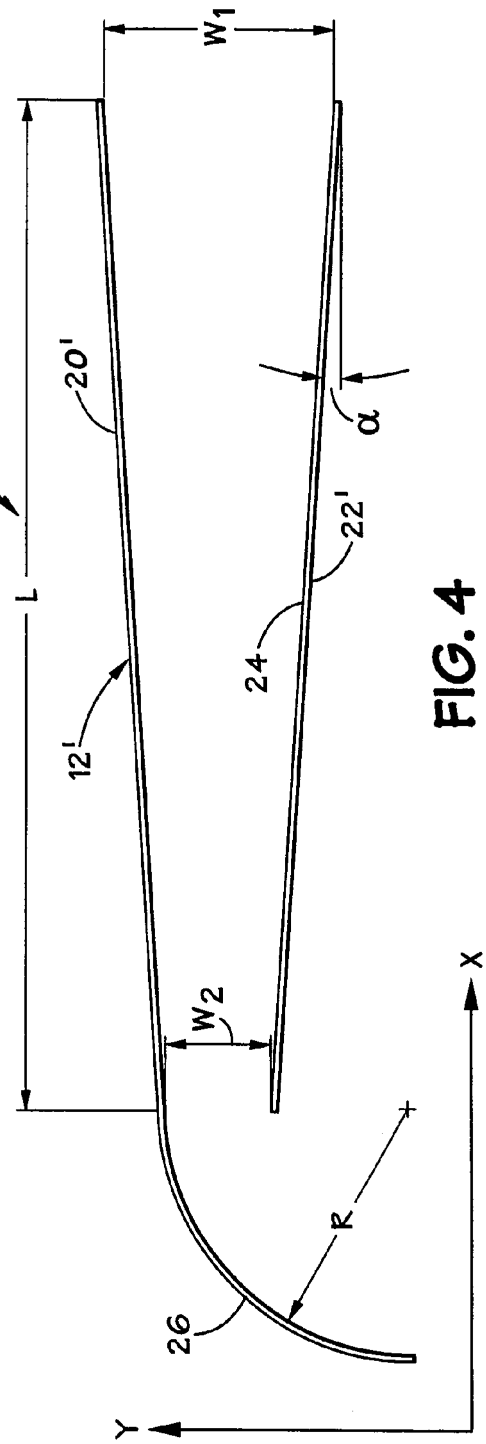



FIG. 4

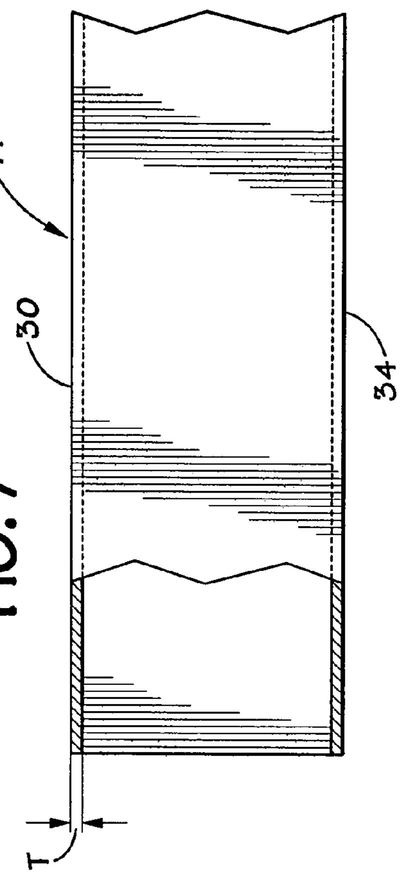



FIG. 7

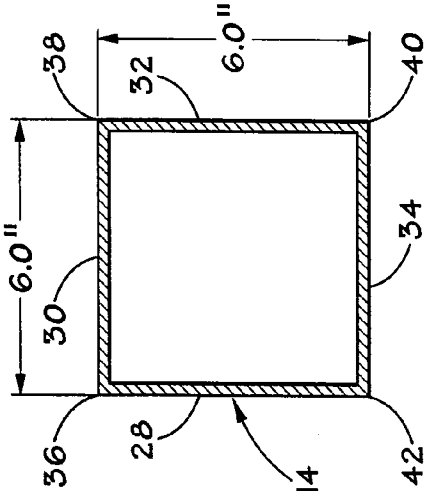



FIG. 6

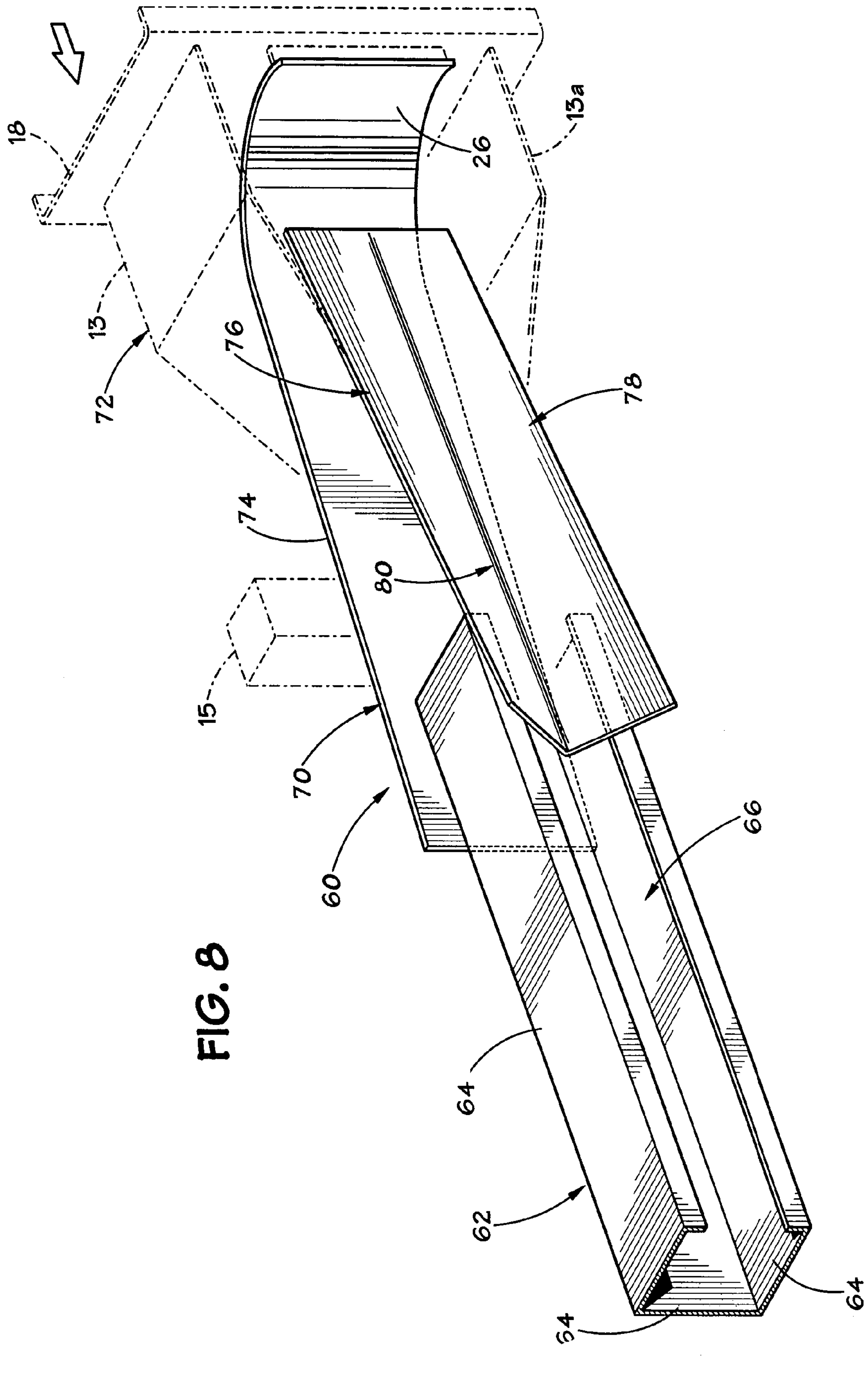



FIG. 8

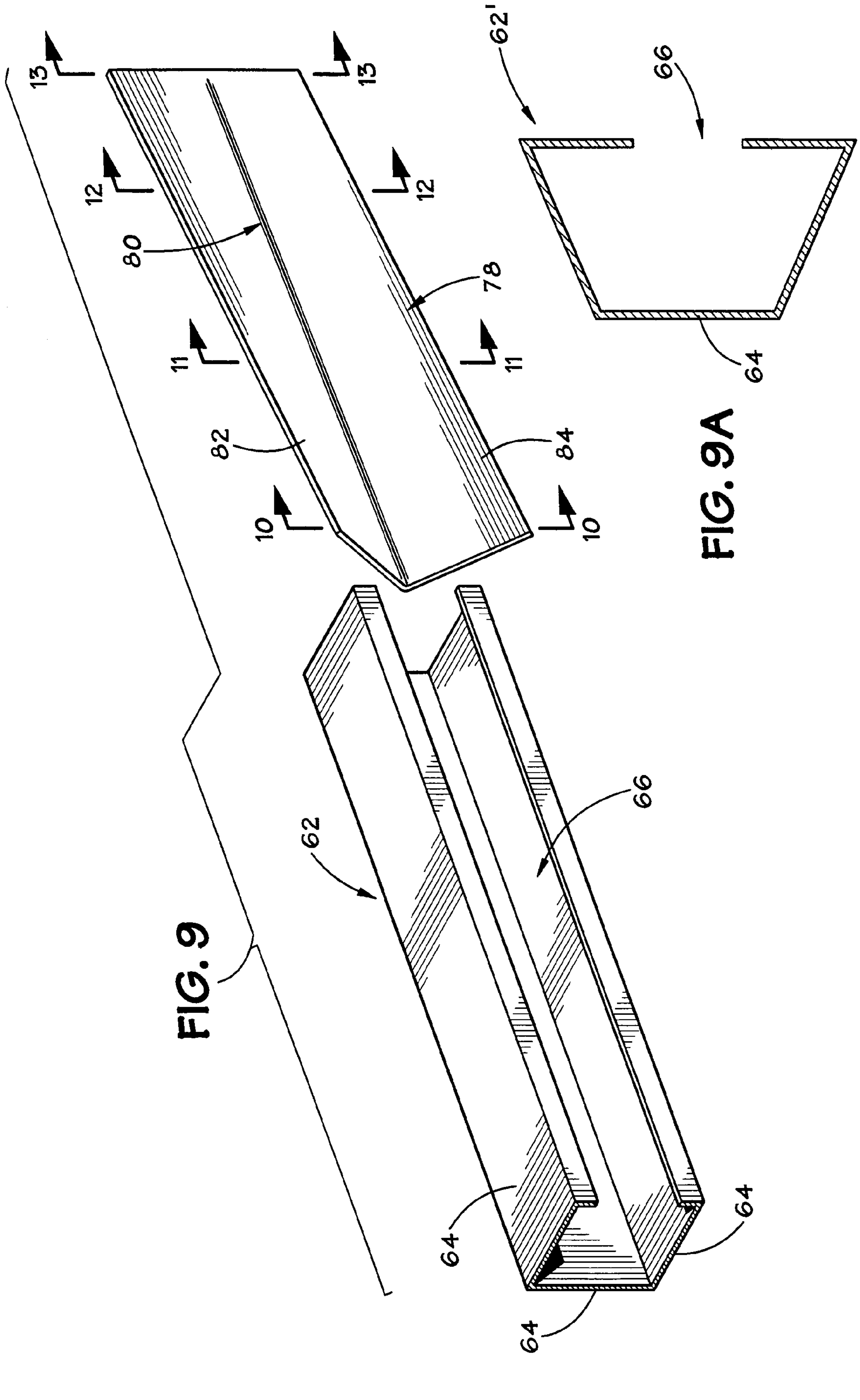



FIG. 9

FIG. 9A

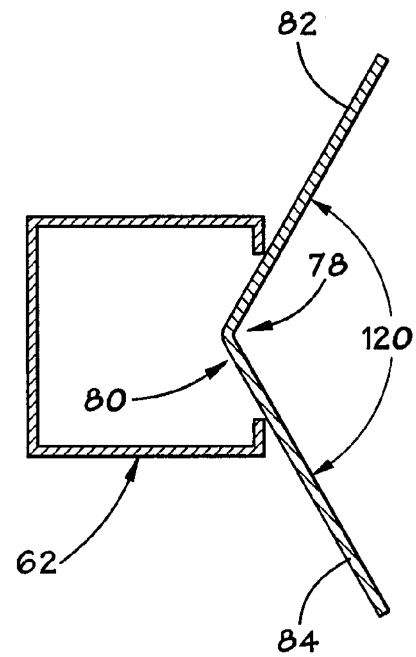



FIG. 10

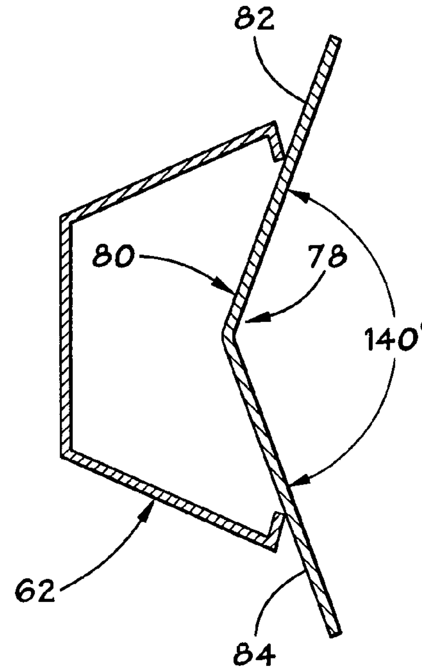



FIG. 11

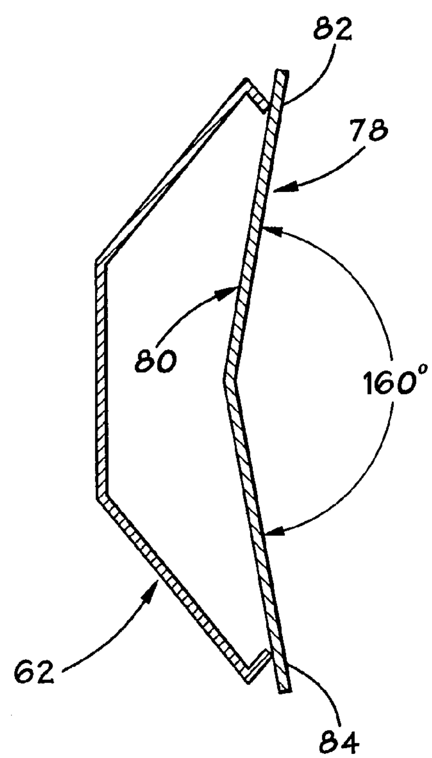



FIG. 12

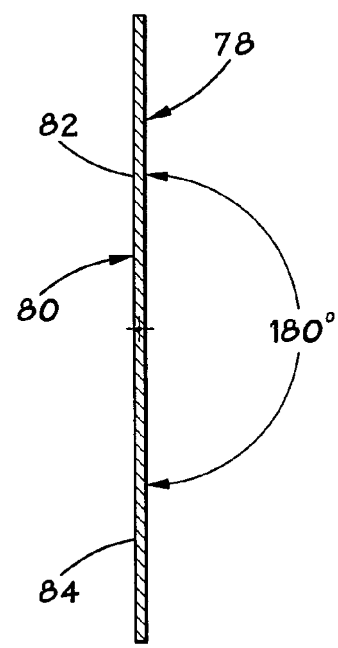



FIG. 13

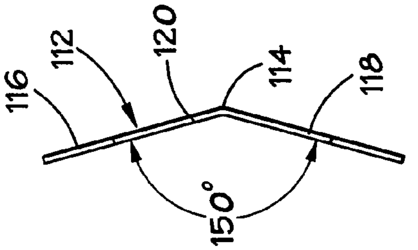


FIG. 17

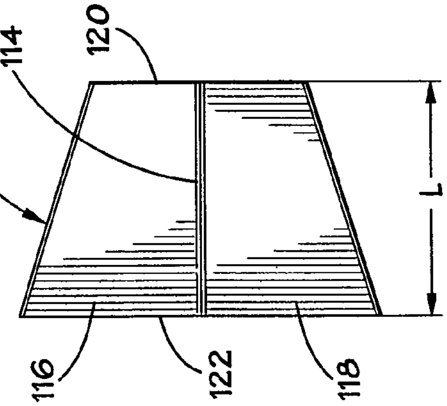


FIG. 15

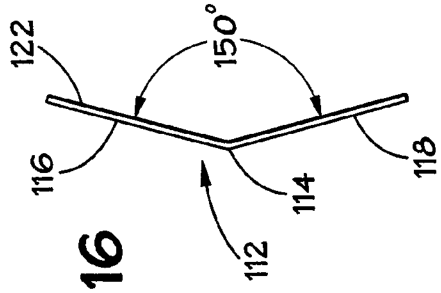


FIG. 16

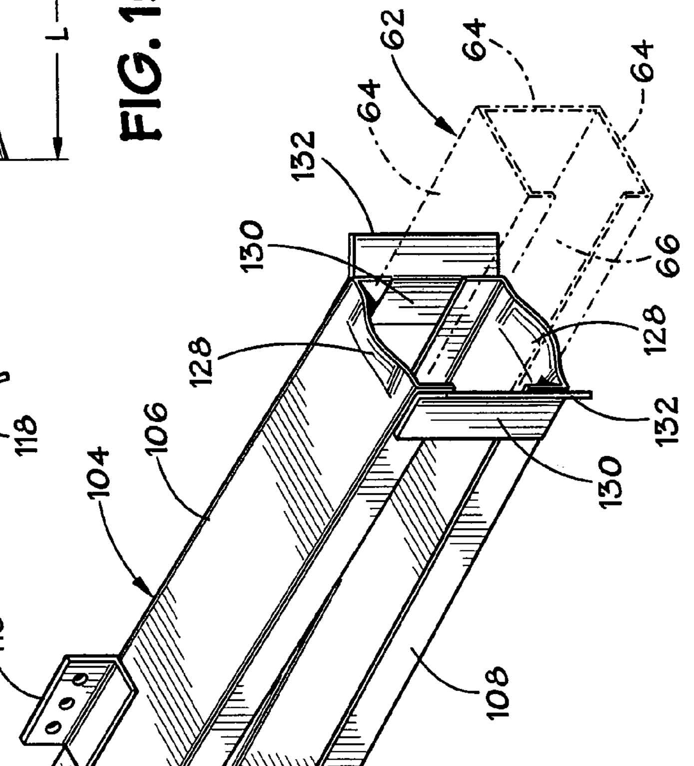
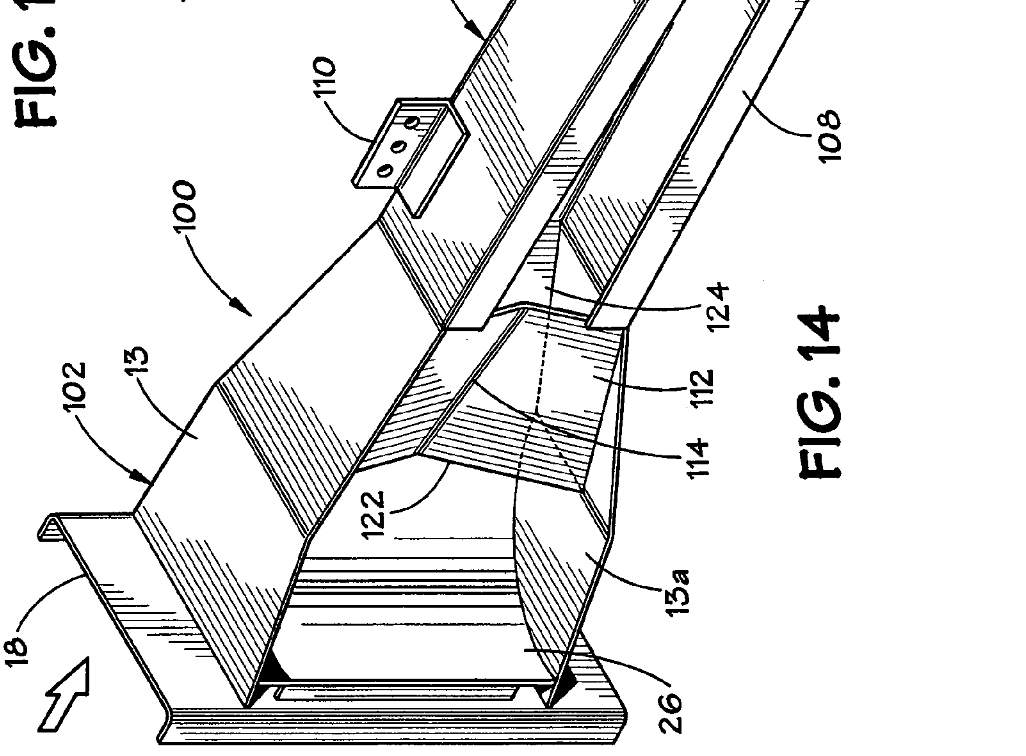



FIG. 14

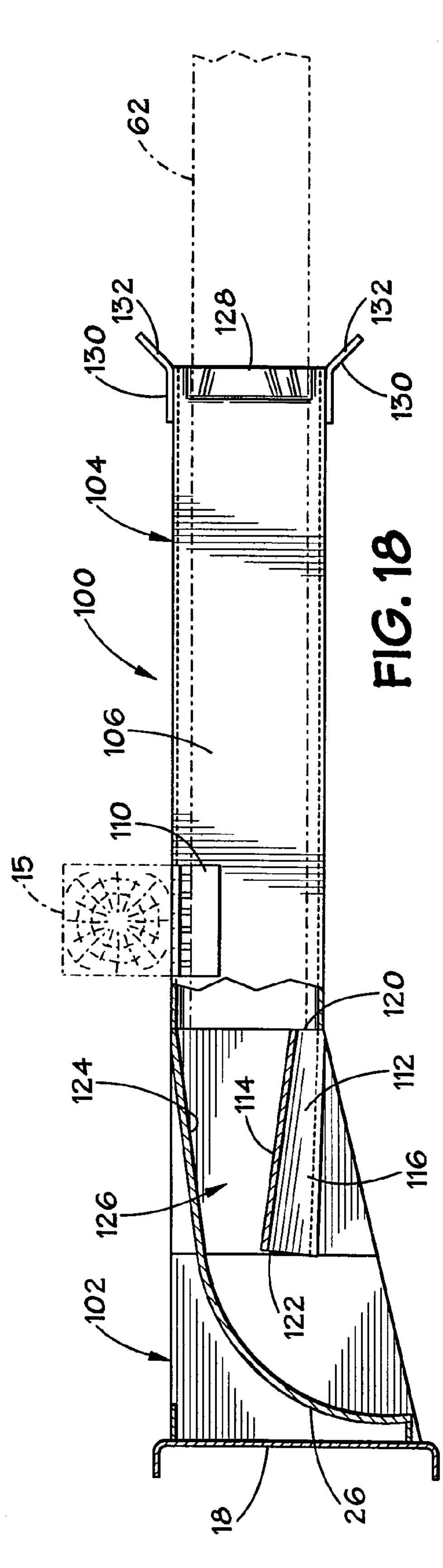

62
132
128
132
130
130
104
100
106
110
15
120
112
124
114
116
126
122
102
18
26

FIG. 18

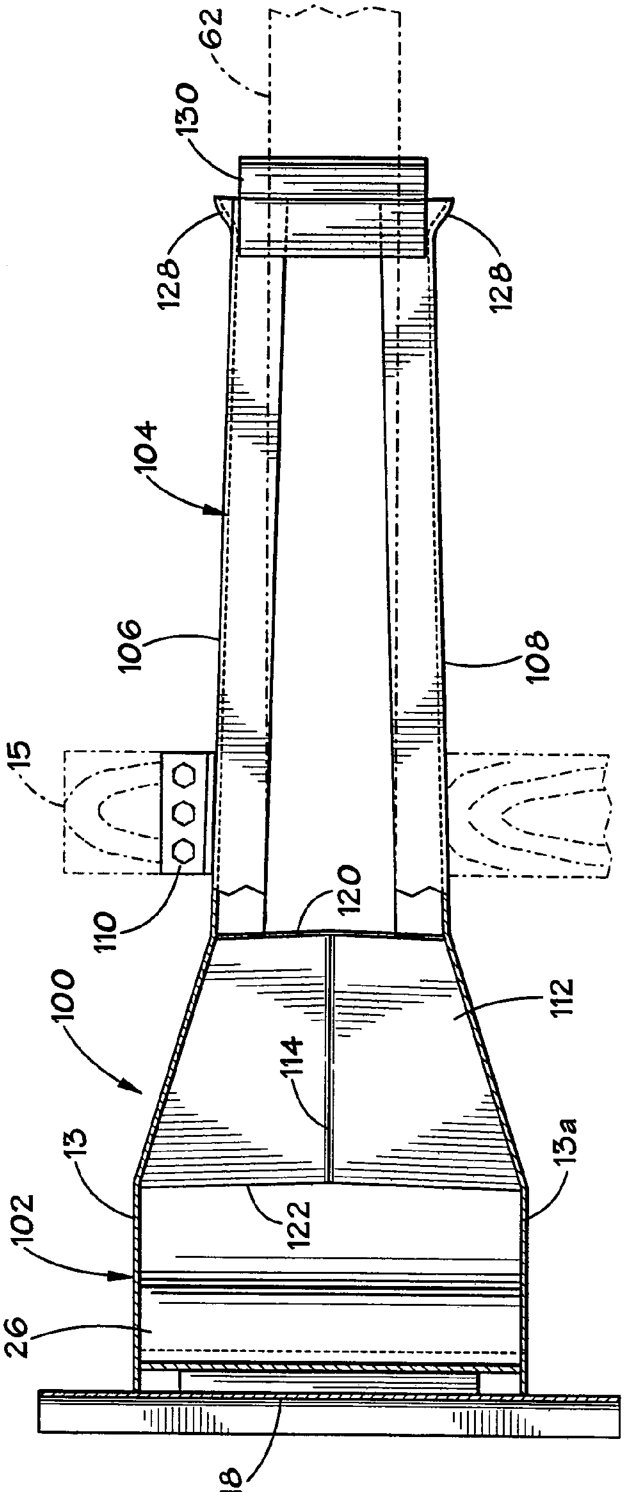

62
130
128
128
104
106
108
15
110
120
100
112
114
13
13a
102
122
26
18

FIG. 19

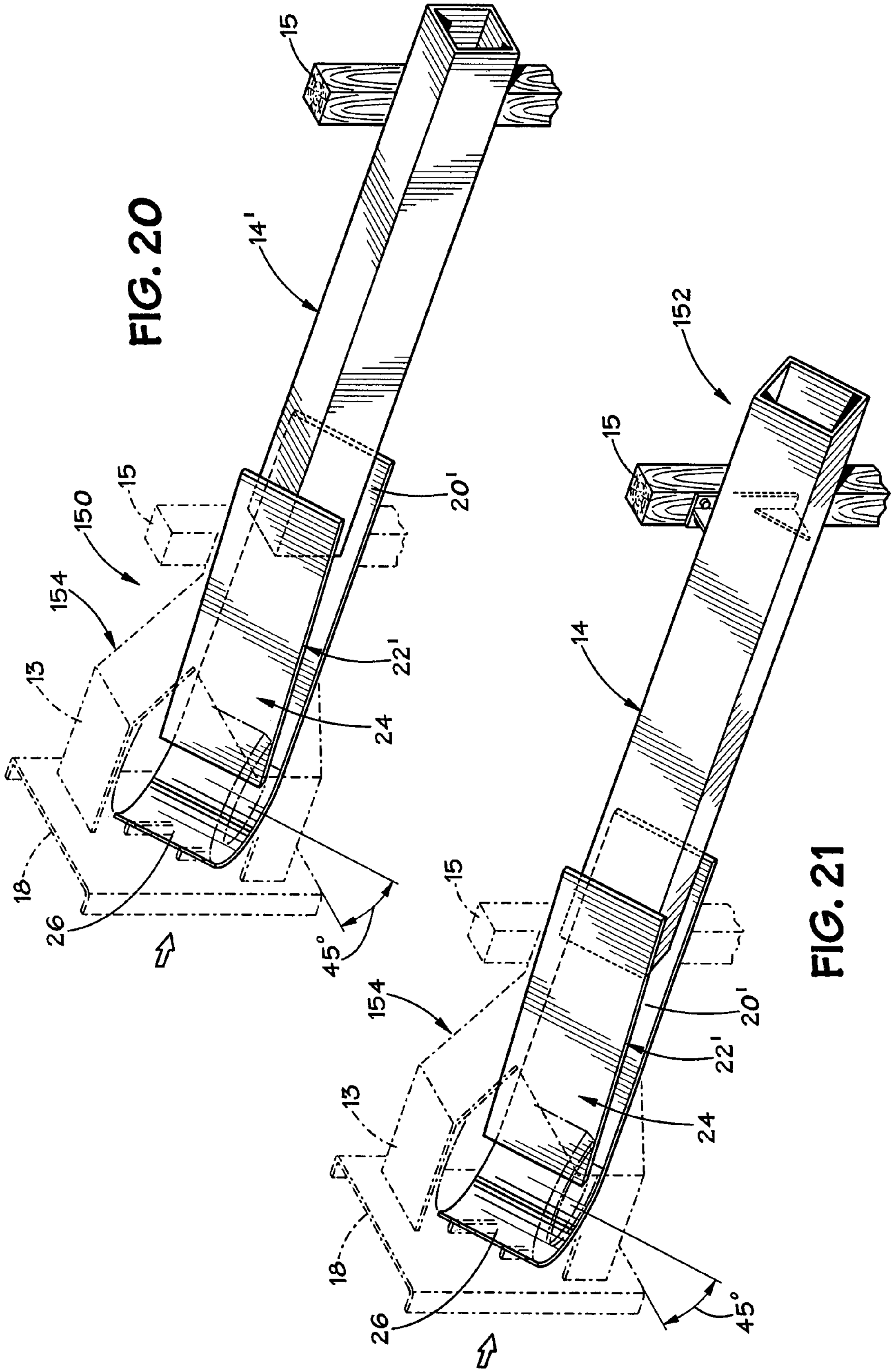



FIG. 20

FIG. 21

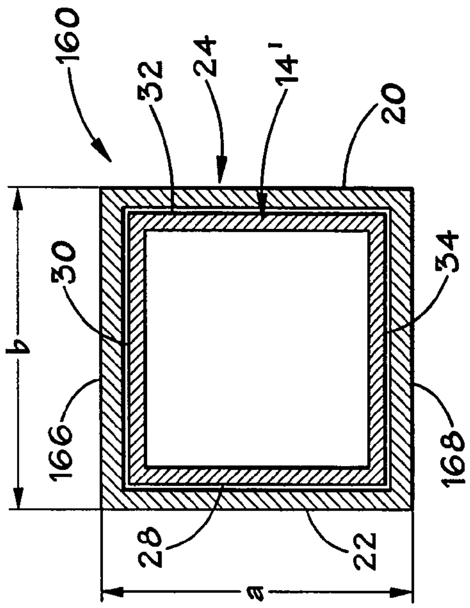

160
32
24
14'
20
30
34
b
166
168
28
22
a

FIG. 23

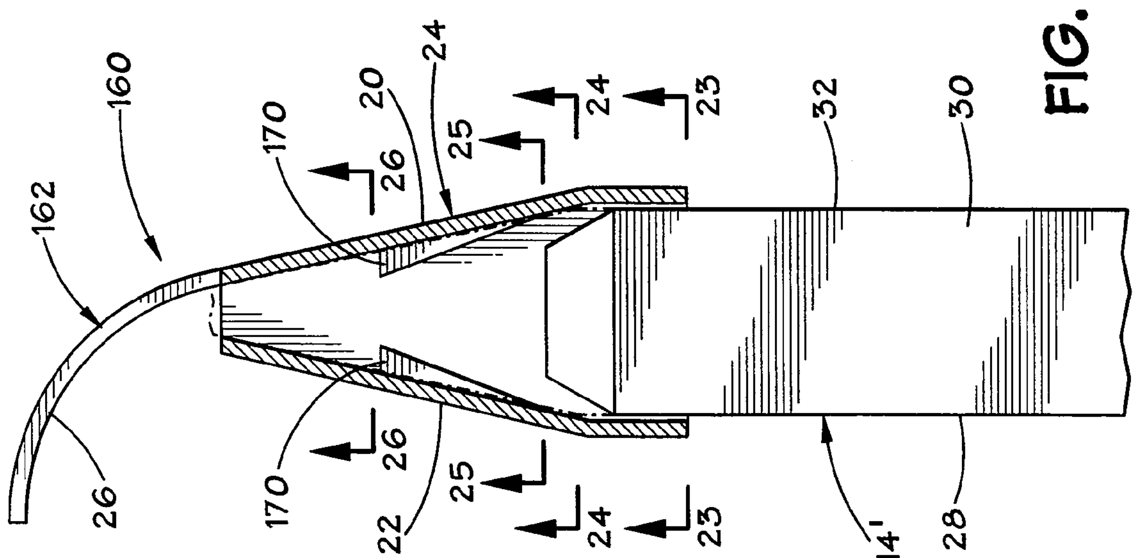

162
160
170
20
24
26
25
24
23
32
30
26
170
26
25
22
24
23
14'
28

FIG. 22

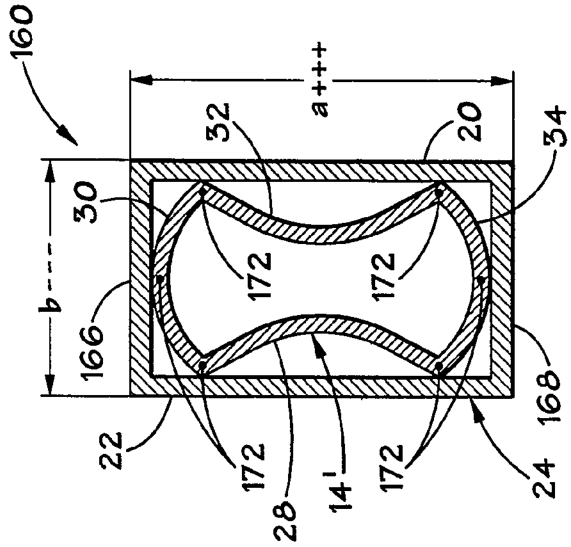



FIG. 26

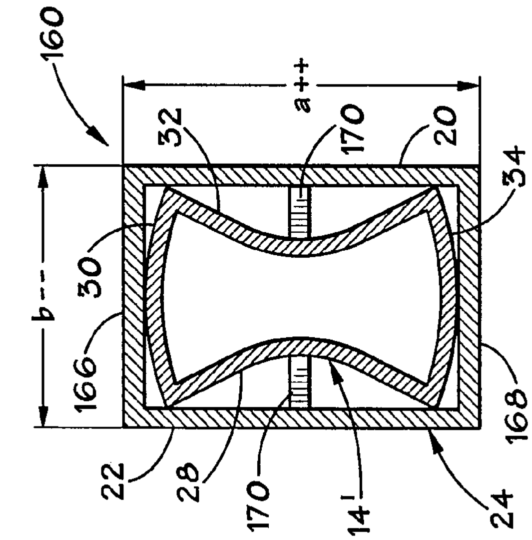



FIG. 25

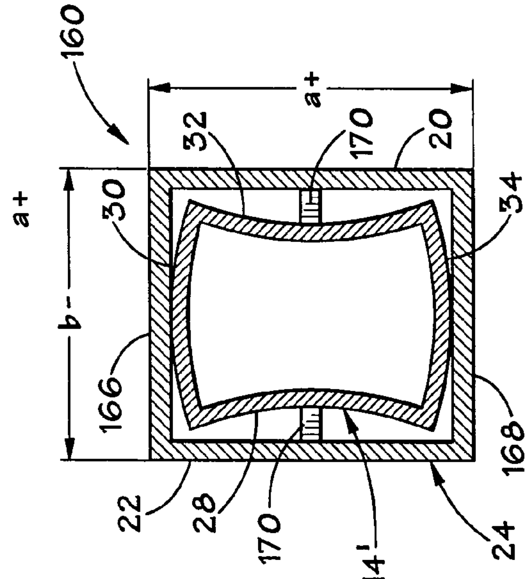



FIG. 24

# BOX BEAM TERMINALS

## RELATED APPLICATIONS

This application is a continuation of U.S. application Ser. No. 10/199,540, filed Jul. 19, 2002, and entitled "BOX BEAM TERMINALS," now U.S. Pat. No. 7,185,882. U.S. application Ser. No. 10/199,540, claims priority from U.S. Provisional Application Ser. No. 60/306,970, entitled "BOX BEAM TERMINALS," filed on Jul. 20, 2001.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to box beam style guardrail installations and safety end treatments for such installations. The invention also relates to methods of use associated with these devices.

2. Description of the Related Art

Guardrail installations are used along roadways to prevent errant vehicles from leaving a roadway wherein they may encounter hazards that are a substantial danger to them. In its simplest form, the guardrail installation features a horizontally disposed rail member that is supported above the ground by a series of support posts. The rail member is most commonly provided by longitudinal segments of corrugated sheet steel having a W-shaped cross-section. Other corrugated rail members, such as the "thrie-beam" are used in some situations. Alternative guardrail installation designs, and those that this patent is concerned with, incorporate a box beam rail member wherein the rail member is a tubular beam member having a square or rectangular cross-section. Box beam terminals are popular in some northern tier markets, including New York and Wyoming, primarily because the use of box beams permits wider support post spacing and greater ground clearance and, hence, reduces snow drift problems in winter time.

A guardrail installation should be installed along a roadside or median such that its ends do not in themselves form a hazard. Early guardrail installations lacked any safety termination at the upstream ends, and occasionally, impacting vehicles became impaled on the ends causing intense deceleration of the vehicle and severe injury to the occupants. In some reported cases, the guardrail end penetrated into the occupant compartment of the vehicle with fatal results.

Upon recognition of the need for proper upstream guardrail termination, guardrail installation designs were developed to reduce the hazard associated with the end of the guardrail. One commonly used technique was to "turn down" the end of the guardrail and bury it into the ground. This method has some recognized disadvantages, including an unintended possibility of ramping an approaching vehicle off the ground during a collision, which can result in a violent vehicular rollover.

A number of end treatments have also been developed for use with corrugated rail members. Perhaps the most popular of these, end treatments is the Guardrail Extruder Terminal, described in U.S. Pat. Nos. 4,928,928 and 5,078,366, which have been assigned to the assignee of the present invention and are incorporated herein by reference. Guardrail Extruder Terminal end treatments are known commercially as "ET-2000." Other end treatments are known as well that are useful for corrugated rail-style guardrail installations.

Box beam guardrail installations have significantly different, and fewer, end treatments as compared with corrugated rail guardrail installations. This is, in part, because the



beam members have a hollow cross section and have a much larger axial buckling load and a much larger lateral bending resistance than the corrugated rail. The tubular nature of the box beam tends to suggest the use of telescoping segments in a collapsing mechanism. One type of box beam guardrail termination is described in U.S. Pat. No. 5,391,016 issued to Ivey et al. and assigned to the assignee of the present invention. In this arrangement, the upstream end of the guardrail installation is provided with nested, telescoping rail segments. The segments are compressed by telescoping inwardly upon one another during an end-on collision. Resistance to the telescoping action is provided by a filler material (i.e., fiberglass) that is mechanically crushed during the compression process. This style of box beam guardrail termination is highly effective. However, proper filler material maybe costly and/or difficult to obtain in some areas. Further, long, slender telescoping tubes, such as those used in some prior art systems, can have stability problems when impacted in an eccentric manner. Such stability problems can restrict the telescoping behavior. Such crushable composite tubes are also subject to manufacturing variability, which can influence the magnitude of the crush force. The decelerations resulting from the staged composite tube design are sensitive to vehicle mass and impact speed.

The present invention addresses the problems of the prior art.

## SUMMARY OF THE INVENTION

The invention features guardrail installation designs that incorporate a box beam rail as the structural rail member. Embodiments are described herein in which the box beam rail member has an open cross-section and a closed cross-section. The upstream end of each of these box beam guardrail installations is provided with an impact head that is designed to bend and deflect a box beam member during a collision, thereby allowing the beam member to be deflected in such a manner that it is not a hazard to traffic or occupants of the impacting vehicle. The impact head includes a striking face and a chute portion that receives the box beam rail member therewithin.

In some described embodiments, the box beam member presents a closed square or rectangular cross-section. The chute portion of the impact head is formed by a pair of side plates that grip opposite corners of the box beam member. During an end-on impact to the impact head, the box beam member is bent by the curved plate portion of the impact head. Preferably, the box beam member is also compressed at opposite corners by a flattening section in the impact head and the beam member flattened out to some degree to assist bending.

In other described embodiments, the box beam member has an open square, rectangular, or trapezoidal cross-section wherein there is an opening in one side of the cross-section. In other words, the box beam member has an "open" cross-section. The chute portion of the impact head includes an angular, or peaked, contact face that engages the opening in the box beam member cross-section. In a currently preferred, described embodiment, a box beam member with an open cross-section is used. The chute portion of the impact head incorporates a contact face having a constant angle of bend along its length. The distance between the contact face and the opposing flat plate decreases as the box beam progresses through the impact head. During an end-on impact, the open box beam member is also bent and deflected by the curved plate portion of the impact head. Additionally, it is preferred that the opening of the box beam's cross-section be urged against the contact face, thereby widening the opening. As the impact progresses, the box-beam member is flattened by expansion of the opening in the cross-section. Such flattening assists in bending of the beam member.

In an alternative embodiment, the contact face comprises a plate that is bent along a longitudinal axis such that the angle of the bend changes along the length of the plate.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an isometric view of a first exemplary embodiment for a box beam terminal for a guardrail installation constructed in accordance with the present invention.

FIG. **2** is a cross section taken along lines **2-2** in FIG. **1**.

FIG. **3** is an isometric view of a second exemplary embodiment for a box beam terminal constructed in accordance with the present invention.

FIG. **4** is a cut-away schematic view of an exemplary impact head used in a box beam terminal.

FIG. **5** is an isometric view of a third exemplary embodiment for a box beam terminal constructed in accordance with the present invention.

FIG. **6** is a cross-section of a typical box beam rail member.

FIG. **7** is a side view, partially cut away, of a typical box beam member.

FIG. **8** is an isometric view of a fourth exemplary embodiment for a box beam terminal constructed in accordance with the present invention and wherein an open box beam is utilized.

FIG. **9** illustrates a box beam member and side plate from the terminal shown in FIG. **8** apart from other components.

FIG. **9**A is a cross-sectional depiction of an open box beam having a trapezoidal configuration.

FIG. **10** is a cross-section of the side plate shown in FIG. **9**, taken along lines **10-10** in FIG. **9**.

FIG. **11** is a cross-section of the side plate shown in FIG. **9**, taken along lines **11-11** in FIG. **9**.

FIG. **12** is a cross-section of the side plate shown in FIG. **9**, taken along lines **12-12** in FIG. **9**.

FIG. **13** is a cross-section of the side plate shown in FIG. **9**, taken along lines **13-13** in FIG. **9**.

FIG. **14** is an isometric view of the most preferred embodiment for a box beam terminal constructed in accordance with the present invention.

FIG. **15** is a side view of a side plate used in the box beam terminal shown in FIG. **14**.

FIG. **16** is a front end-on view of the side plate shown in FIG. **15**.

FIG. **17** is a rear end-on view of the side plate shown in FIG. **15**.

FIG. **18** is a plan, cross-sectional view of the box beam terminal shown in FIG. **14**.

FIG. **19** is a side, cross-sectional view of the box beam terminal shown in FIG. **14**.

FIG. **20** is an isometric view of a further alternative embodiment for a box beam terminal constructed in accordance with the present invention.

FIG. **21** is an isometric view of a further alternative exemplary embodiment for a box beam terminal constructed in accordance with the present invention.

FIG. **22** is a schematic plan view of a further alternative exemplary embodiment for a box beam terminal constructed in accordance with the present invention.

FIG. **23** is a cross-sectional view of portions of an impact head and box beam member taken along the lines **23-23** in FIG. **22**.

FIG. **24** is a cross-sectional view of portions of an impact head and box beam member taken along the lines **24-24** in FIG. **22**.

FIG. **25** is a cross-sectional view of portions of an impact head and box beam member taken along the lines **25-25** in FIG. **22**.

FIG. **26** is a cross-sectional view of portions of an impact head and box beam member taken along the lines **26-26** in FIG. **22**.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The concept of the invention is largely described through discussion of currently preferred and exemplary guardrail installations. The present invention provides end treatments for improved safety relating to end-on impacts to box-beam style guardrail installations.

Referring first to FIGS. **1** and **2**, there is shown a first exemplary embodiment for a box-beam style terminal **10**. The terminal **10** includes an impact head **11** having an elongated chute **12** that is disposed at the upstream end of a box beam rail member **14**. As used herein, the term "upstream" refers to the direction from which an impacting vehicle would be expected to approach. The term "downstream" refers to the opposite direction, i.e., the direction toward which an impacting vehicle would be expected to travel. The terminal **10** includes both the impact head **11** and the rail member **14**. The rail member **14** is a box beam rail member having a tubular, non-solid cross section. It is noted that the rail member **14** is supported above the ground (not shown) by a number of support posts **15** and forms one end of an elongated barrier. Typically, the terminal **10** is located alongside a roadway (not shown) or proximate an obstacle (not shown) in a manner known in the art. The impact head **11** includes a chute portion **12** that is encased within the impact head **11**. The impact head **11**, portions of which are shown in phantom in FIG. **1**, provides a striking plate, or striking face, **18** for a vehicle to impact and serves to transmit the force of the impact to the chute portion **12**. Upper and lower plate members **13**, **13***a* structurally join the striking plate **18** to the chute portion **12**. The chute portion **12** is formed of a pair of plate members **20**, **22** that are secured within the head **11**. Each of the side plate members **20**, **22** is substantially vertically disposed. The forward, or upstream, end of the plate member **20** provides a curved plate portion **26** for deflection of a flattened box beam. It is preferred that the plate members **20**,**22** be oriented to converge toward one another in an upstream direction in order to form a tapered section **24** that flattens the box beam rail member **14**. Flattening is accomplished since corners **36** and **40** (see FIG. **2**) are forced to approach each other, and corners **38** and **42** are forced to move away from each other. However, the invention also contemplates placement of the plate members **20**, **22** (as well as other plate members in other embodiments described herein) in a substantially parallel relation to each other so that the chute portion does not squeeze or flatten the box beam rail member **14**. In such a case, the bending and deflection functions of the impact head are carried out by the curved plate portion **26**, albeit in a less efficient manner.

It is noted that, in this embodiment, the box beam rail member **14** is mounted upon the support posts **15** so that opposing corners **36**, **40** of the rail member are engaged by the chute portion **12**. FIG. **2** illustrates that the downstream end of each of the plate members **20**, **22** presents an L-shaped cross-section forming a 90 degree angle for gripping of opposing corners of the box beam rail member **14**. The plate members **20**, **22** are located laterally across from one another. The plate members **20**, **22** slowly flatten out as the upstream end of the plates **20**, **22** are approached until each of the plate members **20**, **22** provide essentially flat surfaces that face one another. The box beam rail member **14**, as shown best in the cross-sectional view of FIG. **6**, presents a square cross-section made up of four sides **28**, **30**, **32**, **34** adjoined to one another at corners **36**, **38**, **40**, **42**. In a presently preferred embodiment, the box beam member **14** has a square cross-section measuring 6 inches on each side. FIG. **7**, a side, partial cross-section, shows that the sides **30**, **34**, etc. of the box beam member **14** have a thickness ("T") that, currently, is preferred to be either 3/16" or 1/8". A rectangular cross-section may also be used for the box beam rail member **14**, if desired. The rail member **14** is referred to as a "closed box beam" because there is no opening on any side of the beam member's cross-section. As best shown in FIG. **2**, the rail member **14** engages the chute portion **12** so that opposing corners (i.e., **36**, **40**) contact the plate members **20**, **22** of the chute portion **12**.

During an end-on collision to the terminal **10**, the striking plate **18** of the impact head **11** is contacted by the impacting vehicle (not shown) and the chute portion **12** is telescopingly forced onto the rail member **14** by the collision force. As the chute portion **12** is forced onto the rail member **14**, the box beam rail member **14** is flattened by the throat **24** so that the two opposing corners **36**, **40** are forced toward one another to cause the angle formed at each corner **36**, **40** to move from one of 90 degrees to a more obtuse angle. Conversely, the remaining corners **38**, **42** begin to form more acute angles. In this manner, the box beam member **14** is flattened by the throat **24**. Vehicular energy at collision is partially dissipated by the energy required to flatten the rail member **14** in this manner. Vehicular energy is also dissipated through the exchange of momentum between the impacting vehicle and the mass of the moving terminal parts. The curved portion **26** of the impact head **11** then engages the upstream end of the flattened box beam member **14** and causes the flattened box beam member **14** portions to be bent and deflected away from the roadway so that no obstacle is presented by the deflected rail member.

The terminal **10** provides a crashworthy end treatment for box beam style guardrails used on the roadside or in the median. The end treatment flattens and bends a tubular box beam member and deflects it away from the colliding vehicle. The energy of the impacting vehicle is partially dissipated through the controlled flattening and bending of a tubular box beam section.

Referring now to FIG. **3**, there is shown an alternative box beam terminal arrangement **50** for use with a box beam rail member **14**. It is noted that like components between the various embodiments shown will share like reference numerals. The terminal **50** includes an impact head **52** having a chute portion **12'** that is made up of a pair of substantially flat plates **20'**, **22'**. The plates **20'**, **22'** converge as the upstream end of the impact head **52** is approached, thereby forming a flattening section.

FIG. **4** shows the impact head **52** in schematic plan view. As illustrated there, the chute portion **12'** has a first width ($w_1$) at its downstream end and a second width ($w_2$) at its upstream end. Preferably, the second width ($w_2$) is one-half or less of the first width ($w_1$). In currently preferred dimensions for the chute portion **12'**, the first width ($w_1$) is 9.5 inches and the second width ($w_2$) is 4.5 inches. To accomplish the needed narrowing, the side plates **20'**, **22'** converge at an angle $\alpha$ of 3.563° over a length (L) of 40 inches. Similar dimensions and angles are useful for constructing the impact head **11** described earlier. Again with reference to FIG. **4**, it is noted that the curved plate portion **26** has a currently preferred radius (R) of 10 inches.

Referring now to FIG. **5**, an alternative box beam terminal **54** is shown wherein an impact head **52** is disposed upon a rail member **14'** that is oriented so that two of the four sides (**30**, **34**) are horizontally disposed. The upstream portion of the rail member **14'** includes a seam or score **56** along the upper and lower sides **30**, **34** (only the seam on the upper side **30** is visible in FIG. **5**). The seams **56** assist an inward collapse of the rail member **14'** during a collision. FIG. **5** illustrates a collapsed and extruded portion **58** of the rail member **14'**. Those of skill in the art will recognize that the box beam rail member **14'** may also be flattened using an impact head having two side plates that are similar to side plates **20'**, **22'** but that have been rotated approximately 45 degrees within the impact head **52**. The flattened box beam would then be extruded outwardly from the impact head in a direction that lies along a 45 degree angle from the ground rather than substantially parallel to the ground. In such a case, the rail would be flattened by compression of opposite corners rather than by compression of opposite sides.

Turning now to FIGS. **8**, **9**, **10**, **11**, **12**, and **13**, there is shown a further box beam terminal **60**. This embodiment features an "open" box beam member **62** in place of the closed box beam members **14**, **14'** described earlier. The open box beam member **62** has three solid faces **64** and one open face **66**. An open box beam member may have a cross-sectional configuration that is square or rectangular. In addition, an open box beam member may have a trapezoidal cross-sectional configuration, such as the open box beam member **62'** illustrated in FIG. **9**A. Such a configuration is common today in parts of Europe. A trapezoidal open box beam has an open side **66** that is longer than the opposing side **64** and, as a result, forms a trapezoidal shape.

When disposed alongside a roadway as part of a guardrail assembly, the box beam member **60** is oriented so that the open face **66** faces away from the roadway. The box beam terminal **60** also includes a chute portion **70** and an impact head, which is shown generally at **72**. The chute portion **70** includes two side plates **74**, **76** that define a flattening section **78**. One of the side plates **74** has a curved forward portion **26**. The other side plate **76** is bent along its longitudinal axis to present a tapered angular cross section with an angular face **80** that is presented toward the other side plate **74**. FIG. **9** depicts the side plate **76** and open box beam member **62** apart from other components. FIGS. **10-13** are cross-sections of the side plate **76** and illustrate the effect of forceful contact by the side plate **76** against the open face **66** of the box beam rail member **62**. As can be appreciated by reference to these Figures, the angular face **80** is made up of upper and lower faces **82**, **84** that are oriented to form an angle to one another that changes depending upon the location along the plate **76**. The angle formed between the faces **82**, **84** becomes less acute as the upstream end of the terminal **60** is approached. As the exemplary cross-sections of FIGS. **10-13** show, the angle formed varies from 120 degrees to 180 degrees.

During an end-on collision to the impact head **72** of the terminal **60**, the open box beam member **62** is forced into the flattening section **78** of the chute portion **70**. The box beam member **62** is flattened by a narrowing of the throat **78** that occurs as the upstream end of the chute portion **70** is reached. This flattening helps to cause structural collapse of the box beam member **62**. In addition, engagement of the open face **66** with the angular face **80** assists in structural collapse of the box beam member **62**. As the box beam member **62** is urged toward the upstream end of the chute portion **70**, the increase in angle between the upper and lower faces **82**, **84** results in the open face **66** of the box beam member **62** being deformed and opened to a greater degree. The curved portion **26** of the side plate **74** bends the deformed and collapsed beam member **62** away from terminal **60**.

Referring now to FIGS. **14**, **15**, **16**, **17**, **18**, and **19**, there is shown a further, and currently most preferred, embodiment for the box beam terminal of the present invention. Terminal **100** includes an impact head **102** and an open box beam member **62**. In many respects, the terminal **100** is constructed and operates in a manner similar to the terminal **60** described and shown in FIGS. **8-13**. In this embodiment, however, the impact head **102** includes an impact plate **18** that is secured by upper and lower plates **13**, **13***a* to a chute portion **104**. The chute portion **104** is made up of upper and lower hot or cold rolled channel members **106**, **108** that are shaped and sized to receive the box beam rail member **62** therebetween. A bracket **110** is secured to the upper channel member **106** to help in affixing the impact head **102** to a support post **15**. A side plate **112** is disposed between the upper and lower plates **13**, **13***a*, the structure of which is shown in greater detail in FIGS. **15**, **16**, and **17**. The side plate **112** is bent along bend line **114** to present contact faces **116**, **118**. The two contact faces **116**, **118** preferably lie at an angle of about 150° from one another. The side plate **112**, and each of the contact faces **116**, **118**, has a decreased width at the downstream end **120** of the plate **112** than at the upstream end **122** of the plate **112**. Currently, the preferred width of the plate **112** at the upstream end **122** is about 18½ inches while the width at the downstream end **120** is about 11½ inches. The side plate **112** has a currently preferred length "L" of about 12¼ inches, and the preferred thickness of the plate is ⅜ inches.

An opposing side plate **124**, most clearly seen in FIG. **18** is integrally formed with the curved plate portion **26**. The two side plates **112**, **124** converge as the upstream end of the impact head **102** is approached so that a flattening section **126** is formed therebetween. During an end-on collision to the upstream end of the impact head **102**, the rail member **62** is flattened within the section **126** formed between the two side plates **112**, **124**. The flattened beam member is then bent by the curved plate portion **26** in a manner previously described.

The downstream end of each of the channel members **106**, **108** has an outwardly flared portion **128** that assists in handling of the impact head **102** during insertion of the box beam rail member **62** upon installation and prevents edges of downstream segments of box beam rail (not shown) from snagging abruptly on the ends of the channel member **106**, **108** as the impact head **102** moves downstream. The outwardly flared portions **128** are useful for manually gripping the head **102** and sliding it with respect to the box beam rail member **62**. Additionally, brackets **130** are used to interconnect the downstream ends of the channel members **106**, **108**. The brackets **130** are preferably welded to each of the channel members **106**, **108** and include rearwardly and outwardly divergent portions **132**. The divergent portions **132** are useful for contacting and breaking support posts **15** that are located downstream of the impact head **102** during an impact. The divergent portions **132** are also useful to prevent snagging of edges of downstream segments of box beam (not shown) on the brackets **130** as the impact head **102** is moved downstream during a vehicular impact. It is pointed out that the brackets **130**, divergent portions **132**, and outwardly flared portions **128** may be incorporated into any of the embodiments of impact heads described herein, as well.

FIGS. **20** and **21** depict two additional alternative box beam terminals **150**, **152** that have been constructed in accordance with the present invention. The terminal **150** (FIG. **20**) is similar in many respects to the terminal **54** illustrated in FIG. **5**. The box beam member **14'** is a closed box beam that is mounted so that two of its sides are horizontally disposed, or normal to the longitudinal axis of the support posts **15**. However, the chute portion **24** in head **154**, including side plates **20**, **22** and curved plate portion **26**, has been rotated about the axis of beam member **14'** approximately 45 degrees from the its previous position, illustrated in FIG. **5**. As a result, the beam member **14'** is engaged by and subjected to flattening by the chute portion **24** by compressing opposing corners rather than opposing sides, as was the case in terminal **54**. While FIG. **20** shows the downstream ends of side plates **20**, **22** as being flat, it should be understood that they may also form angles for gripping opposing corners of the rail member **14'** in a manner similar to that shown in FIGS. **1** and **2**. It is noted that, when the chute portion **24** is oriented as shown in FIG. **20**, i.e., having been rotated about the axis of the beam **14'**, the rail member **14'** is deflected and extruded from the impact head **154** in a more upwardly direction than with the previous devices described. Specifically, the rail member **14'** will exit the impact head in a direction that forms an approximate 45 degree angle with respect to the ground as well as approximately 45 degrees with the vertical.

FIG. **21** depicts box beam terminal **152**, which is a variant of the terminal **150** shown in FIG. **20**. The box beam terminal **152** uses an impact head **154** that has been constructed with a chute portion **24** that has been rotated 45 degrees, like terminal **150**. However, the box beam rail member **14** also has been rotated 45 degrees about its axis so that none of the four sides of the beam member **14** is horizontally disposed. In the terminal **152**, the impact head **154** will engage the box beam member **14** so that it will be compressed upon opposite sides rather than opposite corners.

FIGS. **22-26** schematically illustrate still a further alternative box beam terminal embodiment **160** constructed in accordance with the present invention. The terminal **160** features an impact head **162** that is disposed upon the upstream end of a closed box beam rail member **14'**. The impact head **162** includes a chute portion **24** that has two side plates **20**,**22** as well as upper and lower plates **166**, **168**, respectively, all of which are interconnected (as shown in FIGS. **23-26**) so as to provide a closed cross-section. Proximate the downstream opening for the chute portion **24**, the side plates **20**, **22** have a height "a", and the upper and lower plates **166**, **168** have a width "b" (see FIG. **23**). However, as the upstream end of the impact head **162** is approached, the height of the side plates **20**, **22** increases, as illustrated by the dimensions a+, a++, and a+++in FIGS. **24**, **25**, and **26**. Conversely, the width of the upper and lower plates **166**, **168** decreases, as illustrated by the dimensions b–, b––, and b––– in FIGS. **24**, **25**, and **26**. The chute portion **24** incorporates tapered deflection bars **170** (visible in FIGS. **24-25**) that are mounted on the side walls **20**, **22** of the chute portion **24**. The deflection bars **170** engage opposing sides **28**, **32** of the box beam member **14'**. As the impact head **162** is moved downstream onto the beam member **14'**, the sides

28, 32 are deformed and deflect inwardly toward one another. This deflection causes the upper and lower sides 30, 34 of the beam member 14' to be deflected outwardly, as FIGS. 24-26 depict. When the beam member 14' is cross-sectionally deformed in this manner, it becomes easier for the curved plate portion 26 to bend and deflect the beam member 14'. As the box beam member 14'is forced upstream beyond the cross-section shown in FIG. 25, the deflected shape of the beam member 14' and the decreasing width dimension "b" of the upper and lower plates 166, 168 are sufficient to cause the beam member to continue to flatten.

FIG. 26 illustrates a further feature that can assist the impact head 160 in collapsing and bending the beam member 14'. Plastic hinges 172 are shown formed into the walls of the box beam member 14'. The plastic hinges 172 contribute to the dissipation of the impacting vehicle's energy in the form of strain energy. Vehicular energy is also dissipated through friction between the box beam 14' and the deflection bars 170 as well as through friction between the box beam member 14' and other portions of the chute 24. Vehicular energy is further dissipated by further deformations of the flattened box beam as it is forced around the curved deflector section of the terminal.

Box beam terminals constructed in accordance with the current invention provide for a controlled, uniform deceleration of an impacting vehicle. The variability of impact force on the vehicle associated with such deceleration is greatly reduced with the new invention. Long, slender telescoping tubes, such as those used in some prior art systems, can have stability problems when impacted in an eccentric manner. Such stability problems can restrict the telescoping behavior. Crushable composite tubes are also subject to manufacturing variability, which can influence the magnitude of the crush force. Further, the decelerations resulting from staged composite tube design are sensitive to vehicle mass and impact speed. The current invention minimizes stability issues. Material costs are also reduced with the present invention, particularly over systems that utilize more expensive or difficult to obtain materials, such as fiber-reinforced composite tubes.

Those of skill in the art will recognize that numerous modifications and changes may be made to the exemplary designs and embodiments described herein and that the invention is limited only by the claims that follow and any equivalents thereof.

What is claimed is:

1. A box beam rail terminal comprising:

a rail member having four sides and an upstream end, the four sides positioned substantially orthogonal to each other to define a substantially box-shaped rail member;

an impact head mounted on the upstream end of the box beam rail member, the impact head comprising:

a striking plate for receiving an impacting vehicle;

a chute portion having a pair of converging side plates for receiving the upstream end of the box-shaped rail member, each side plate positioned proximate an opposing side of the box-shaped rail member, the pair of converging side plates compressing the opposing sides of the box-shaped rail member toward each other to flatten the box-shaped rail member during a substantially end-on collision; and

a curved plate portion for bending and deflecting a portion of the box-shaped rail member.

2. A box beam rail terminal comprising:

a longitudinal box beam rail member comprising four sides and presenting an upstream end, the four sides positioned substantially orthogonal to each other to define a substantially box-shaped rail member;

an impact head mounted on the upstream end of the box beam rail member, the impact head comprising:

a striking plate for receiving an impacting vehicle;

a chute portion comprising a pair of side plates for receiving the upstream end of the box beam rail member, the pair of side plates configured to flatten the box beam rail member by compressing opposing sides of the box beam rail member toward each other; and

a curved plate portion for bending and deflecting a portion of the rail member.

3. The box beam rail terminal of claim 2, wherein the pair of side plates converge in an upstream direction.

4. The box beam rail terminal of claim 2, further comprising a deflection bar mounted upon at least one of the pair of side plates, the deflection bar positioned to engage and deform one of the four sides of the box beam rail member.

5. The box beam rail terminal of claim 2, wherein the box beam rail member comprises a closed box beam member having a closed cross-section.

6. The box beam rail terminal of claim 2, wherein the first and second side plates each comprise substantially flat plates.

7. The box beam rail terminal of claim 2, wherein the four sides of the longitudinal box beam rail member comprise a first pair of opposing sides and a second pair of opposing sides, and wherein the pair of side plates of the chute converge to compress the second pair of sides of the box beam rail member toward each other to flatten the longitudinal box beam rail member.

8. The box beam rail terminal of claim 7, wherein at least one of the first pair of sides includes a score along an upstream portion of the longitudinal box beam rail member, the score assisting an inward collapse of the rail member during a collision.

9. The box beam rail terminal of claim 7, wherein at least one of the first pair of sides includes a seam along an upstream portion of the longitudinal box beam rail member, the seam assisting an inward collapse of the rail member during a collision.

10. The box beam rail terminal of claim 7, wherein:

the first pair of sides of the longitudinal box beam rail member are substantially horizontally disposed;

the second pair of sides of the longitudinal box beam rail member are substantially vertically disposed; and

the first and second side plates of the chute are substantially vertically disposed.

11. The box beam rail terminal of claim 7, wherein none of the first pair of sides and the second pair of sides of the longitudinal box beam rail member are horizontally disposed.

12. The box beam rail terminal of claim 2, wherein the chute portion further comprises an upper plate and a lower plate, the upper plate, the lower plate, and the pair of side plates coupled to form a closed cross-section.

13. The box beam rail terminal of claim 12, wherein:

the chute portion has an upstream end and a downstream end;

the pair of side plates having a first height at the downstream end and a second height at the upstream end, the second height greater than the first height; and

the upper and lower plates each having a first width at the downstream end and a second width at the upstream end, the second width less than the first width.

**14**. A box beam rail terminal comprising:

a longitudinal box beam rail member having four sides coupled to form a substantially tubular rail member;

an impact head comprising:

a striking plate for receiving an impacting vehicle; and

a flattening portion for flattening and bending the substantially tubular rail member during a substantially end-on collision, the flattening portion having a pair of converging contact faces for contacting and compressing opposing sides of the substantially tubular rail member toward each other.

**15**. The box beam rail terminal of claim **14** wherein, the flattening portion comprises:

a first side plate and a second side plate that converge in an upstream direction; and

a curved plate.

**16**. The box beam rail terminal of claim **15**, further comprising a deflection bar mounted upon at least one of the first and second side plates, the deflection bar positioned to engage and deform one of the four sides of the box beam rail member.

**17**. The box beam rail terminal of claim **15**, wherein the first and second side plates each comprise substantially flat plates.

**18**. The box beam rail terminal of claim **15**, wherein the four sides of the longitudinal box beam rail member comprise a first pair of opposing sides and a second pair of opposing sides, and wherein the pair of side plates of the chute converge to compress the second pair of sides of the box beam rail member toward each other to flatten the longitudinal box beam rail member.

**19**. The box beam rail terminal of claim **18**, wherein:

the first pair of sides of the longitudinal box beam rail member are substantially horizontally disposed;

the second pair of sides of the longitudinal box beam rail member are substantially vertically disposed; and

the first and second side plates of the chute are substantially vertically disposed.

**20**. The box beam rail terminal of claim **18**, wherein none of the first pair of sides and the second pair of sides of the longitudinal box beam rail member are horizontally disposed.

**21**. The box beam rail terminal of claim **15**, wherein the flattening portion further comprises an upper plate and a lower plate, and wherein the upper plate, the lower plate, and the pair of side plates are coupled to form a closed cross-section.

**22**. The box beam rail terminal of claim **21** wherein:

the flattening portion has an upstream end and a downstream end;

the pair of side plates having a first height at the downstream end and a second height at the upstream end, the second height greater than the first height; and

the upper and lower plates each having a first width at the downstream end and a second width at the upstream end, the second width less than the first width.

**23**. The box beam rail terminal of claim **14**, wherein at least one of the four sides includes a score along an upstream portion of the longitudinal box beam rail member, the score assisting an inward collapse of the rail member during a collision.

**24**. The box beam rail terminal of claim **14**, wherein at least one of the four sides includes a seam along an upstream portion of the longitudinal box beam rail member, the seam assisting an inward collapse of the rail member during a collision.

* * * * *