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(54) BUCKLING AND SHEARING OPPOSING REINFORCEMENT BRACKET FOR WOODEN I-JOIST

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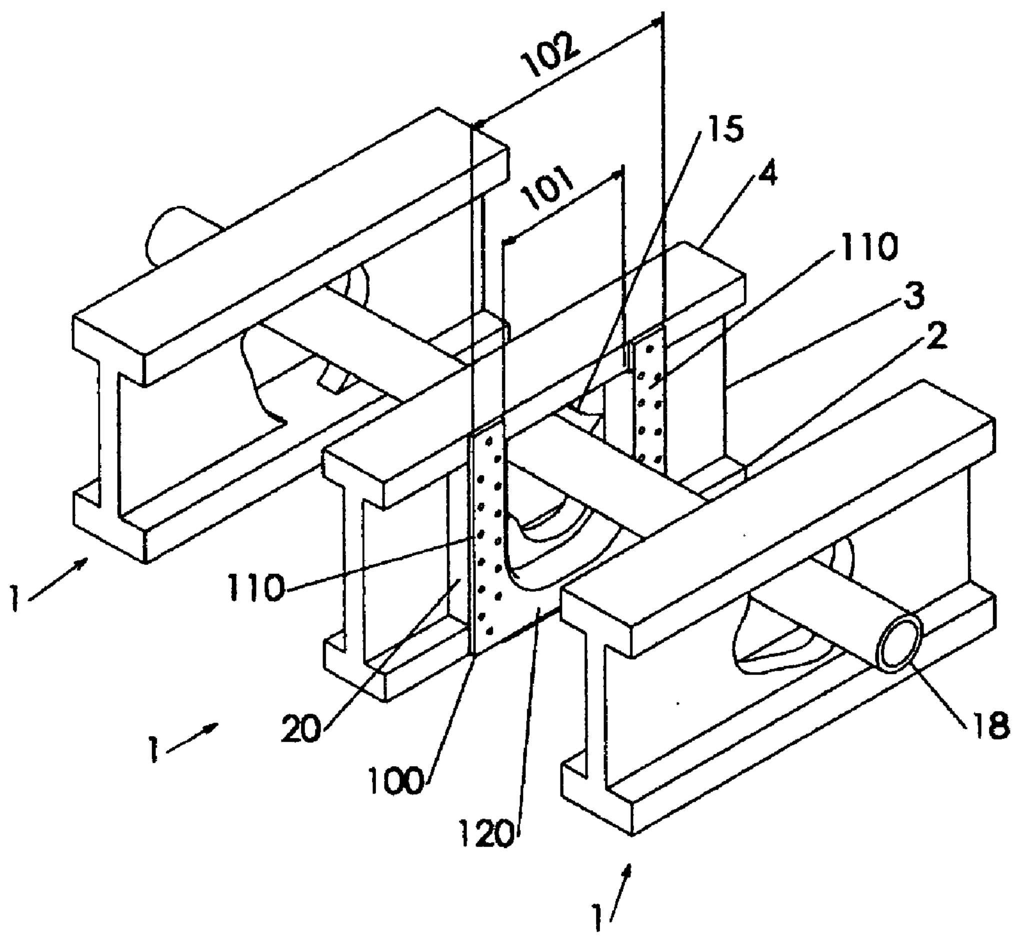
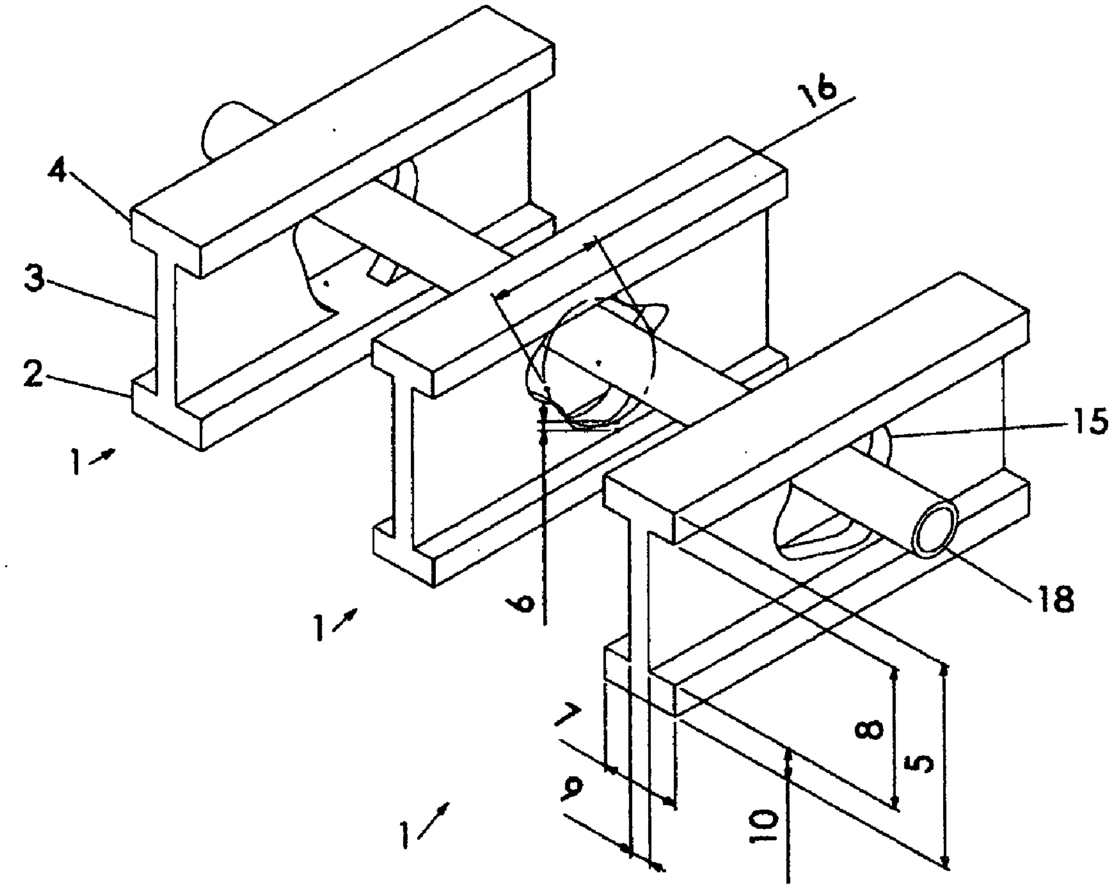
(52) U.S. Cl. 52/1

(57) ABSTRACT

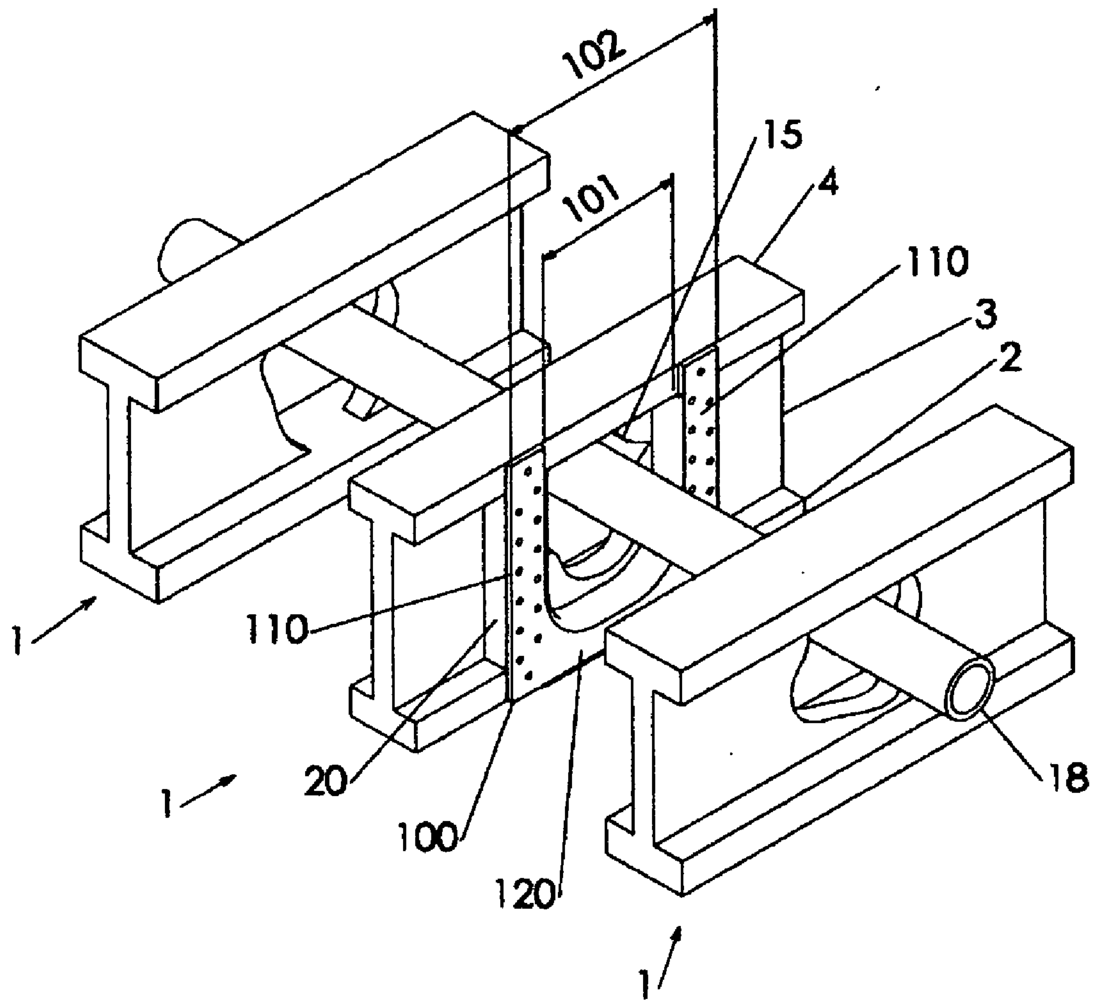
A reinforcement bracket is provided for buckling and shearing opposing support of a wooden I-joist. The reinforcement bracket may have two substantially parallel bridging structures combined by a spacing structure while providing a central contour recess. In the case where a hole is cut into a wooden I-joist in size and/or at a location exceeding the I-joist's safety standards, the reinforcement bracket may be laterally attached to the I-joist such that both bridging structures flank the cut hole while the cut hole remains accessible due to the central contour recess. The central recess contour provides thereby for a simple attachment at a construction site irrespective an eventual pipe or the like protruding through the cut hole. The reinforcement bracket is preferably monolithically fabricated from sheet metal and scaled in conjunction with dimensional standards of commercially available wooden I-joists.





Prior Art

Fig. 1



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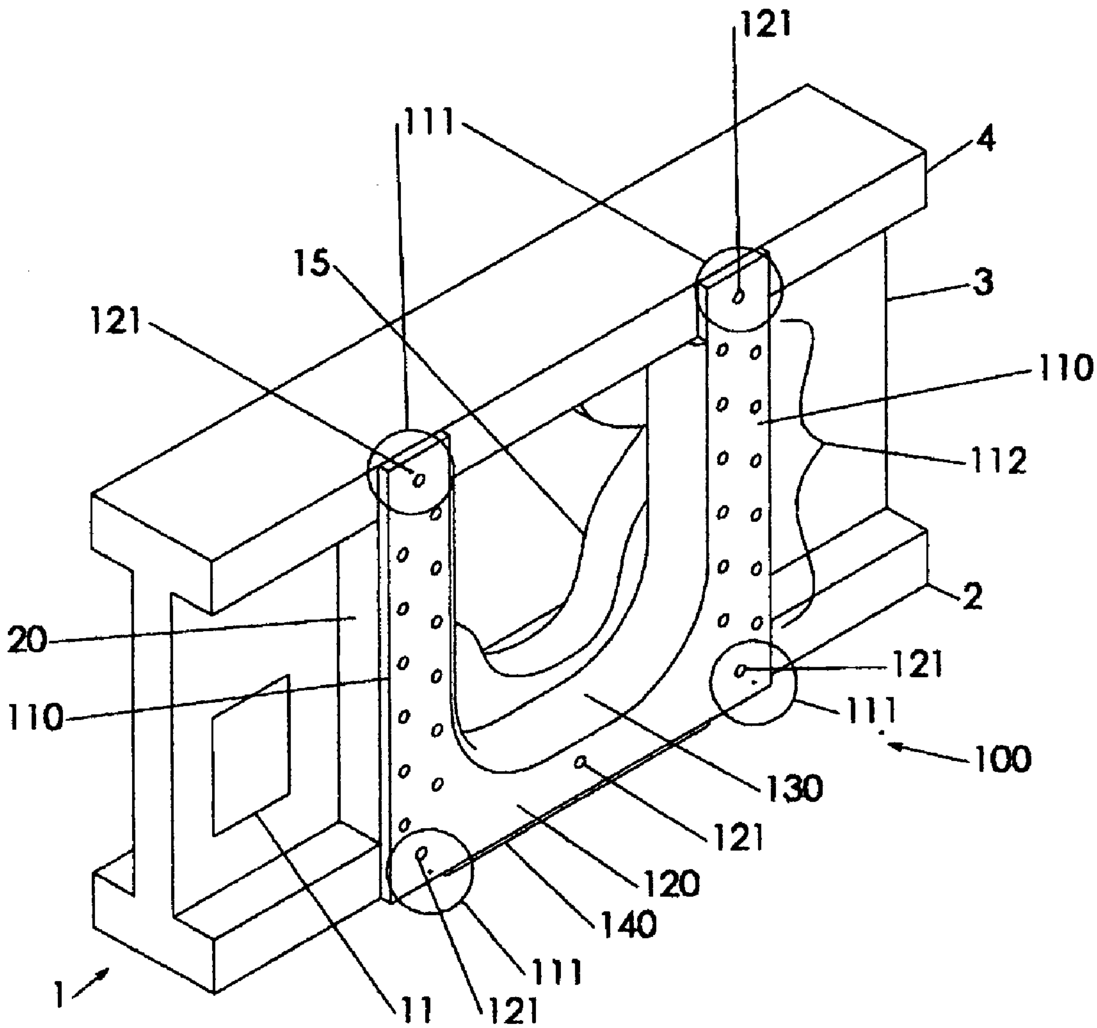
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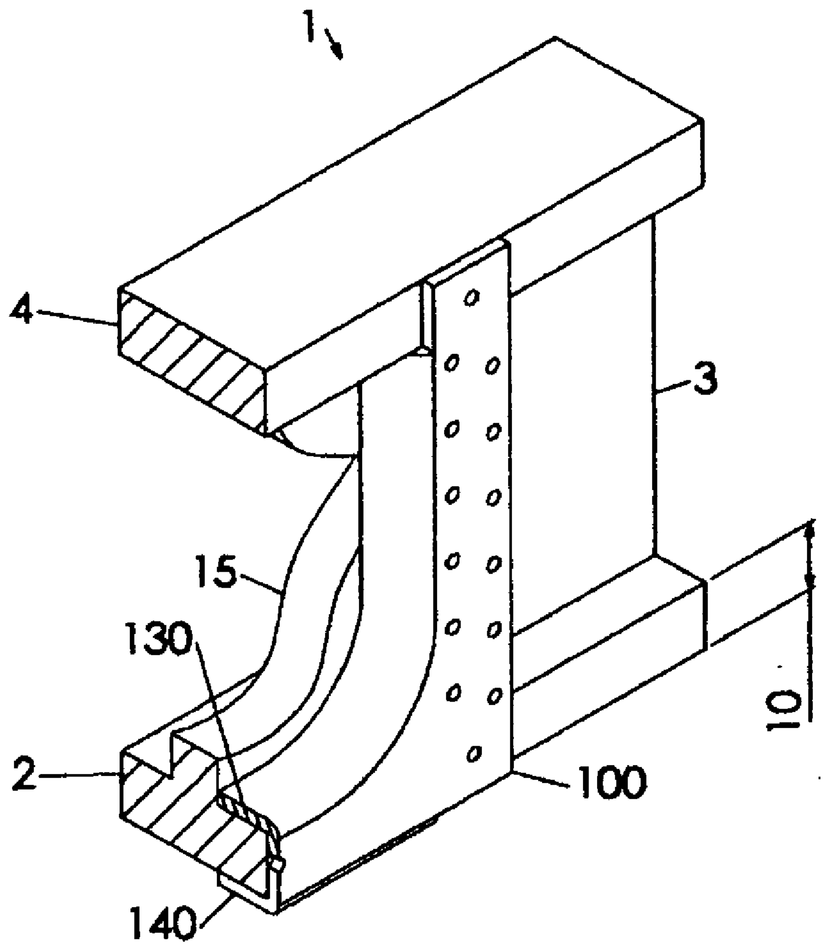
Fig. 3



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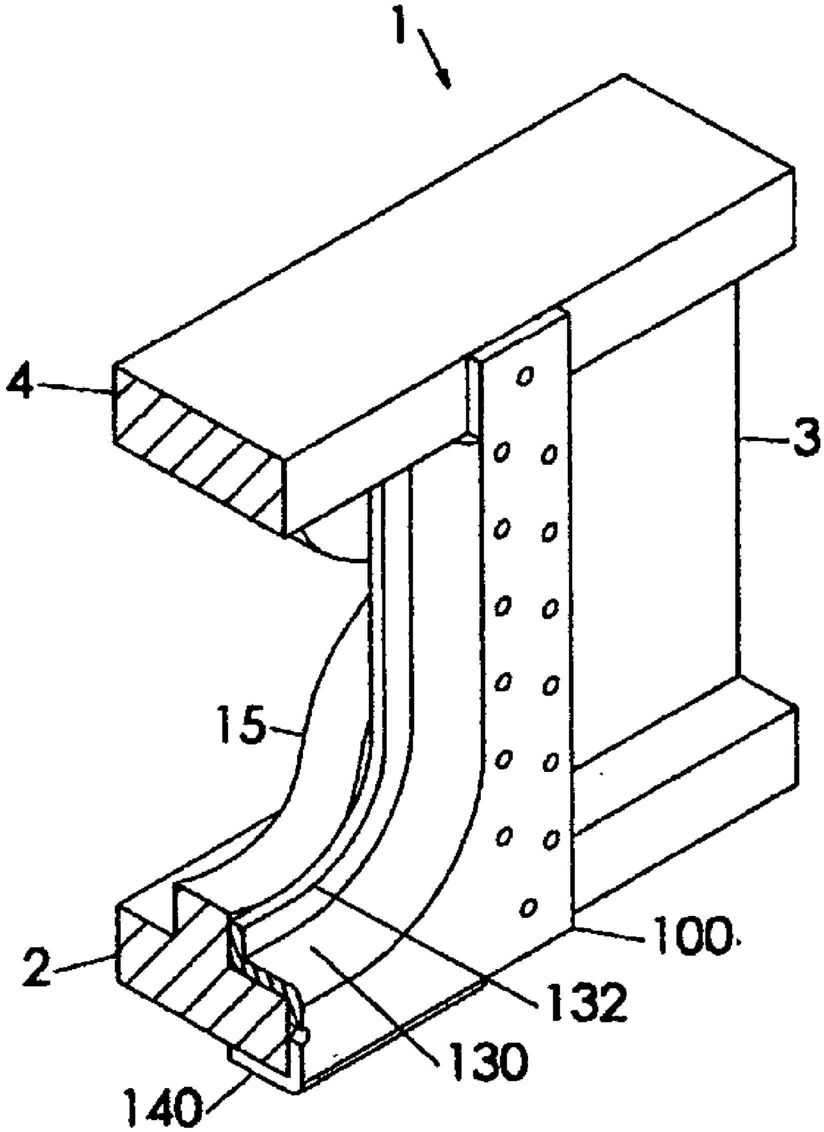

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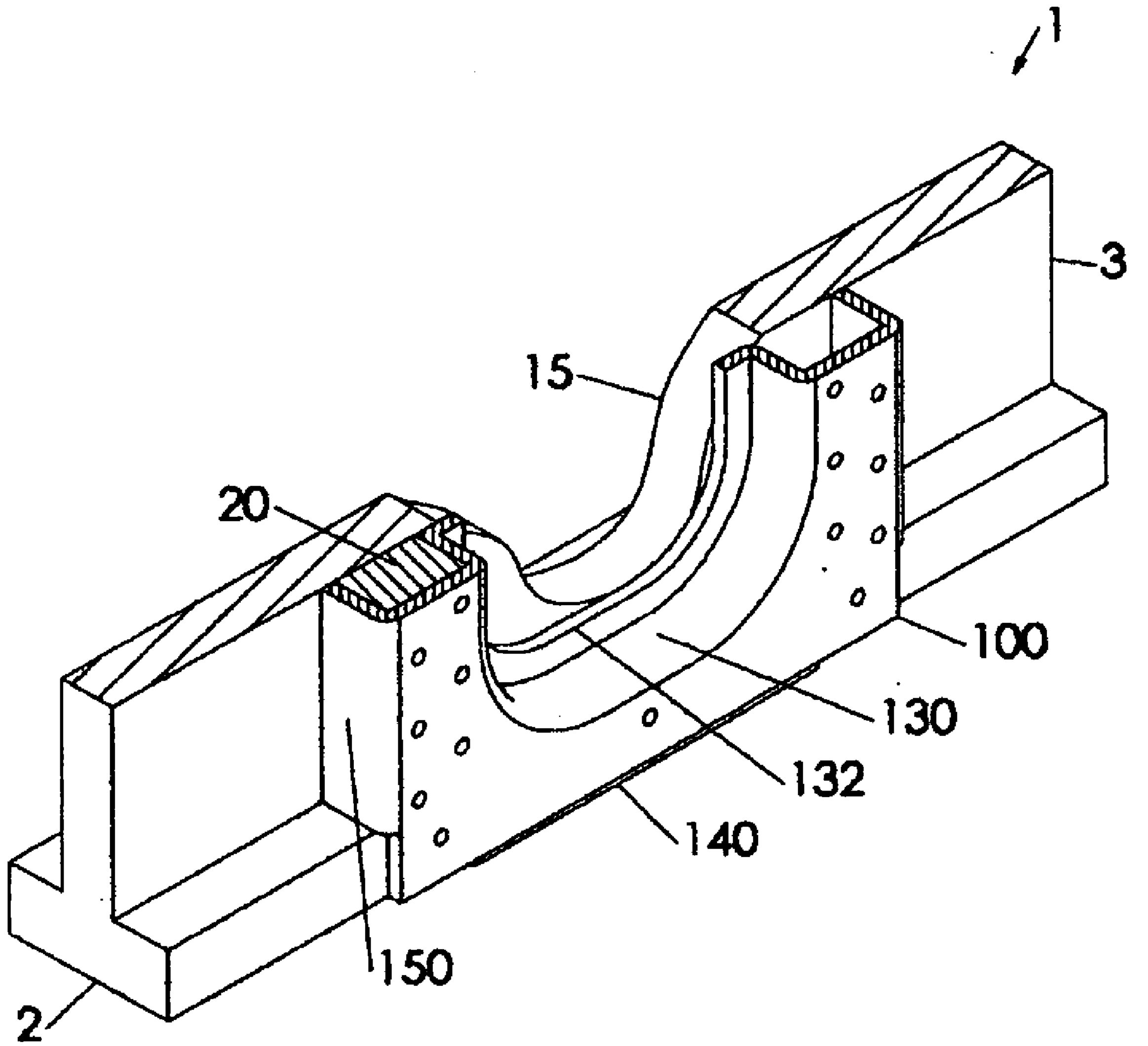

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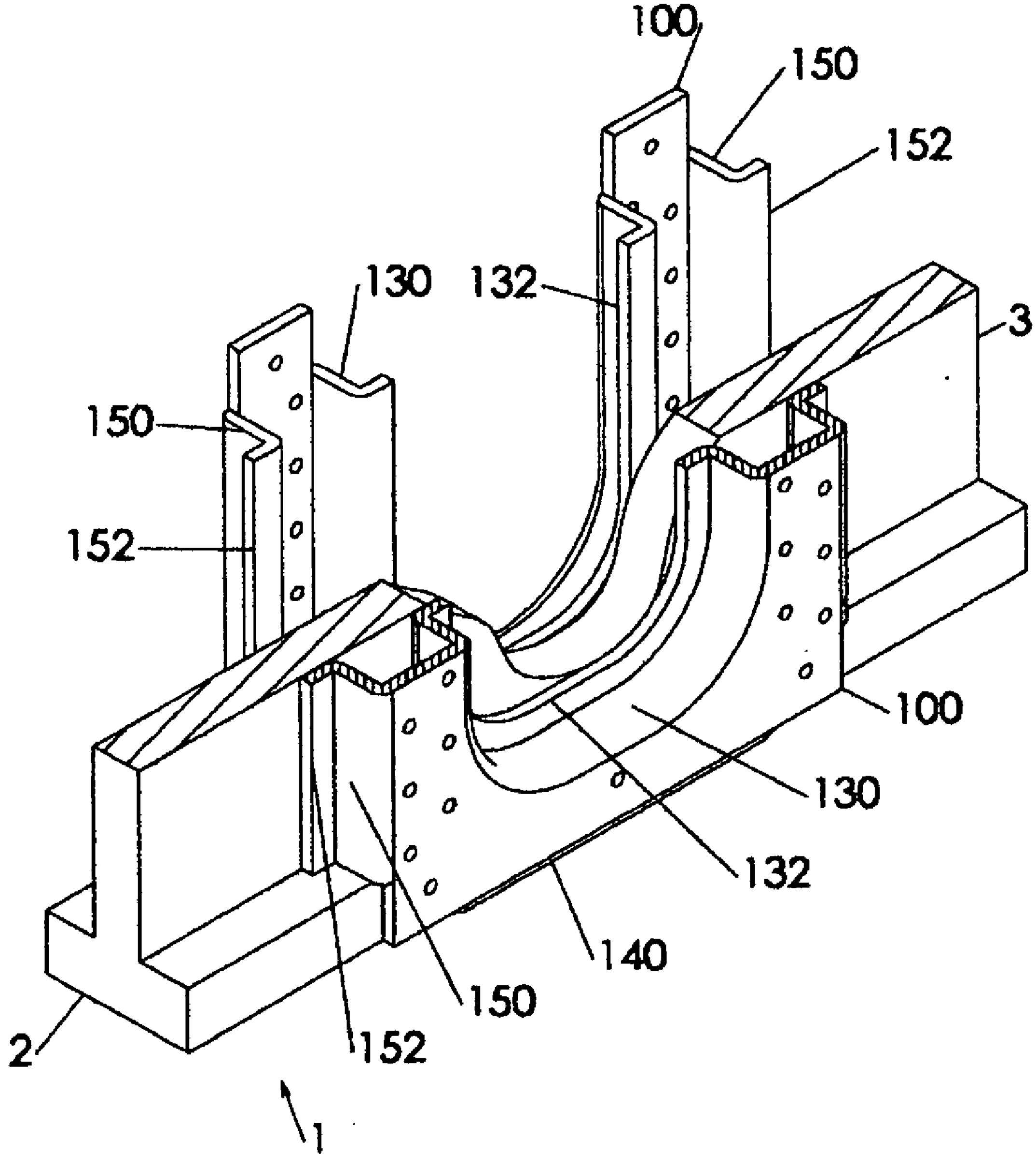

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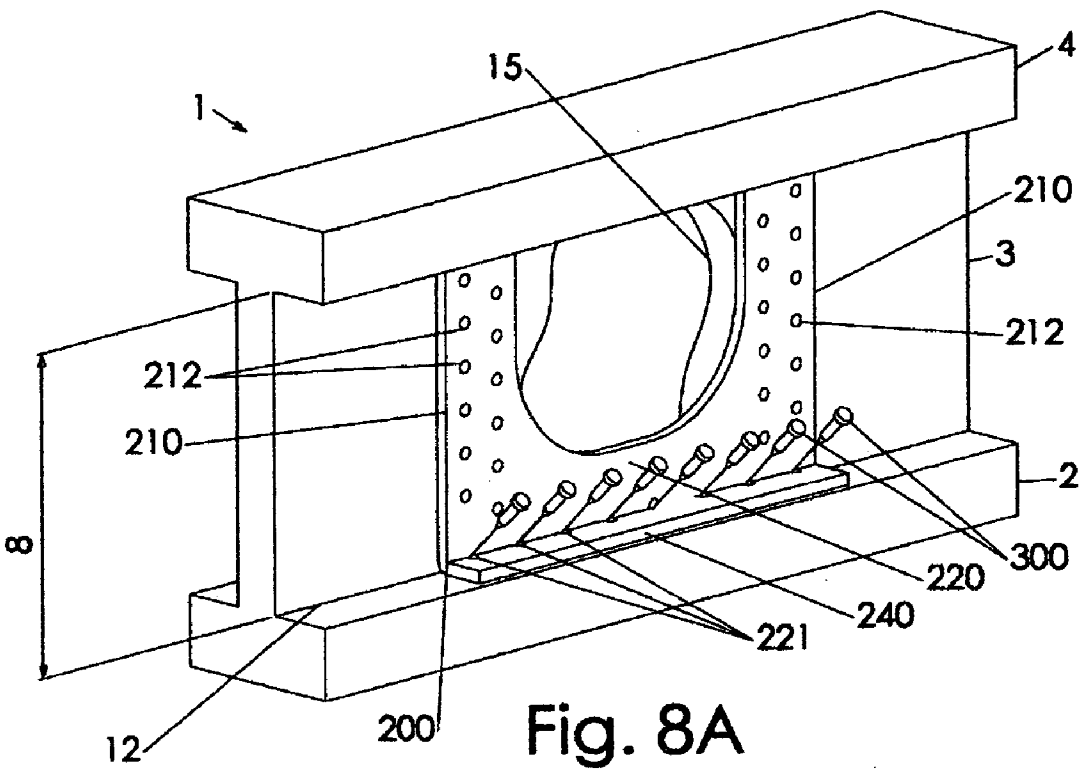
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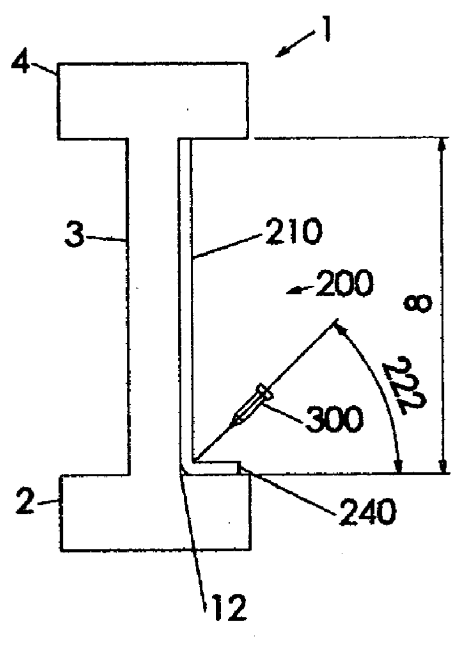
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Fig. 8B

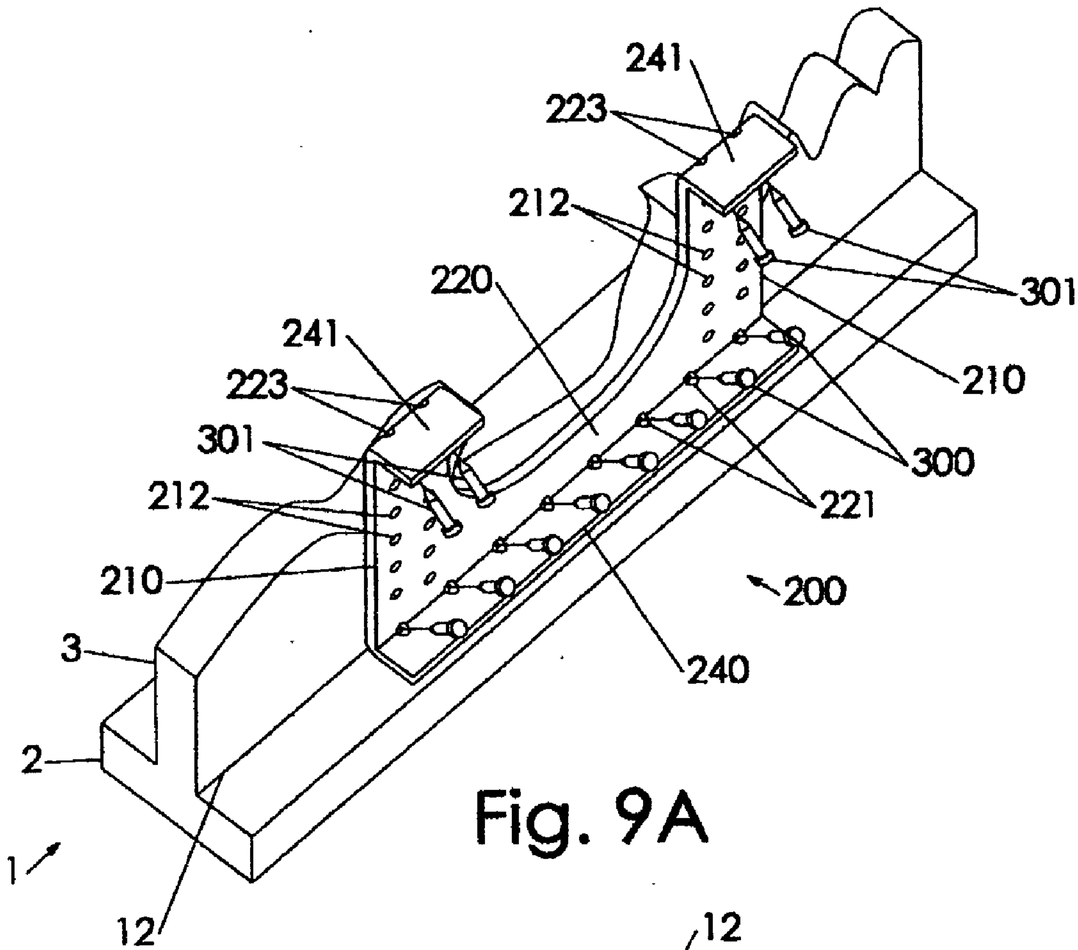
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Fig. 9A

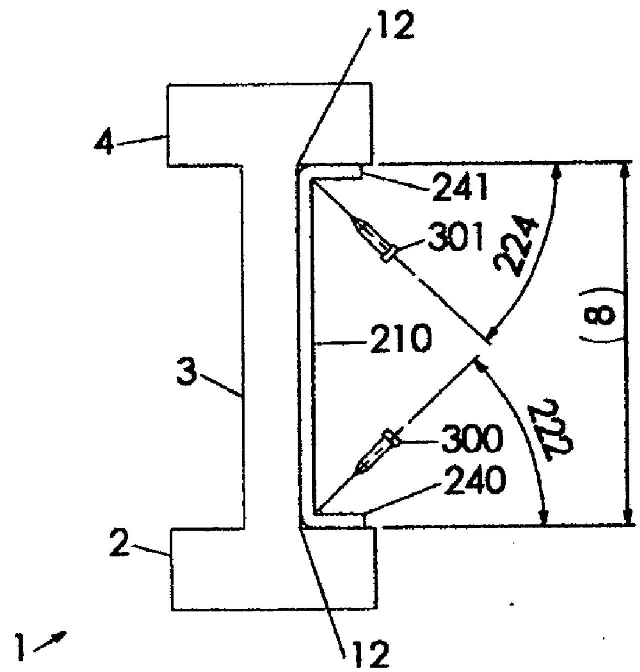
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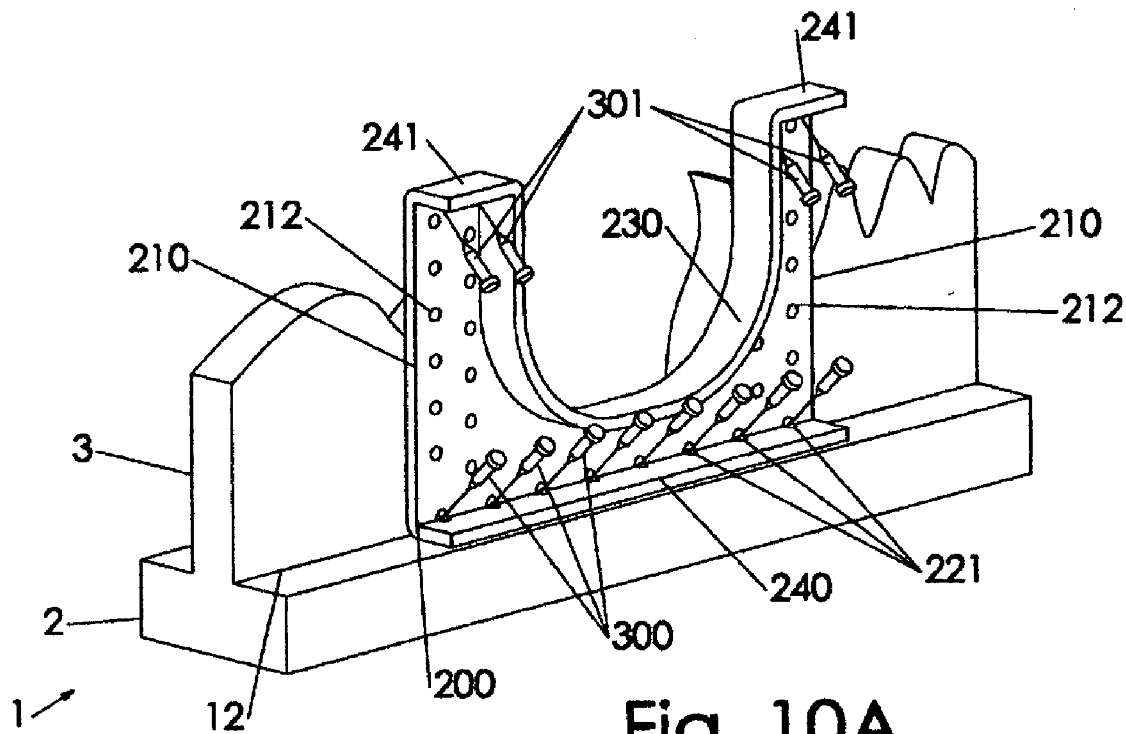
Fig. 9B



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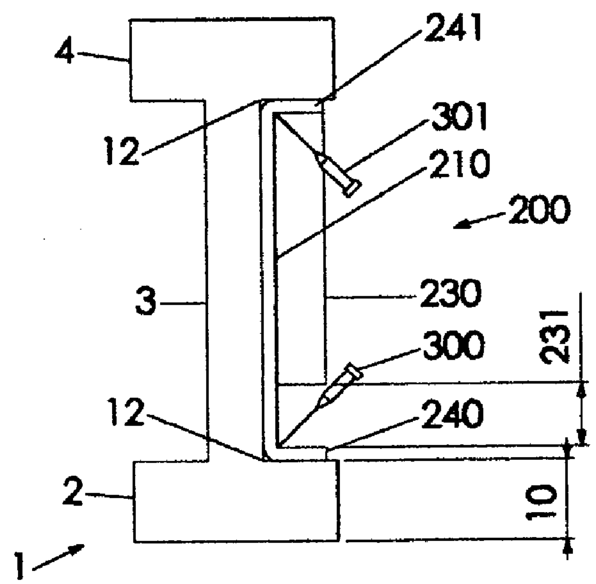

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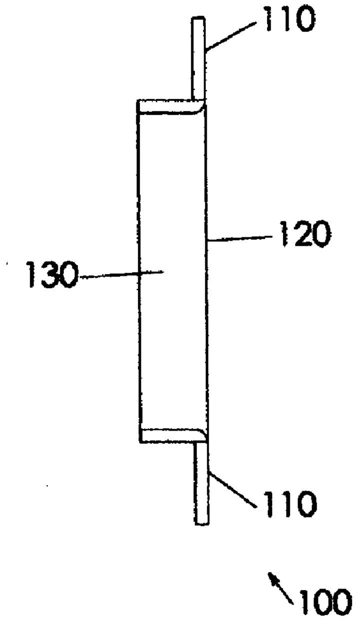

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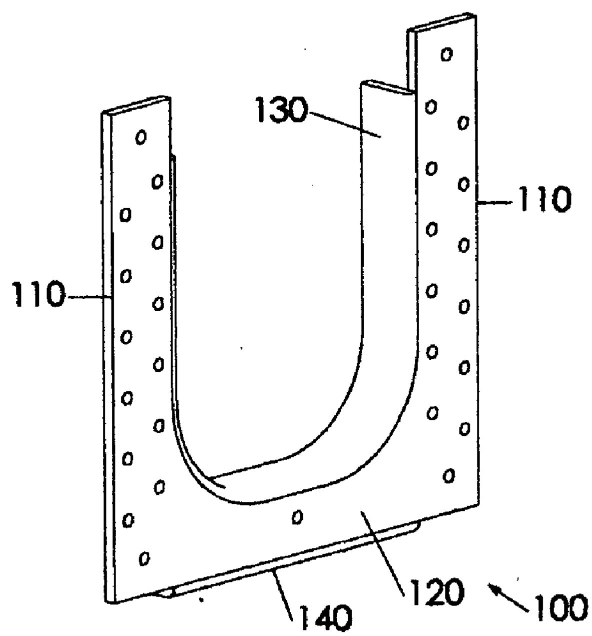

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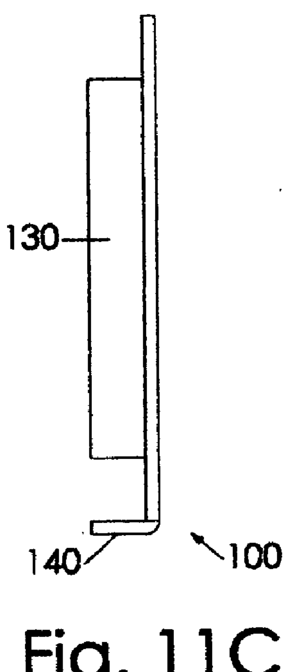

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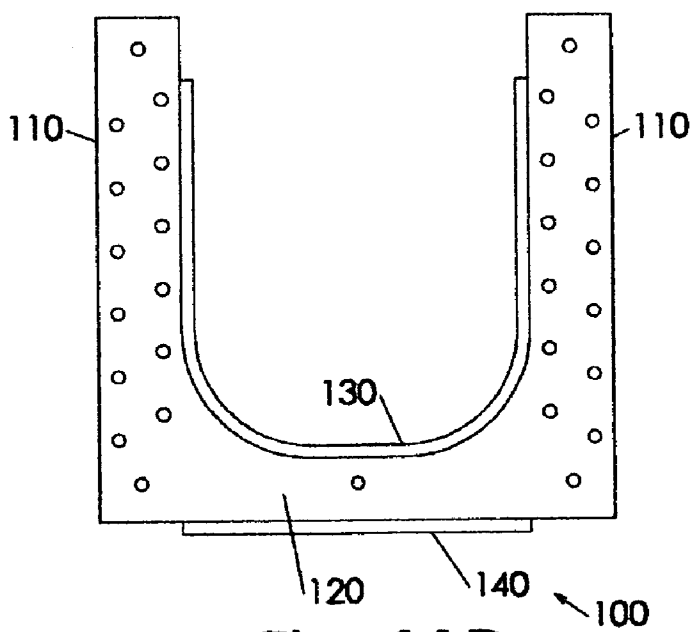

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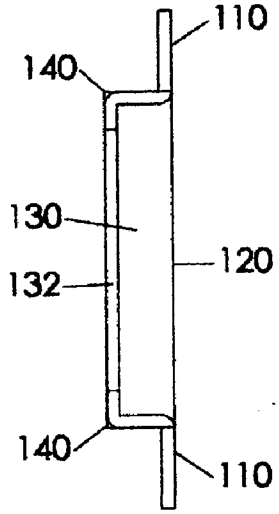

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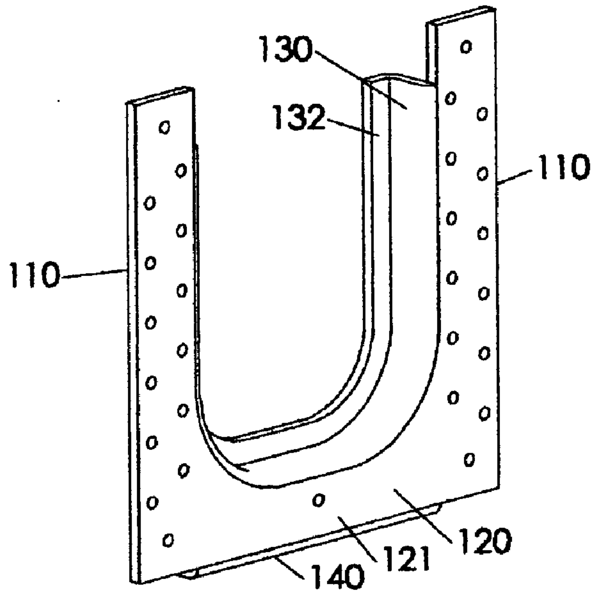

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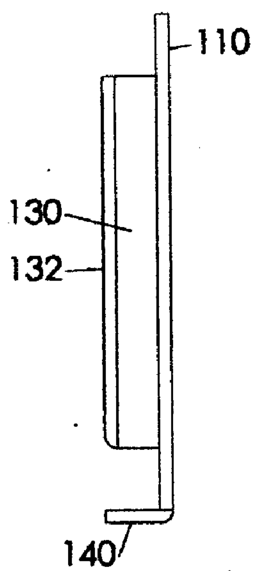

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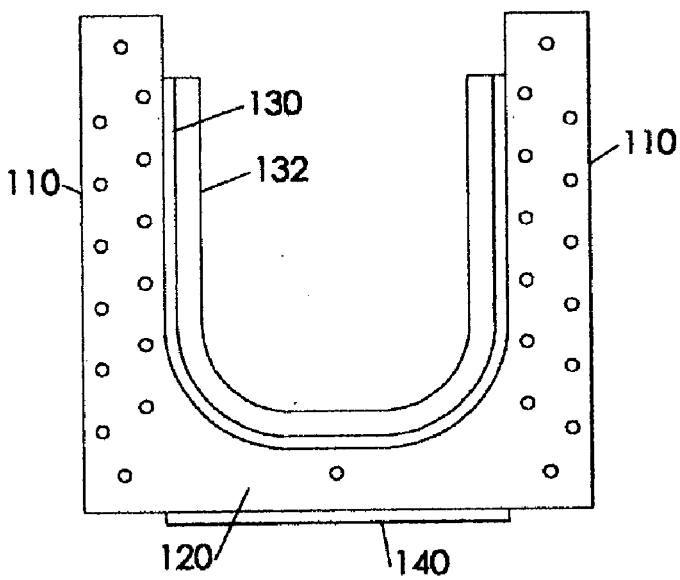

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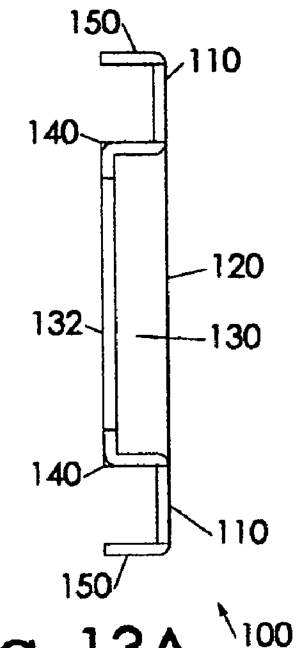

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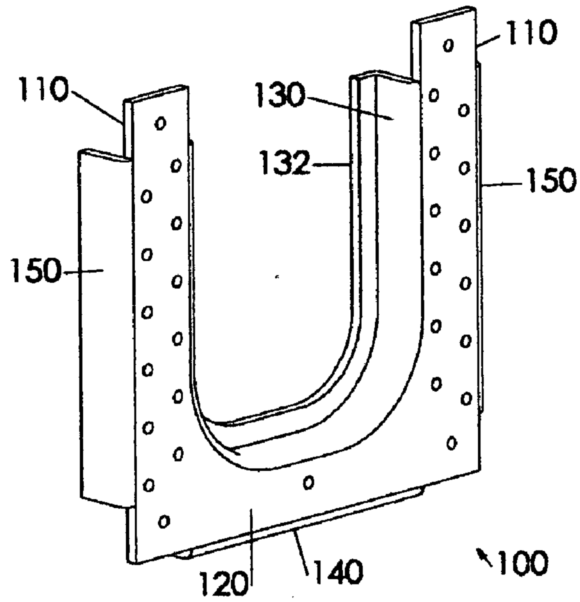

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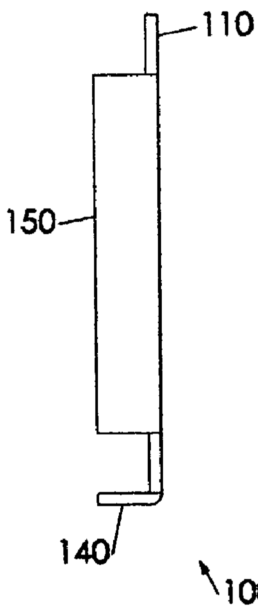

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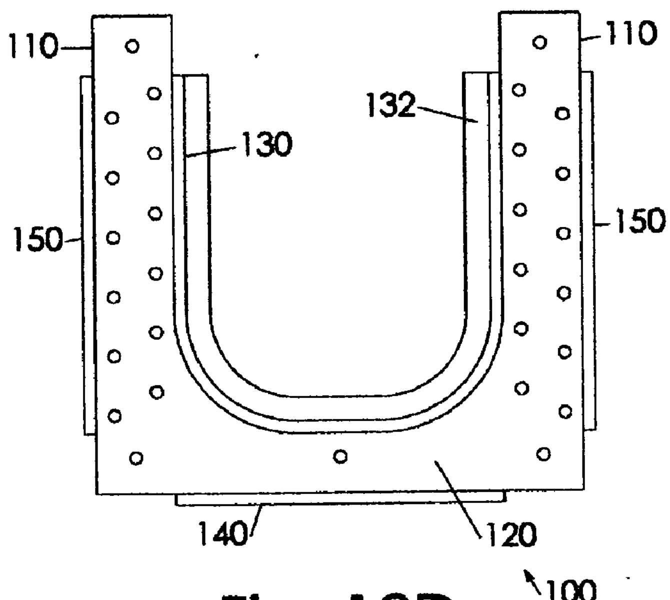

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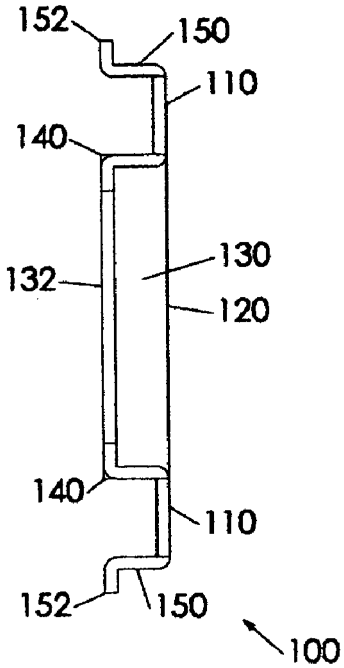

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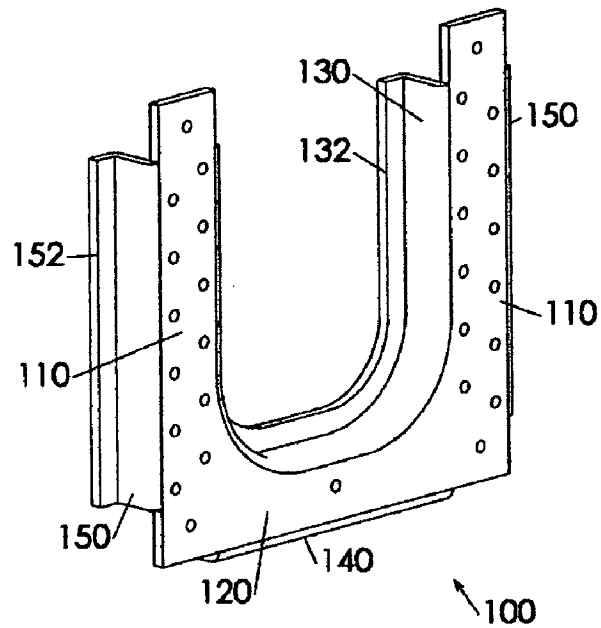

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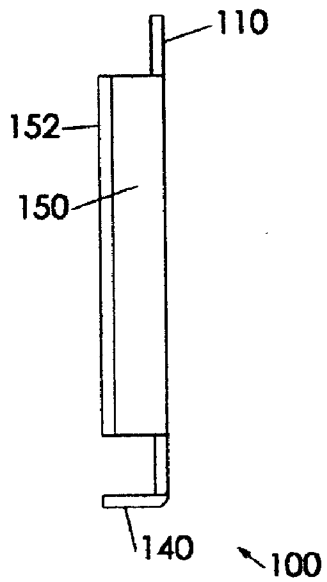

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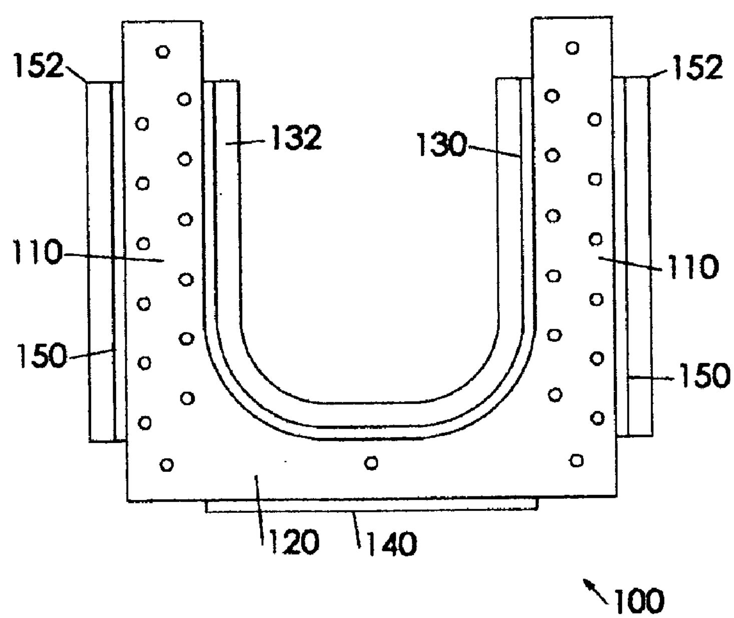

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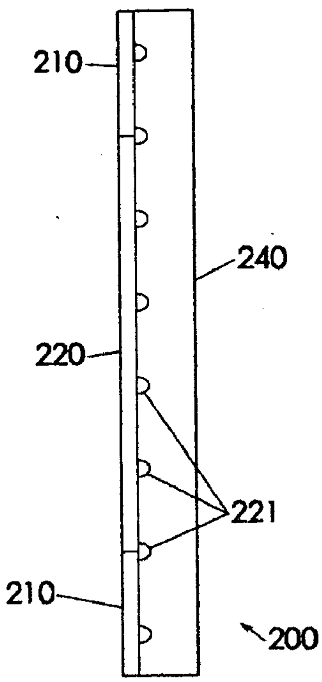

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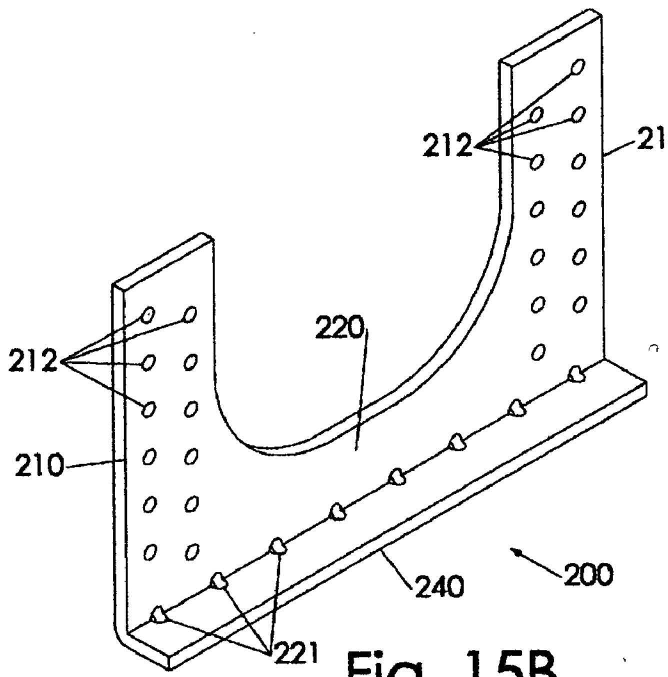

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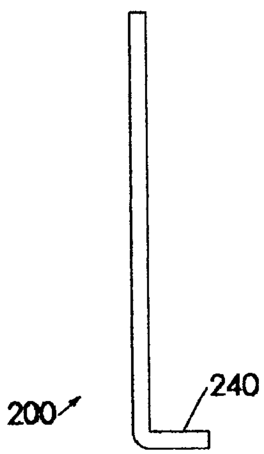

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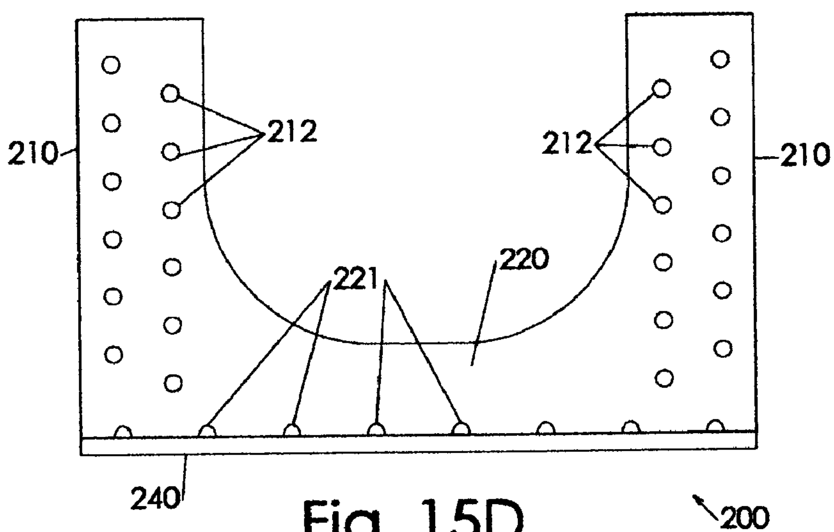

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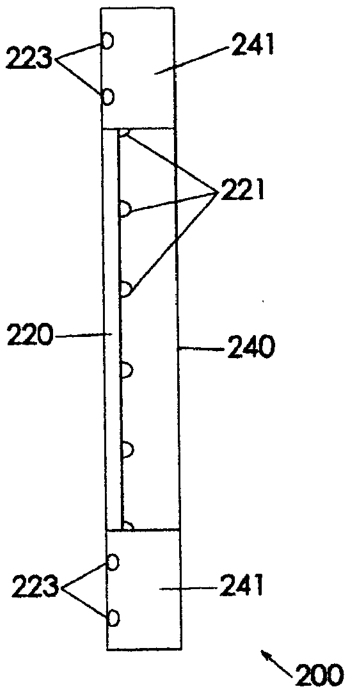

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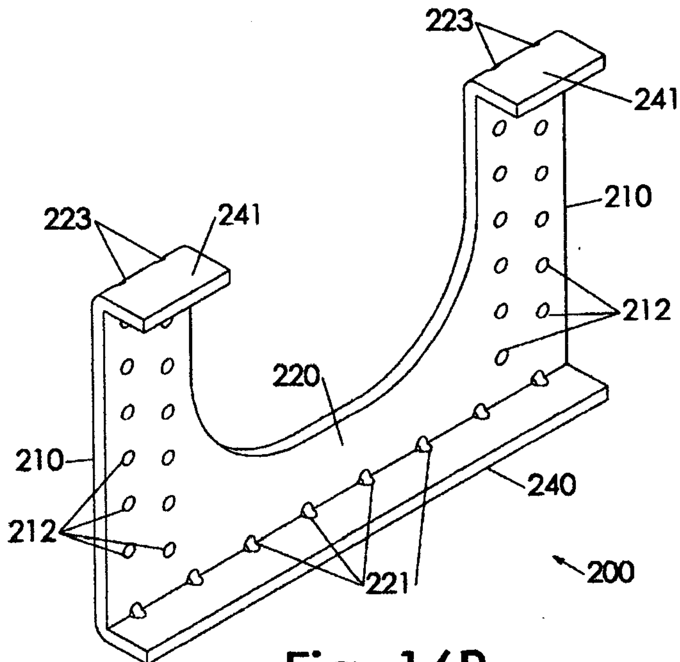

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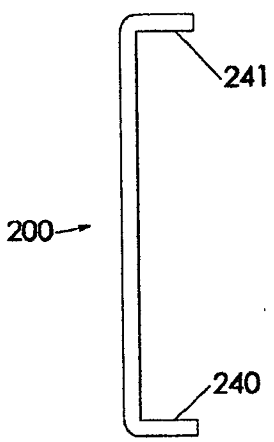

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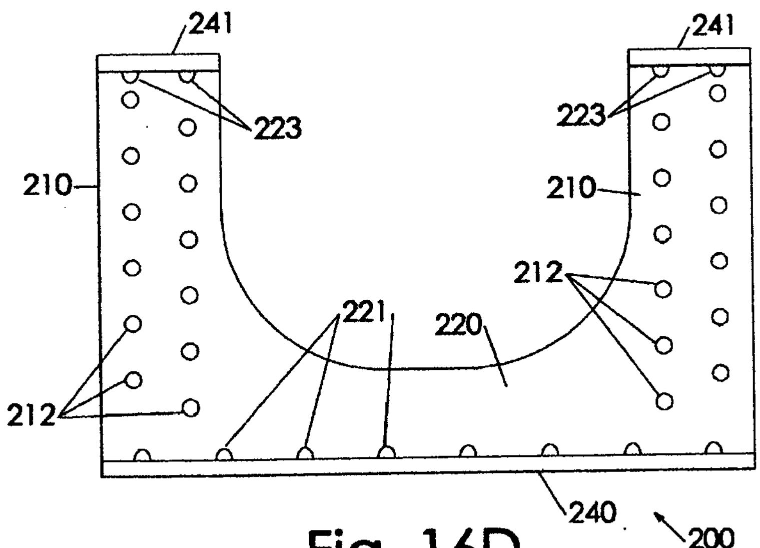
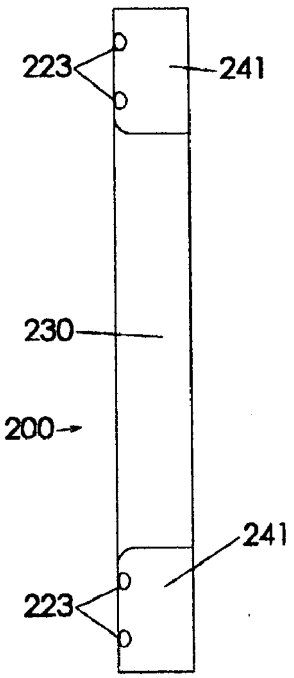


Fig. 16D



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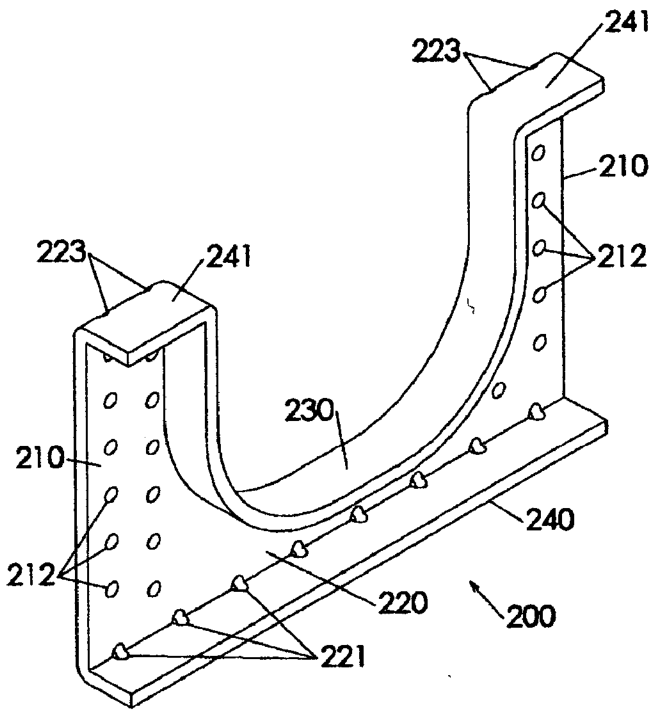

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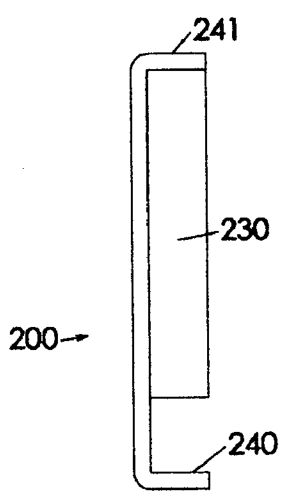

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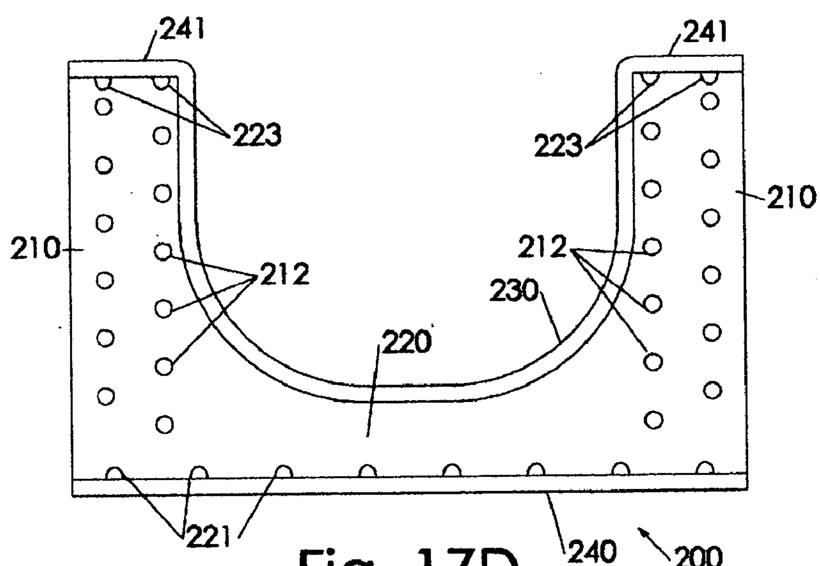

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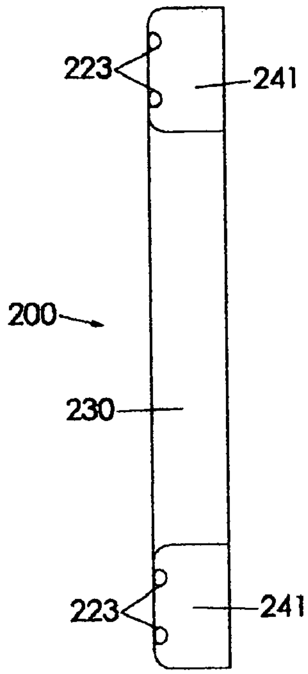

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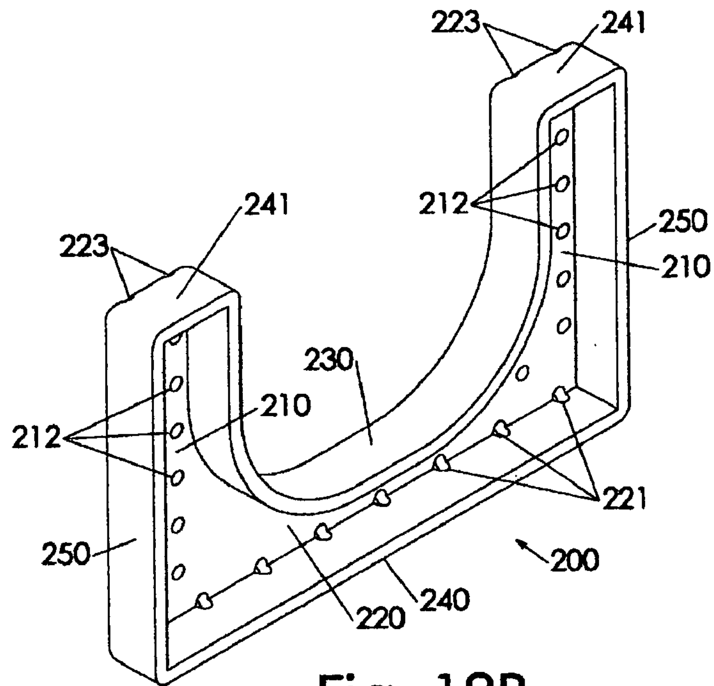

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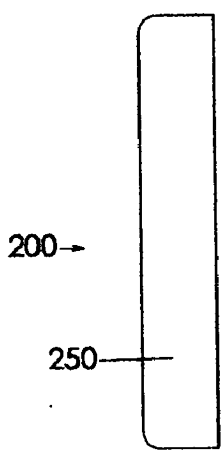

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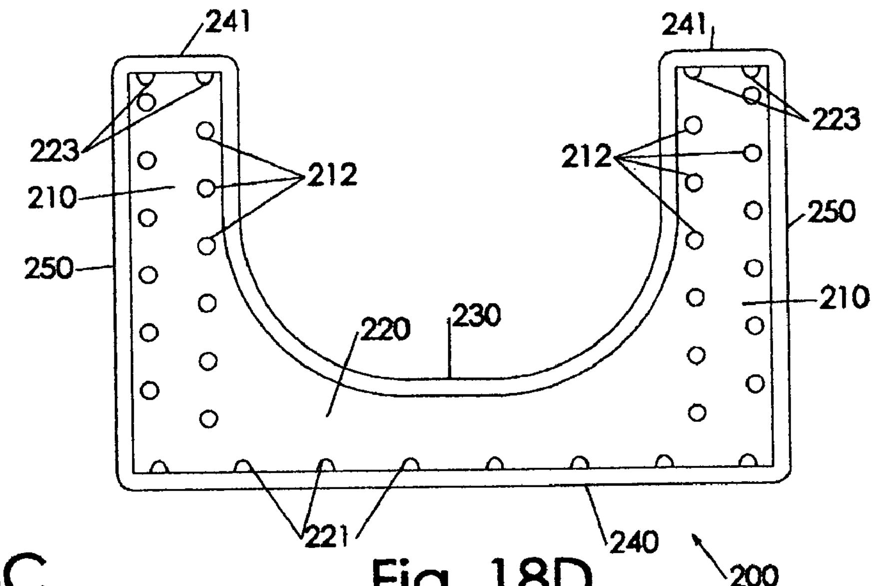

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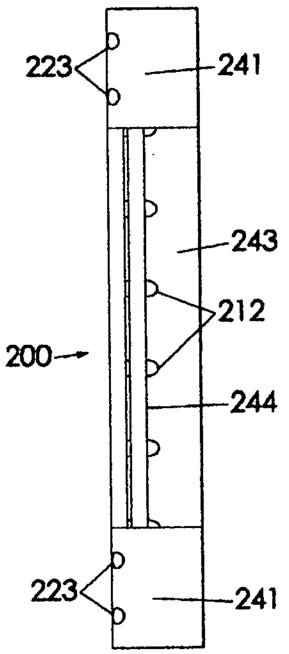

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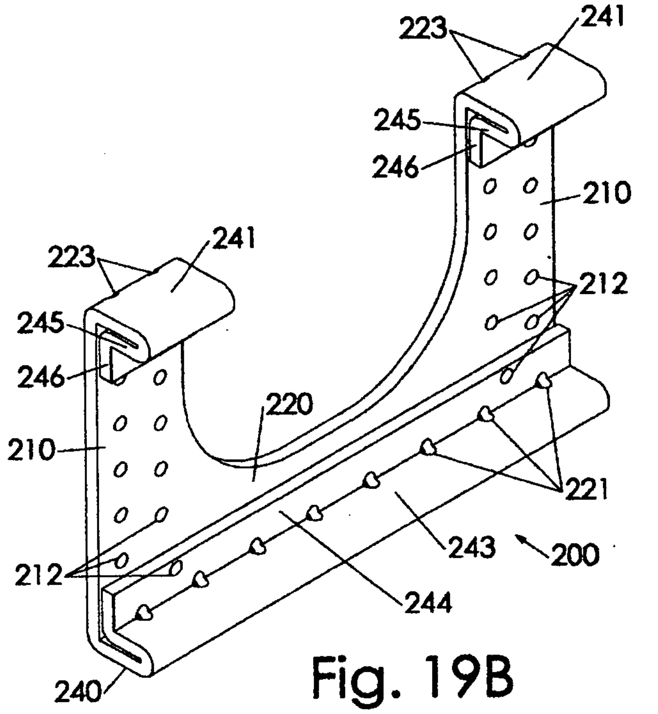

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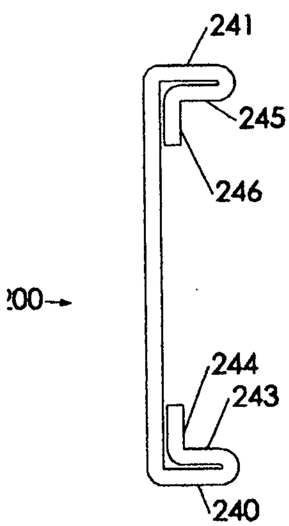

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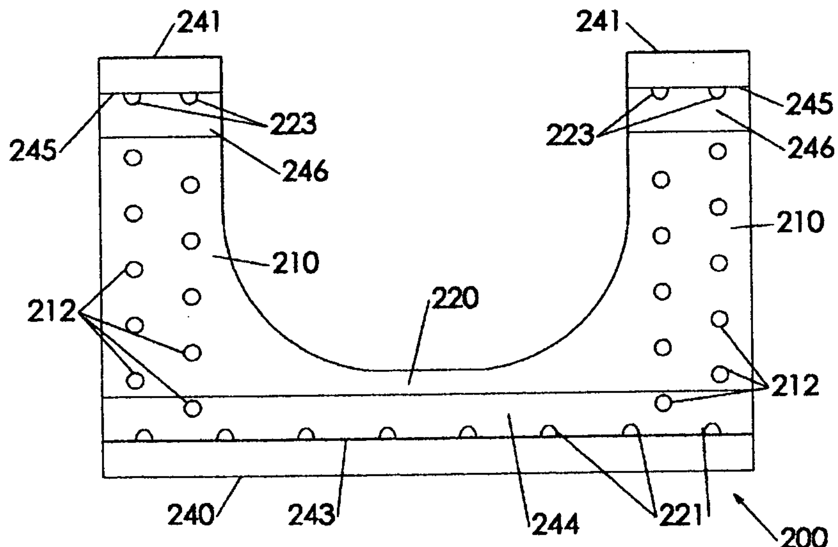

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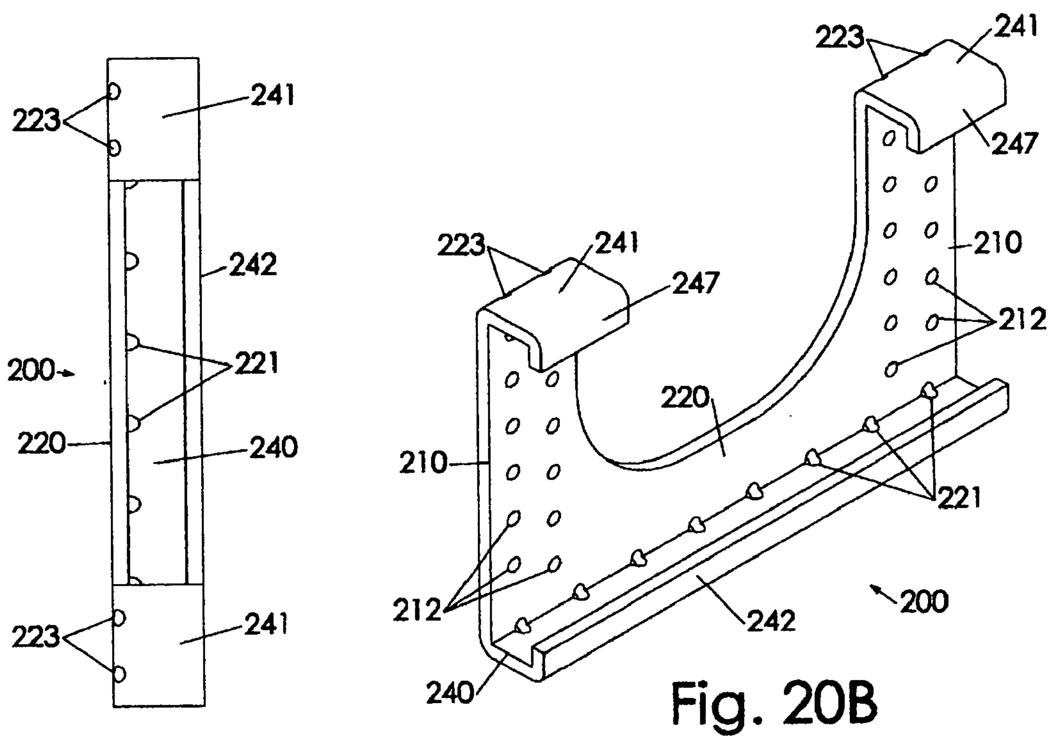


Fig. 20A

Fig. 20B

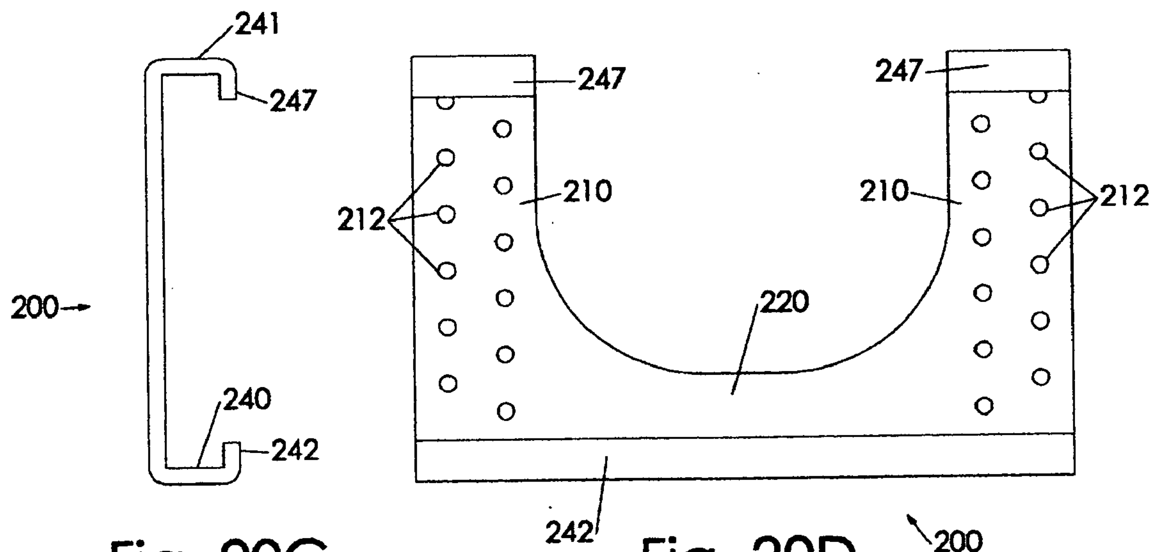
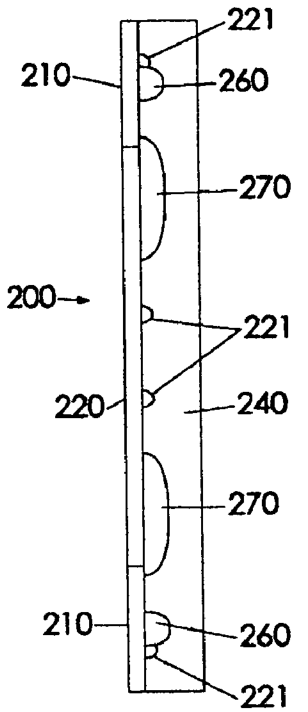


Fig. 20C

Fig. 20D



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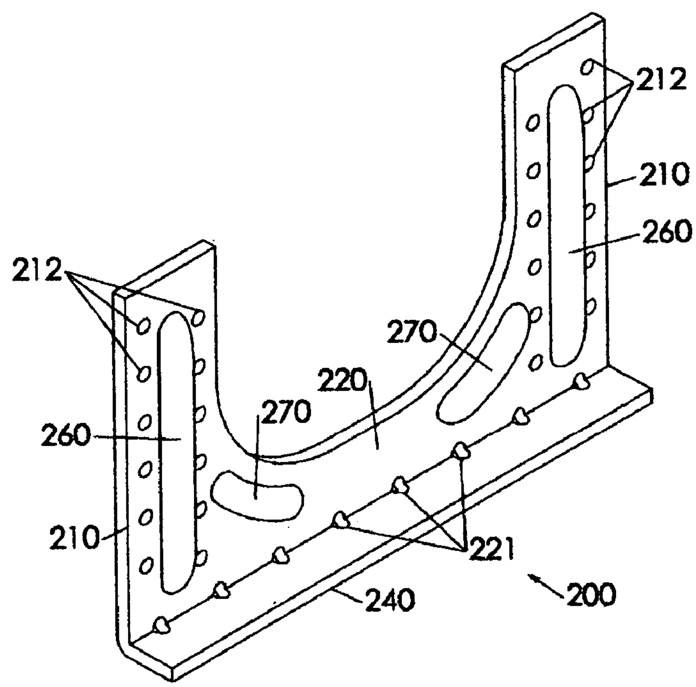

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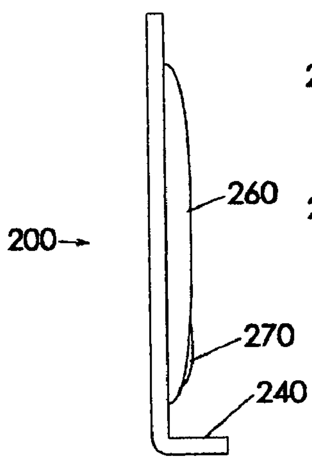

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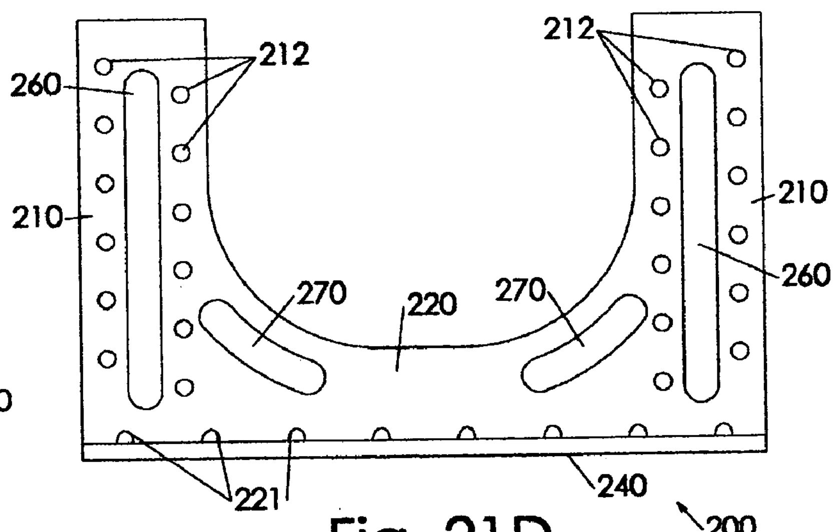

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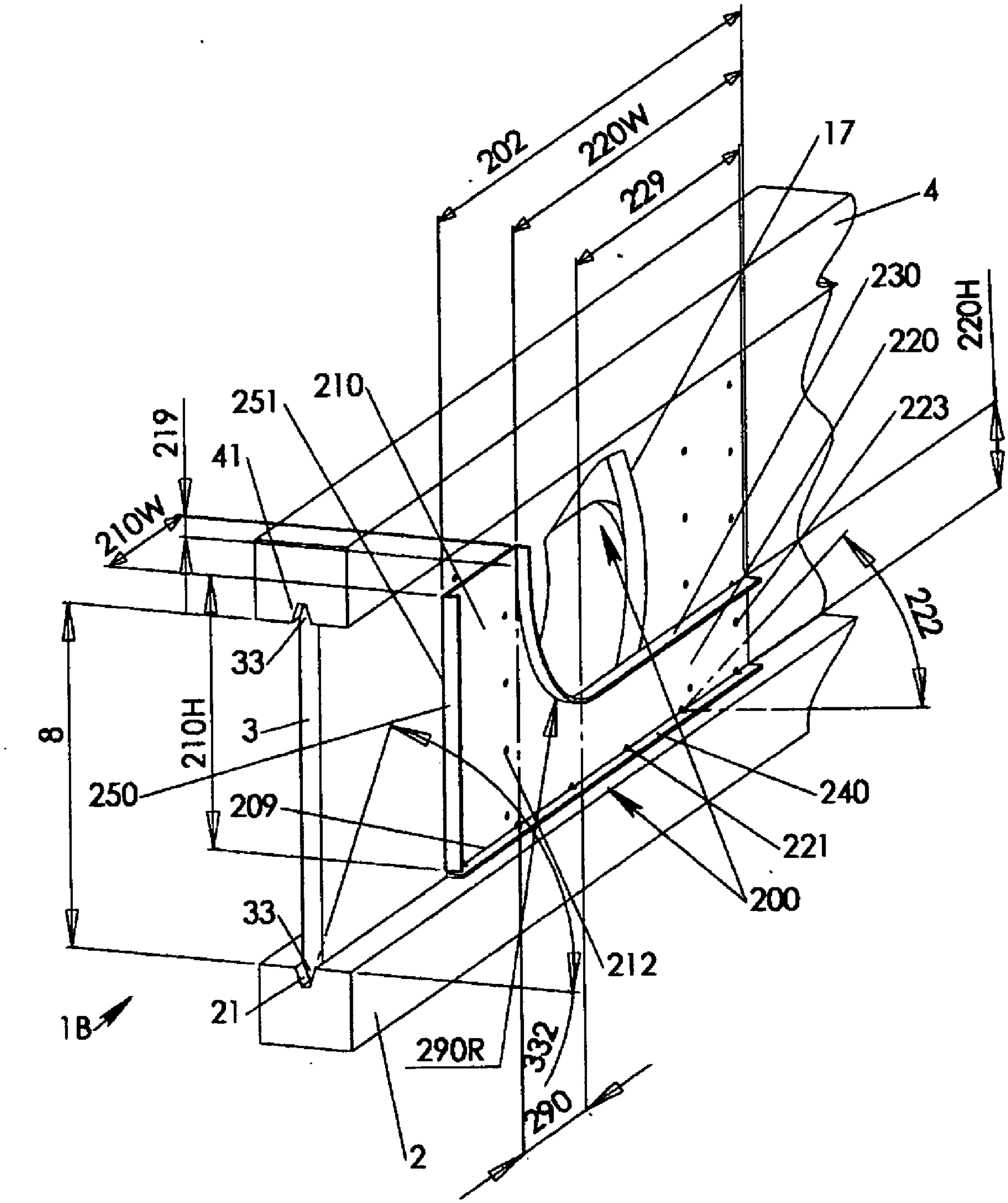
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Fig. 22

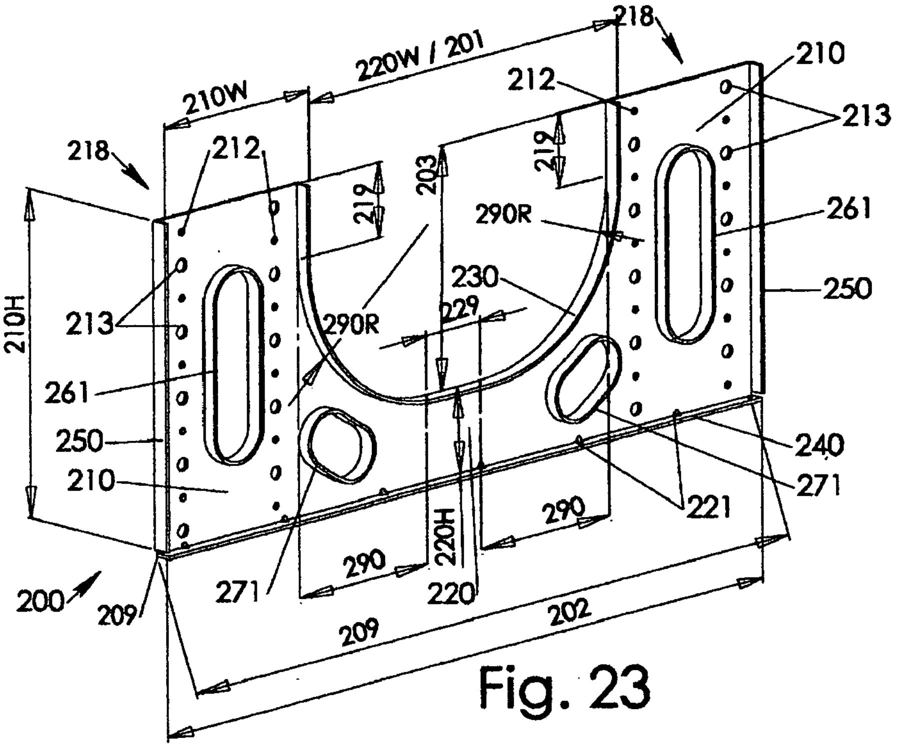

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Fig. 23

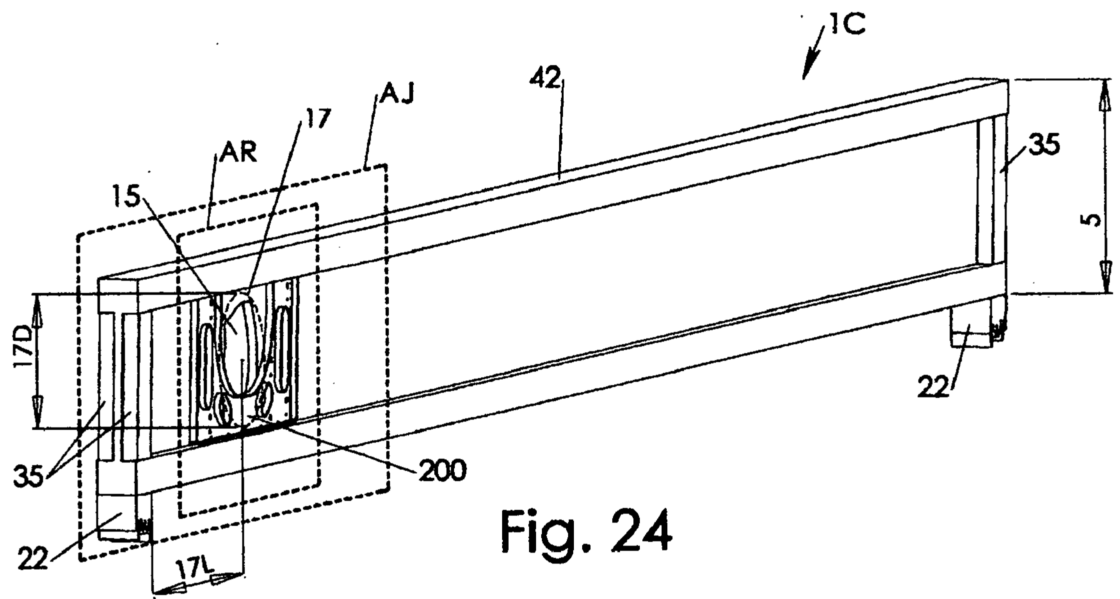

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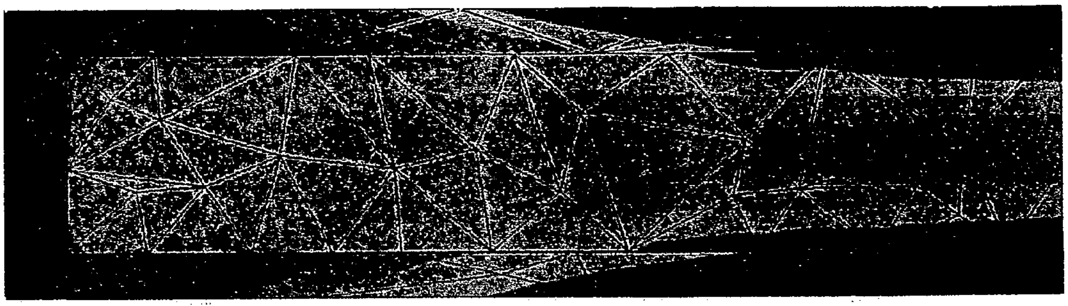
Fig. 24



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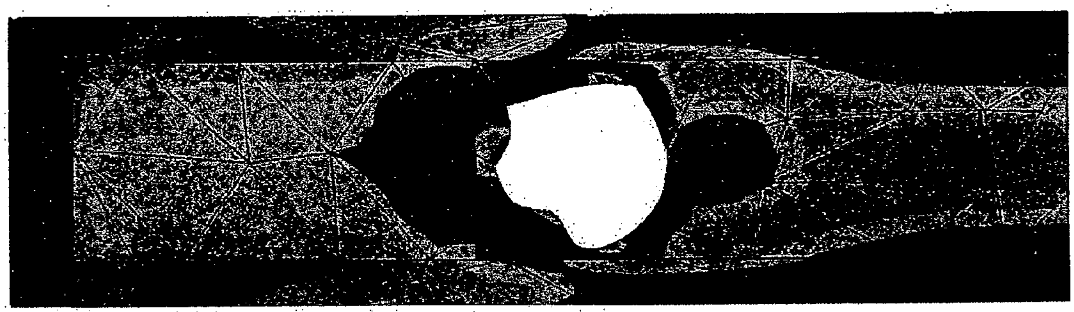
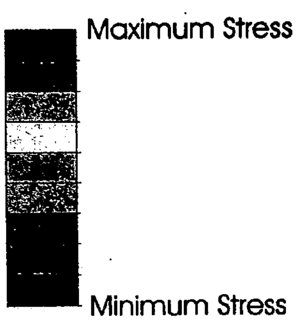


Fig. 26

Fig. 27



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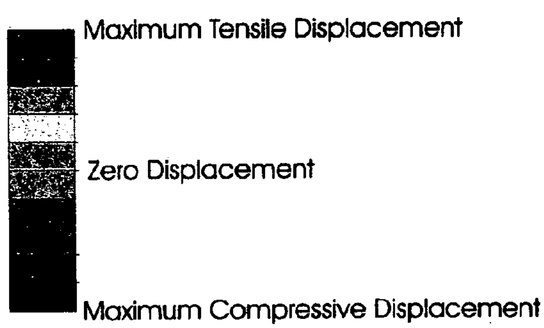

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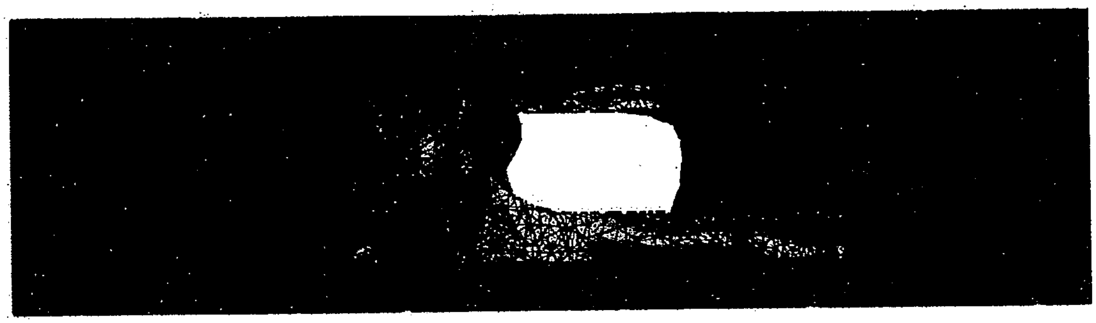

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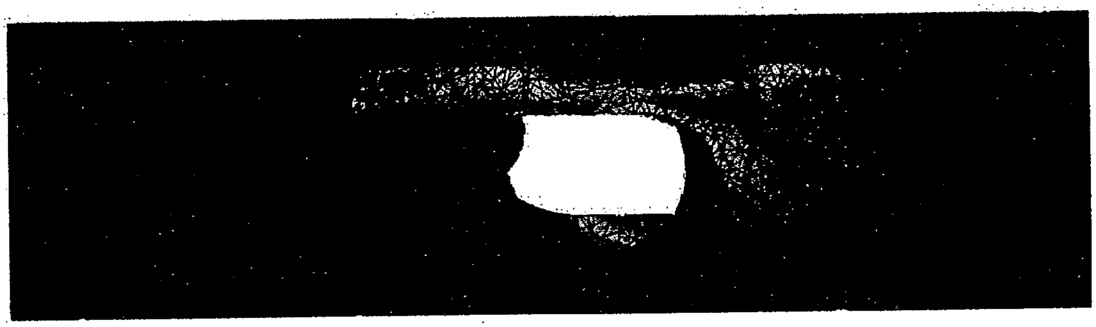

Fig. 31

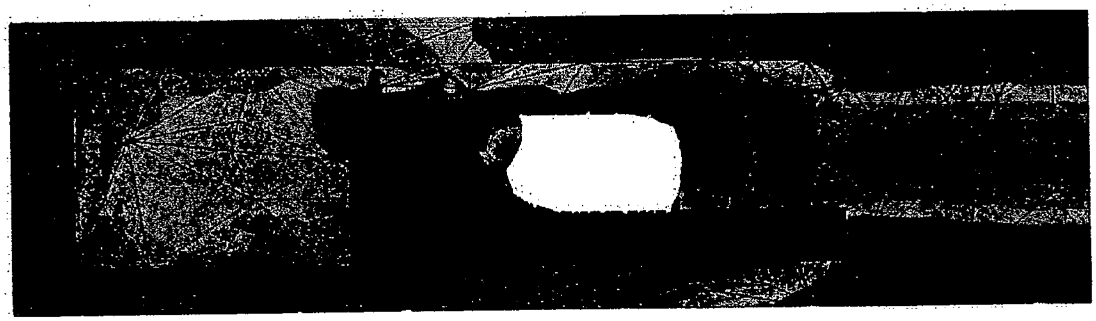

Fig. 32

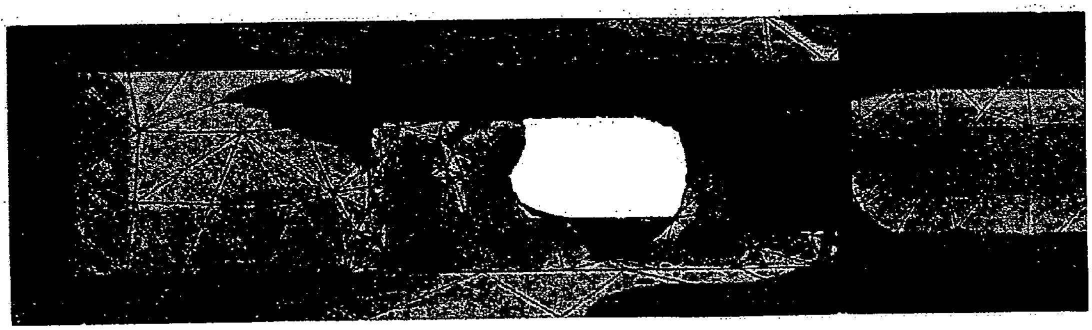

Fig. 33

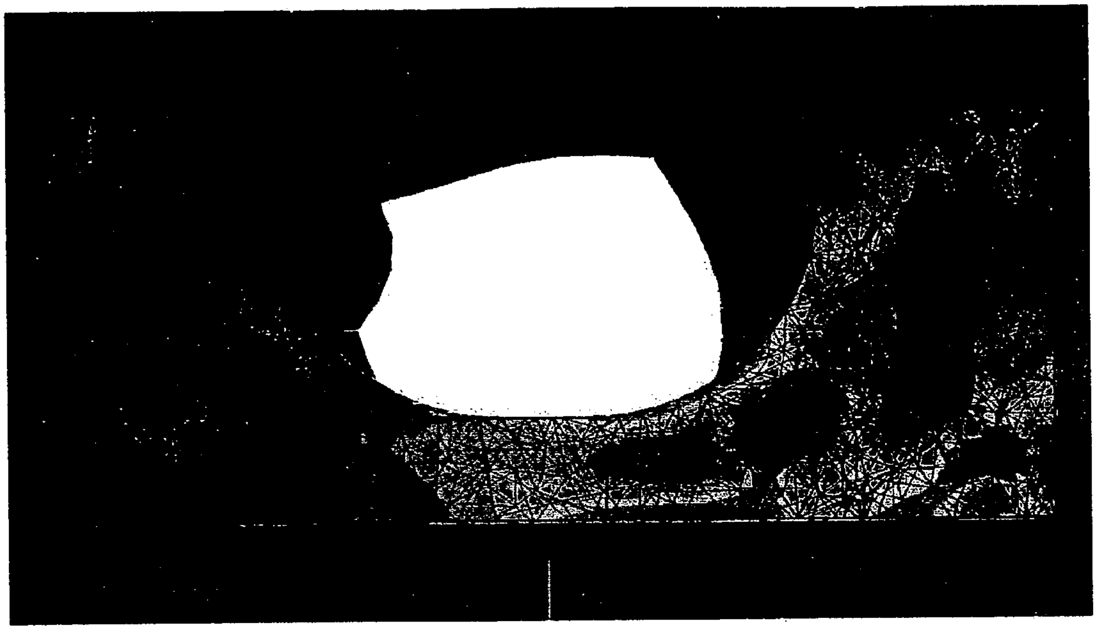

Fig. 34

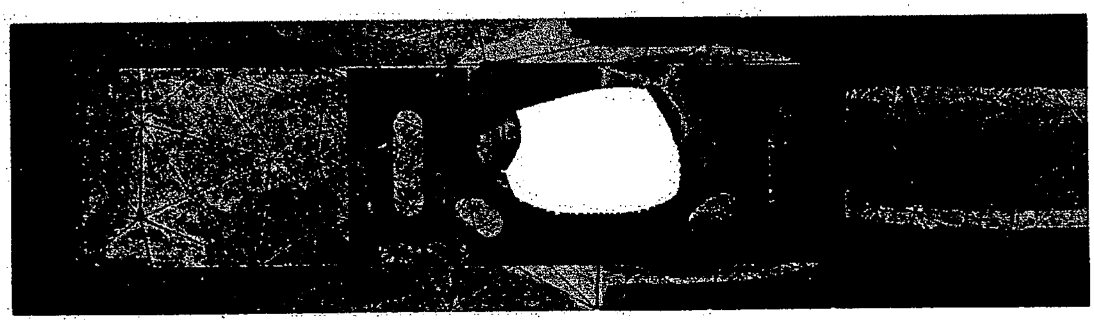

Fig. 35

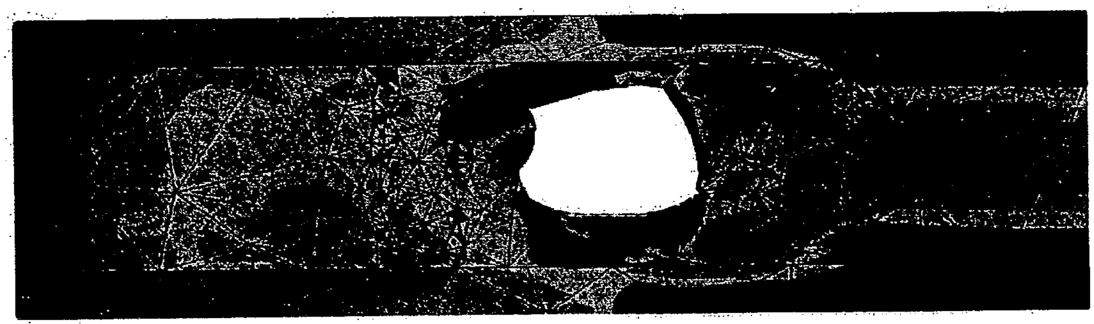

Fig. 36

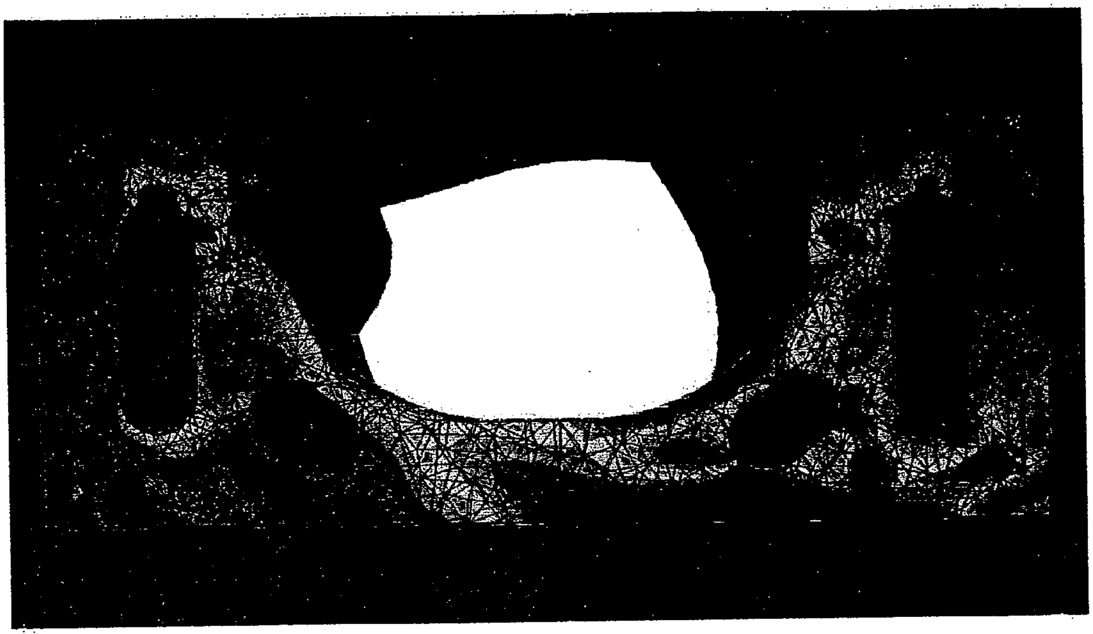

Fig. 37

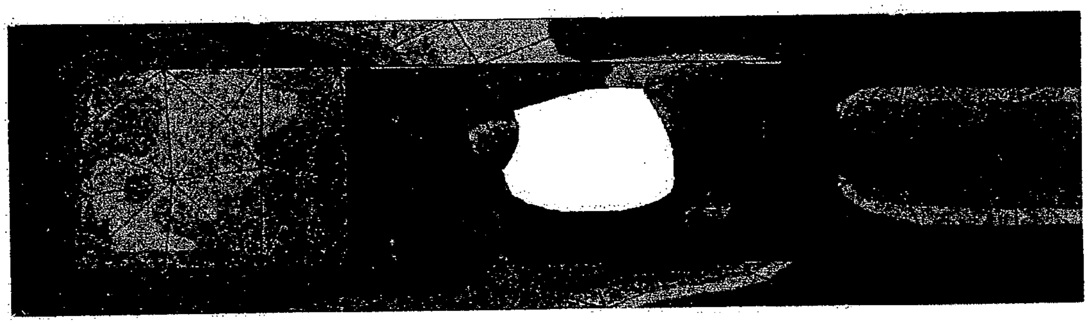

Fig. 38

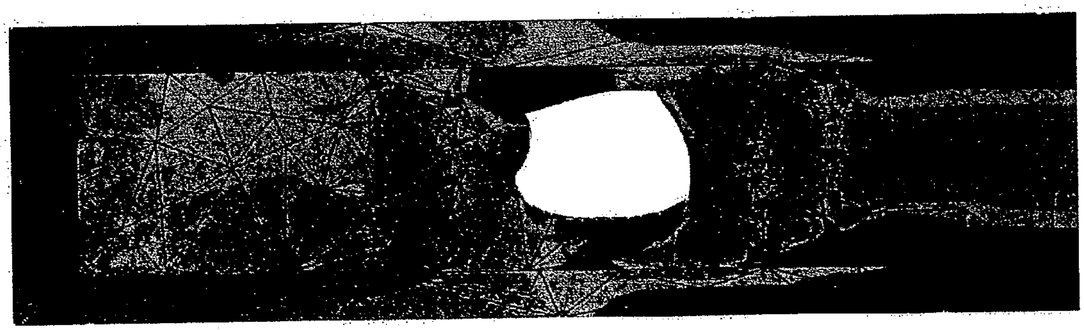

Fig. 39

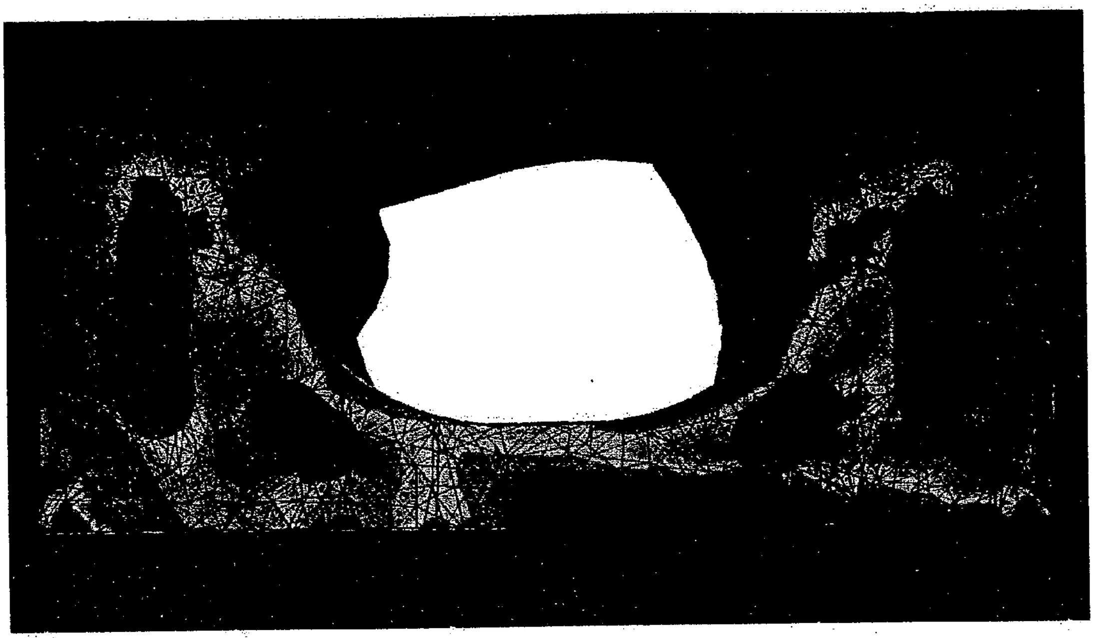

Fig. 40

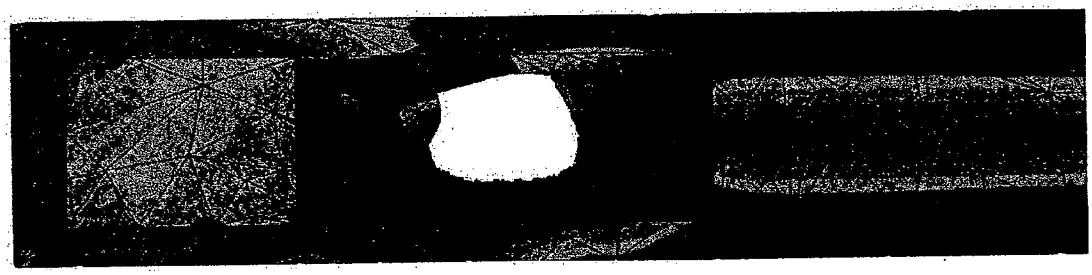

Fig. 41

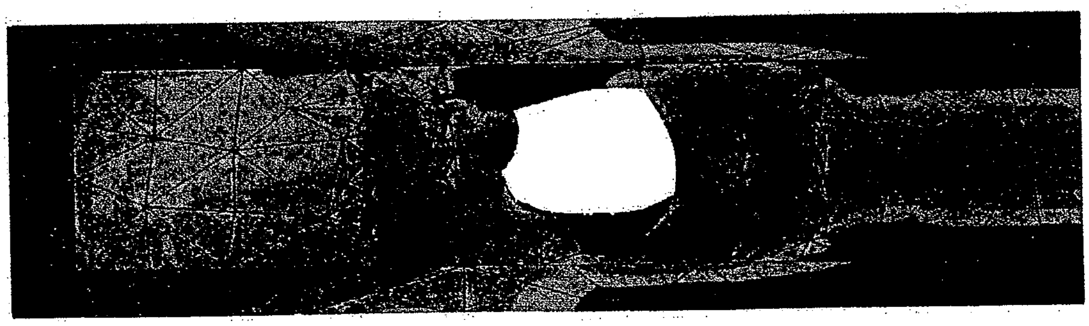

Fig. 42

BUCKLING AND SHEARING OPPOSING REINFORCEMENT BRACKET FOR WOODEN I-JOIST

CROSS REFERENCE

[0001] The present application is a Continuation in Part of U.S. patent application Ser. No. 10/410,505 titled "Buckling Opposing Support for I-joist" of the same inventor, filed 04108/2003.

FIELD OF INVENTION

[0002] The present invention relates to reinforcement brackets for wooden I-joists. Particularly, the present invention relates to brackets for buckling and shearing opposing support of a wooden I-joist having a web hole exceeding the wooden I-joist's modification limits.

BACKGROUND OF INVENTION

[0003] I-beams are well-known profiles designed for carrying static loads with a minimal own weight. An I-beam has a cross section similar to that of a capital "I" with top and bottom chords that are vertically spaced apart by a central web portion. A special type of wooden and/or wood like I-beam is used in architectural constructions. This type of I-beam is known as I-joist. I-joists are described, for example in U.S. Pat. No. 4,195,462 to Keller and U.S. Pat. No. 6,460,310 to Ford et al.

[0004] I-joists are configured for carrying maximum loads while keeping their own weight to a minimum. For that purpose, I-joists have top and bottom chords with enlarged cross sections where compressive and tensile stresses are at a maximum. A central web portion connects both chords and keeps them at a distance and in plane with the load direction. The central web is also symmetrically positioned with respect to both chords. Under load the chords tend to deflect in plane with the applied load and consequently in plane with the web. The web is configured to provide sufficient stiffness and strength against the deformation tendency of the chords.

[0005] The web has a relatively thin cross-section geometry, which results in a certain buckling tendency of it. The buckling tendency of the web portion is a major criterion for the over all load carrying capacity of an I-joist. The structural integrity of the web is often compromised in architectural constructions. To assure sufficient buckling resistance of the modified web, manufacturers may provide dimensional safety limits for maximum diameter and other critical dimensions for holes cut into the web. Unfortunately, such standards are often not met by the construction workers that are typically in charge of fabricating the holes into the web. In a progressing architectural construction where access to the I-joist's web portion is already impaired, it becomes difficult to control the holes cut into the webs. Therefore, there exists a need for assuring the I-joists static load capacities irrespective of the actually hole shape cut into a web. The present invention addresses this need.

[0006] Reinforcement brackets for modified structural beams are well-known in the art. For example, U.S. Pat. No. 5,519,977 to Callahan et al (1). describes a reinforcement bracket for modified sections of a wooden joists. The invention is configured for joists with rectangular cross section. Support is mainly provided by configuring the bracket as a profile protruding in direction of the beam and having bending resistance that is maximized in protrusion direction of the joist. An eventually increased buckling tendency of the modified joist is not addressed by the invention. More over, the bracket attached at the modified joist offsets the all over section modulus of the combined cross section of joist and bracket out of the load plane. As an unfavorable result, a modified joist section supported by Callahan's bracket may have a greater buckling tendency than the same modified joist section not supported by Callahan's bracket.

[0007] Another example for a reinforcement bracket is described in U.S. patent application Publication 2002/0121066 also to Callahan et al (2). There, the bracket of the above-described invention is modified to accommodate for material separations cut through the top chord of an I-joist. In general, the applicability of this device may be limited since material separations of the chords are highly questionable due to their tremendous negative effect on the joist's load carrying capacity. As is well-known in the art and dependent on the load carrying condition, building codes strictly mandate that transverse holes bored or cut into a joist must remain at a certain distance from the top or bottom of the joist. For an I-joist in particular, it is recommended by manufacturers to avoid cutting either of the cords of a load carrying I-joist section. In addition, the buckling increasing effect of the bracket becomes even more dominant where the remaining cross section of the modified I-joist is much thinner than the rectangular section of a conventional modified joist.

[0008] Also, in Callahan et al (2) the connection between the bracket and the I-joist relies substantially on screws or nails laterally attached to the remainder of the chords. Chords that are fabricated from vertically stacked, laminated wood are highly sensible to splicing initiated by horizontally attached nails or screws. Attaching a support device on the chords for the purpose of transmitting bending loads from the I-joist onto the bracket consequently may result in splicing of the chords. The splicing of the chords results in a further weakening of the modified I-joist section. The splicing also reduces the rigidity of connection between the bracket and the modified I-joist section. Therefore, there exists a need for a support structure that may be attached to a modified I-joist with reduced and/or without laterally attaching to the chord(s). The present invention addresses this need.

[0009] Prototype testing of the present invention has revealed that in addition to the buckling loads, significant shear loads are communicated between the I-joist's web and the reinforcement bracket. Shear loads become increasingly dominant with decreasing distance from the assembly location of the reinforcement bracket to the next I-joist bearing. The shear loads occur across the height of the web and need to be transferred between the web and the attached reinforcement bracket in a balanced fashion to avoid tearing out of attachment screws and/or other damage to the web at the assembly location. In addition, the reinforcement bracket needs to be configured for a gradual transfer of shear loads in span direction of the I-joist across an eventual web hole while covering the web hole as little as possible and while keeping stress peaks and stress gradients in the brackets structure at a minimum. At the same time, the reinforcement bracket needs to be light weight and simple to be attached to facilitate its use at construction sites. The present invention addresses also these needs.

SUMMARY

[0010] A support device for an I-joist provides buckling and shearing opposing support to the remaining web portions adjacent a hole erroneously cut into the I-joist's web. The buckling opposing support is established by bridging structures that protrude between and span across the top and bottom chords of the I-joist. The bridging structures are configured to provide a maximum bending resistance in a direction between the chords.

[0011] The support device is configured for a lateral attachment to an I-joist. The support device may be scaled and prefabricated in a number of configurations that correspond to dimensional standards of I-joists. Hence, by selecting a support device in a scale that corresponds to a dimensional standard of an I-joist at hand, a construction worker may easily repair an erroneously cut hole and or reinforce an I-joist's web portion by simply attaching the support device at an appropriate location.

[0012] In the preferred embodiment, the support device has an approximate U-shape such that it may be attached to the I-joist in a progressed construction assembly where other profile(s) is/are already assembled through the cut web hole.

[0013] The support device is preferably made of sheet metal and provides holes for readily attaching it to the web portion by nailing, screwing or other well-known fastening techniques feasible for attaching a sheet metal part to a wooden or wood like material. The support device further provides secondary holes for an eventual secondary attachment to the chord(s) for the purpose of adding rigidity to the assembled support device. Additional stiffening features may be part of the support device to either increase the device's stiffness against the web portions buckling tendency and/or to increase an interlocking and/or snuggly fit between the device and the I-joist. The bridging structures may further operate to transmit compressive forces eventually occurring between the chords as a result from the I-joists deflection. In that way, the buckling tendency of the web portion may be additionally opposed.

[0014] The support device or reinforcement bracket is configured for attachment and operation without substantially reducing the structural integrity and stress absorbing capability of the chords. Eventual attaching of the support device is provided in a fashion that keeps the chords' splicing tendency to a minimum.

[0015] Shearing opposing support is provided by a shear load resistant interface in between the combined reinforcement bracket and spacing structure. The shear load is transferred between the web and the attached bridging structure across the height of the bridging structure, which is a multiple of the spacing structure's height. This results in an angular displacement of the attached bridging structure with respect to the spacing structure with stress peaks and maximum stress gradients in the interface and spacing structure. The interface has a configuration that assists in keeping stress peaks and stress gradients to a minimum. The interface configuration may include a transition radius between a width contour of the spacing structure and an adjacent height contour of the bridging structure.

BRIEF DESCRIPTION OF THE FIGURES

[0016] **FIG. 1** shows an exemplary section view of a prior art assembly of representative first I-joists with a profile assembled in between.

[0017] **FIG. 2** depicts the exemplary section view of **FIG. 1** with a support device in accordance with a first embodiment of the present invention attached at a central first I-joist.

[0018] **FIG. 3** illustrates a first I-joist section with a support device in accordance with a first embodiment of the invention and a support structure attached in between.

[0019] **FIG. 4** shows a section view of **FIG. 3** along a vertical plane approximately through a center of the support device.

[0020] **FIG. 5** shows a vertical central section view of a first I-joist and a support device in accordance with a second embodiment of the invention.

[0021] **FIG. 6** depicts a horizontal central section view of a first I-joist, the support structure of **FIG. 3** and a support device in accordance with a third embodiment of the invention.

[0022] **FIG. 7** depicts a horizontal section view of a first I-joist and a first support device in accordance with a fourth embodiment of the invention. A second support device in accordance with the fourth embodiment is shown in attachment position opposing the first support device.

[0023] **FIGS. 8A, 8B** depict a fifth embodiment in perspective view and in front view in protrusion direction of the first I-joist.

[0024] **FIGS. 9A, 9B** depict a sixth embodiment in perspective view and in front view in protrusion direction of the I-joist. In **FIG. 9A**, only a bottom portion of the first I-joist is shown with the web portion broken apart to free the view onto the entire support device.

[0025] **FIGS. 10A, 10B** depict a seventh embodiment in perspective view and in front view in protrusion direction of the first I-joist. In **FIG. 10A**, only a bottom portion of the first I-joist is shown with the web portion broken apart to free the view onto the entire support device.

[0026] **FIGS. 11A-11D** illustrate various views of the support device in accordance with the first embodiment of the invention.

[0027] **FIGS. 12A-12D** illustrate various views of the support device in accordance with the second embodiment of the invention.

[0028] **FIGS. 13A-13D** illustrate various views of the support device in accordance with the third embodiment of the invention.

[0029] **FIGS. 14A-14D** illustrate various views of the support device in accordance with the fourth embodiment of the invention.

[0030] **FIGS. 15A-15D** illustrate various views of the support device in accordance with the fifth embodiment of the invention.

[0031] **FIGS. 16A-16D** illustrate various views of the support device in accordance with the sixth embodiment of the invention.

[0032] **FIGS. 17A-17D** illustrate various views of the support device in accordance with the seventh embodiment of the invention.

[0033] **FIGS. 18A-18D** illustrate various views of the support device in accordance with the eighth embodiment of the invention.

[0034] **FIGS. 19A-19D** illustrate various views of the support device in accordance with the ninth embodiment of the invention.

[0035] **FIGS. 20A-20D** illustrate various views of the support device in accordance with the tenth embodiment of the invention.

[0036] **FIGS. 21A-21D** illustrate various views of the support device in accordance with the eleventh embodiment of the invention.

[0037] **FIG. 22** is a perspective view of a reinforcement bracket of a twelfth embodiment attached to a representative second Ijoist.

[0038] **FIG. 23** is a perspective view of a preferred thirteenth embodiment of the invention.

[0039] **FIG. 24** is a perspective view of a representative third I-joist having an erroneously cut hole and the reinforcement bracket of **FIG. 23** assembled at the erroneously cut hole.

[0040] **FIG. 25** is a color plot of a representative stress analysis of a portion of the third I-joist without erroneously cut hole, the portion being approximately within frame AJ of **FIG. 23**. The color coding in the Figure corresponds to the stress color scale of **FIG. 28** and is equalized in its color-stress correspondence with **FIGS. 26, 32, 33, 35, 36, 38, 39, 41, 42**.

[0041] **FIG. 26** is a color plot of a representative stress analysis of a portion of the third I-joist, the portion being approximately within frame AJ of **FIG. 23**. The color coding in the Figure corresponds to the stress color scale of **FIG. 28** and is equalized in its color-stress correspondence with **FIGS. 25, 32, 33, 35, 36, 38, 39, 41, 42**.

[0042] **FIG. 27** is a color plot of a representative displacement analysis of a portion of the third I-joist with assembled reinforcement bracket of **FIG. 23,** the portion being approximately within frame AJ of **FIG. 24**. The Figure depicts isolated up scaled displacement in direction along the I-joist length corresponding to shear displacement of the I-joist and its deforming influence on the assembled reinforcement bracket of **FIG. 23**. The color coding in the Figure corresponds to the displacement color scale of **FIG. 29**.

[0043] **FIG. 28** is a stress color scale with medium blue corresponding to a minimum stress and red corresponding to a maximum stress.

[0044] **FIG. 29** is a displacement color scale with maximum compressive displacement corresponding to dark blue and maximum tensile displacement corresponding to red.

[0045] **FIG. 30** is a front view color plot approximately within frame AJ of **FIG. 24** of a representative stress analysis of the reinforcement brackets of **FIG. 22** assembled by attachment via attachment holes **212** on the third I-joist. The attachment at the attachment holes **212** is considered substantially rigid such that rotational web displacement resulting from the shear displacement in the vicinity of the attachment holes **212** is transmitted onto the attachment holes **212** and the surrounding structure of the reinforcement bracket. The color coding in the Figure corresponds to the stress color scale of **FIG. 28** and is equalized in its color-stress correspondence with **FIGS. 31, 34, 37, 40**.

[0046] **FIG. 31** is a back view of the color plot of **FIG. 30**. The color coding in the Figure corresponds to the stress color scale of **FIG. 28** and is equalized in its color-stress correspondence with **FIGS. 30, 34, 37, 40**.

[0047] **FIG. 32** is a front view color plot of a representative stress analysis of a portion of the first I-joist with assembled and attached reinforcement brackets of **FIG. 22,** the portion being approximately within frame AJ of **FIG. 24**. The attachment condition corresponds to that of **FIGS. 30, 31**. The color coding in the Figure corresponds to the stress color scale of **FIG. 28** and is equalized in its color-stress correspondence with **FIGS. 25, 26, 33, 35, 36, 38, 39, 41, 42**.

[0048] **FIG. 33** is a back view of the color plot of **FIG. 32**. The color coding in the Figure corresponds to the stress color scale of **FIG. 28** and is equalized in its color-stress correspondence with **FIGS. 25, 26, 32, 35, 36, 38, 39,41, 42**.

[0049] **FIG. 34** is a color plot approximately within frame AR of **FIG. 24** of a representative stress analysis of the reinforcement bracket of **FIG. 23** assembled by attachment via attachment holes **212** on the third I-joist. The attachment at the attachment holes **212** is considered substantially free of friction such that rotational web displacement resulting from the shear displacement in the vicinity of the attachment holes **212** is not transmitted onto the attachment holes **212** and the surrounding structure of the reinforcement bracket. The color coding in the Figure corresponds to the stress color scale of **FIG. 28** and is equalized in its color-stress correspondence with **FIGS. 30, 31, 37, 40**.

[0050] **FIG. 35** is a front view color plot of a representative stress analysis of a portion of the third I-joist with assembled and attached reinforcement bracket of **FIG. 23,** the portion being approximately within frame AJ of **FIG. 24**. The attachment condition corresponds to that of **FIG. 34**. The color coding in the Figure corresponds to the stress color scale of **FIG. 28** and is equalized in its color-stress correspondence with **FIGS. 25, 26, 32, 33, 36, 38, 39, 41, 42**.

[0051] **FIG. 36** is a back view of the color plot of **FIG. 35**. The color coding in the Figure corresponds to the stress color scale of **FIG. 28** and is equalized in its color-stress correspondence with **FIGS. 25, 26, 32, 33, 35, 38, 39, 41, 42**.

[0052] **FIG. 37** is a color plot approximately within frame AR of **FIG. 24** of a representative stress analysis of the reinforcement bracket of **FIG. 23** assembled by attachment via attachment holes **212** on the third Iioist. The attachment at the attachment holes **212** is considered rigid such that rotational web displacement resulting from the shear displacement in the vicinity of the attachment holes **212** is transmitted onto the attachment holes **212** and the surrounding structure of the reinforcement bracket. The color coding in the Figure corresponds to the stress color scale of **FIG. 28** and is equalized in its color-stress correspondence with **FIGS. 30, 31, 35, 40**.

[0053] FIG. 38 is a front view color plot of a representative stress analysis of a portion of the third I-joist with assembled and attached reinforcement bracket of FIG. 23, the portion being approximately within frame AJ of FIG. 24. The attachment condition corresponds to that of FIG. 37. The color coding in the Figure corresponds to the stress color scale of FIG. 28 and is equalized in its color-stress correspondence with FIGS. 25, 26, 32, 33, 36, 36, 39, 41, 42.

[0054] FIG. 39 is a back view of the color plot of FIG. 38. The color coding in the Figure corresponds to the stress color scale of FIG. 28 and is equalized in its color-stress correspondence with FIGS. 25, 26, 32, 33, 35, 36, 38, 41, 42.

[0055] FIG. 40 is a color plot approximately within frame AR of FIG. 24 of a representative stress analysis of the reinforcement bracket of FIG. 23 assembled by attachment via attachment holes 212 and 221 on the third I-joist. The attachment at the attachment holes 212 and 221 is considered rigid. Rotational web displacement from the shear displacement in the vicinity of the attachment holes 212 is transmitted onto the attachment holes 212 and the surrounding structure of the reinforcement bracket. The color coding in the Figure corresponds to the stress color scale of FIG. 28 and is equalized in its color-stress correspondence with FIGS. 30, 31, 35, 37.

[0056] FIG. 41 is a front view color plot of a representative stress analysis of a portion of the third I-joist with assembled and attached reinforcement bracket of FIG. 23, the portion being approximately within frame AJ of FIG. 24. The attachment condition corresponds to that of FIG. 40. The color coding in the Figure corresponds to the stress color scale of FIG. 28 and is equalized in its color-stress correspondence with FIGS. 25, 26, 32, 33, 35, 36, 38, 39, 42.

[0057] FIG. 42 is a back view of the color plot of FIG. 41. The color coding in the Figure corresponds to the stress color scale of FIG. 28 and is equalized in its color-stress correspondence with FIGS. 25, 26, 32, 33, 35, 36, 38, 39, 41.

DETAILED DESCRIPTION

[0058] Prior art FIG. 1 shows exemplary sections of first I-joists 1 assembled as it may occur in architectural constructions. There, holes 15 may be cut into the I-joists' 1 central web portions 3 such that a profile 18 may be installed in between the top chord 4 and the bottom chord 2 in directions other than parallel to the I-joists 1. The profile 18 may be an electrical line, a plumbing pipe or the like.

[0059] To reduce a buckling tendency of the modified I-joist 1, manufacturers provide dimensional safety limits for holes 15 cut into I-joist 1. These safety limits may not be met by the construction workers, which are typically in charge of fabricating the holes 15 at the construction site. A buckling tendency of the web 3 may become unpredictable and excessive where the hole 15 exceeds the safety limits.

[0060] With respect to the present invention, the first, second and third I-joists 1, 1B, 1C (see also FIGS. 22, 24) are I-shaped profiles made from wooden and/or wood like material. I-joists 1, 1B, 1C may be provided by manufacturers in a number of dimensional standards, which include a chord width 7, a total height 5, a chord height 10, a web thickness 9 and web height 8. I-joists 1, 1B, 1C may be preferably symmetric with respect to a horizontal and a vertical center plane of the I-joist 1, 1B, 1C as is well appreciated by anyone skilled in the art. The symmetric shape provides for a symmetric section modulus that keeps a buckling tendency to a minimum in unmodified condition of the I-joists 1, 1B, 1C in general and the web 3 in particular.

[0061] Additional elements like, for example a profile 18 may extend through the web portions 3 of adjacent I-joists 1,1B, 1C. The exemplary profile 18 may be an electrical line, a plumbing pipe or the like. To install the profile 18 at the construction site, holes 15 are cut into the I-joists 1, 1B, 1C.

[0062] Holes 15 may be cut in accordance with maximum safety dimensions established by manufacturers for their respective I-joist products. The maximum safety dimensions may include a maximum allowable hole diameter 16, a minimum remaining web height 6 adjacent the top cord 4 andlor the bottom chord 2. The maximum safety dimensions are exemplary illustrated as a dot dashed line.

[0063] Holes 15 may exceed the maximum safety dimensions, which results in an unpredictable buckling tendency of the remaining web portion 3 adjacent the erroneously cut hole 15. As illustrated in FIG. 2, a support device or reinforcement bracket 100 may be laterally attached to the I-joist I having an erroneously cut hole 15. The support device 100 is primarily attached to the web portion 3 via an additional support structure 20.

[0064] The support device 100 provides bridging structures 110 that spans across the web height 8 with its central portion. The bridging structures 110 has a buckling opposing configuration along their respective bridging height 210H (see FIGS. 22, 23) and establish with their central portion a buckling opposing interface with the web 3 once attached to the web 3. By placing a bridging structure 110 of the first embodiment immediately adjacent the erroneously cut hole 15 and combining it with the additional support structure 20, the unpredictable buckling tendency of the I-joist 1 in the vicinity of the erroneously cut hole 15 is brought within predictable limits.

[0065] In the context of the present invention the terms "top", "bottom", "horizontal", "vertical", "height","width" are introduced in reference to an assembly position of the support device 100 on an I-joist 1, 1B, 1C in a conventional assembly position with one chord above the other, where the I-joist 1, 1B, 1C may have its maximum load carrying capacity.

[0066] A buckling opposing interface is defined by contacting the remainder of the web 3 with the central portion of the bridging structure 110 that is provided with a bending stiffness at a level such that the buckling tendency of the remaining web 3 is kept equal or below to a reference buckling value associated with the maximum safety dimensions. The buckling opposing interface may be preferably established by fastening the central portion to the remaining web 3.

[0067] The support device 100 is scaled in conjunction with the dimensional standards of the I-joists 1. Hence, by merely selecting the properly scaled support device 100, a hole 15 erroneously cut in any standard I-joist 1 may be easily repaired.

[0068] The erroneously cut hole **15** is preferably flanked on both sides by a bridging structure **110**. To accommodate for the preferred dual application of two flanking bridging structures **110**, the present invention has a preferred configuration as an approximately U-shaped device in which two bridging structures **110** are combined by a chord embedding structure **120**. The chord embedding structure **120** is configured to snugly fit over a lateral portion of preferably one of the chords **2**, **4**. In that way, the support device **100** may be easily brought into assembly position by pushing the cord embedding structure **120** onto one of the chords **2**, **4**. The support device's **100** U-shape provides for an access to the assembly location regardless the eventual presence of profile **18** protruding through the I-joists **1**, **1**B, **1**C.

[0069] The scope of the invention is not limited to a particular number, orientation and/or spacing of the bridging structures **110** to each other. Nevertheless, in the preferred embodiment of the invention, the bridging structures **110** are preferably parallel to each other and are substantially perpendicular oriented with respect to the chord embedding structure **120**. Thus, once the support device **100** is attached to the I-joist **1**, the bridging structures **110** are substantially perpendicular to the protrusion direction of the I-joist **1**, **1**B, **1**C. As another result, a low overall width **102** of the support device **100** is assured for a given clearance distance **101**. The clearance distance **101** may be selected in accordance with the maximum allowable hole diameter **16**.

[0070] In the first, second, third and fourth embodiments of the invention described in the above and the below and as is shown in **FIG. 3**, each bridging structure **110** is a profile that extends substantially perpendicular to the I-joist's **1** protrusion direction in assembly position. End portions **111** of the bridging structures **110** continue and extend across the lateral portions of the chords **2**, **4**. The end portions **111** may be attached to the chords **2**, **4** via secondary holes **121** primarily for the purpose of adding rigidity to the assembled support device **100**.

[0071] Particularly, the secondary holes **121** may be configured in size and number to keep a splicing risk of the chords **2**, **4** to a minimum.

[0072] The central portion of the bridging structures **110** feature primary attachment holes **112**. Holes **112**, **121** are configured for receiving fasteners well known for architectural constructions. Such fasteners may include but are not limited to nails, screws and the like. The holes may be substituted by indentations such that a nail or screw is initially forced through solid material of the support device **100**.

[0073] In the first embodiment, the bridging structure **110** is configured for including an additional support structure **20** in the buckling opposing interface. The primary holes **112** serve thereby for attaching the central portion to the support structure **20** via well known fasteners such as nails, screws and the like. The support structure **20** may be a piece of rectangular wood with a cross section corresponding to a gap between the central bridge portion and the web **3**.

[0074] The support device **100** is preferably monolithically made of sheet metal, which assures minimum increase of the I-joist's **1** overall width **7**. As a primary means for stiffening the support device **100**, a first stiffening rib **130** is provided along the inside contour of the support device **100**. The first stiffening rib **130** protrudes substantially perpendicular with respect to a reference plane **11**. The reference plane **11** is substantially parallel to the main planar body of the support device **100** in assembly position. The reference plane **11** is defined by correspondingly opposing lateral edges of the chords **2**, **4** at the same side of the I-joist **1**. In context with the present invention, the term side of the I-joist **1** refers to either a left or a right side of the I-joist **1** in the protrusion direction of the I-joist **1** and with the I-joist **1** being oriented with the chord **4** being on top of the chord **2**.

[0075] The main planar body is a substantially flat portion of the support device **100** including the flat portion of the bridging structures **110** and the flat portion of the chord embedding structure **120**. The first stiffening rib **130** has a height that corresponds to the half of the difference between chord width **7** and web thickness **9** such that the top edge of the first stiffening rib **130** snugly contacts the web **3** when the support device **100** is attached to the I-joist **1**, **1**B, **1**C. A horizontal portion of the first stiffening rib **130** is positioned on the support device **100** such that in assembled position of the support device **100** the first rib's **130** horizontal portion contacts a lateral portion of one of the chords **2**, **4** inside the I-joist **1**.

[0076] As shown in **FIGS. 4 and 5**, the support device **100** may also feature a second stiffening rib **140** that protrudes in direction substantially parallel to the first stiffening rib **130** from the bottom edge of the chord embedding structure **120**. The second stiffening rib **140** and the horizontal portion of the first stiffening rib **130** are in a distance substantially equal to the chord height **10**. The second stiffening rib **130** is positioned on the support device **100** such that in assembled position of the support device **100** the second stiffening rib **140** contacts the lateral portion of one of the chords **2**, **4** outside the I-joist **1**.

[0077] The first rib's **130** horizontal portion and the second rib **140** provide for an intermediate reliable positioning of the support device **100** in its final assembly position such that the support device **100** may be temporarily held in assembly position by merely pushing the support device **100** with its chord embedding structure **120** over a lateral portion of a chord **2** or **4**. This is particularly advantageous where the support device **100** needs to be assembled at locations that are difficult to access by a construction worker. A support device **100** in accordance with the first embodiment is shown in top view in **FIG. 11A**, in perspective view in **FIG. 11B**, in side view in **FIG. 11C**, which is in protrusion direction of the I-joist **1**, **1**B, IC, and in front view in **FIG. 11D**, which is in direction of the reference plane **11**.

[0078] In **FIG. 5**, a second embodiment is illustrated in which the first stiffening rib **130** features a first flange **132**, which on one hand increases the stiffness of the first stiffening rib **130** and on the other hand provides for an area contact between the first stiffening rib **130** and the web **3**. A support device **100** in accordance with the second embodiment is shown in top view in **FIG. 12A**, in perspective view in **FIG. 12B**, in side view in **FIG. 12C**, which is in protrusion direction of the I-joist **1**, and in front view in **FIG. 12D**, which is in direction of the reference plane **11**.

[0079] In **FIG. 6**, a third of the preferred embodiments is illustrated, in which third stiffening ribs **150** protrude from the outer edge of one or both of the bridging structures **110**. The third stiffening ribs **150** protrude in direction substantially parallel to the first stiffening rib **130** and may be of substantially equal height as the first stiffening rib **130**. The third stiffening ribs **150** provide additional bending stiffness to the central portion of the bridging structures **110**. The third stiffening ribs **150** may be in a distance to a vertical portion of the first stiffening rib **130** such that the support structure **20** may be snugly held between them. This may additionally ease the assembly process, since the support structure **20** may be brought into position relative to the support device **100** prior to assembly of the support device **100** itself. A support device **100** in accordance with the third embodiment is shown in top view in **FIG. 13A**, in perspective view in **FIG. 13B**, in side view in **FIG. 13C**, which is in protrusion direction of the I-joist **1**, and in front view in **FIG. 13D**, which is in direction of the reference plane **11**.

[**0080**] In **FIG. 7**, a fourth of the preferred embodiments is illustrated in which the third stiffening ribs **150** feature second flanges **152**, which on one hand increase the stiffness of the third stiffening rib **150** and on the other hand provide for an additional area contact between the third stiffening ribs **150** and the web **3**. **FIG. 7** shows an additional support device **100** of the fourth embodiment in a second assembly position on the opposite side of the web **3**. In that fashion maximum buckling opposing support may be provided from both sides to the web **3**. Opposing contact pressure in the buckling opposing interfaces holds thereby the web **3**. The opposing contact pressure may be applied by fasteners holding together two opposing flanges **132** and/or **152** through the web **3**. The dual assembly position of **FIG. 7** is not limited to a particular embodiment of the support structure **100**. A support device **100** in accordance with the fourth embodiment is shown in top view in **FIG. 14A**, in perspective view in **FIG. 14B**, in side view in **FIG. 14C**, which is in protrusion direction of the I-joist **11***b*, **1**C, and in front view in **FIG. 14D**, which is in direction of the reference plane **11**. The flanges **132** and **152** may also feature primary attachment holes **112** for a direct attachment to the web **3**.

[**0081**] In the first, second, third and fourth embodiments, the main planar body of the support device 100 is placed immediately adjacent the reference plane **11**. The stiffening ribs **130**, **140**, **150** point towards the web **3** in assembled position. The buckling opposing interface is defined either by attachment of the bridging structures' **110** planar portions to the web **3** via the support structure **20** and/or by attachment of the flanges **132** and/or **152** to the web **3**.

[**0082**] In the remaining fifth, sixth, seventh, eights, ninth, tenth, eleventh, twelfth and thirteenth embodiments described in the below under **FIGS. 8-10** and **FIGS. 15-24** the support device **200** is configured for a direct contact of the main planar body portion with the web **3**. In assembly position of the support device **200**, the stiffening ribs **230**, **240**, **250**, **260**, **270** protrude away from the web **3**. The buckling opposing interface is defined primarily by attachment of the bridging structures' **110** planar portions directly to the web **3**.

[**0083**] Whereas the first, second, third and fourth embodiments are configured for preferably including the support structure **20**, the remaining embodiments are specifically configured to provide a buckling opposing interface without use of the additional support structure **20**. The remaining embodiments provide for a splicing opposing connection of the support device **200** in a corner line **12** along a boundary between web **3** and either of the chords **2**, **4**.

[**0084**] The fifth embodiment of the invention is shown in assembled position in **FIGS. 8A and 8B**. The main planar body of the support device **200** contacts one side of the web **3** along the web height **8**. A horizontally oriented spacing structure **220** combines and holds the two bridging structures **210** in a predetermined clearance distance as is described for the first, second, third and fourth embodiments. Primary attachment holes **212** are placed along the protrusion direction of the bridging structures **212** for a direct attachment of the bridging structures **212** to the web **3**.

[**0085**] A fourth primary stiffening rib **240** spans across the two bridging structures **210**. The fourth primary stiffening rib **240** may be interrupted or continuous as is exemplarily depicted in the Figures. The fourth primary stiffening rib **240** is substantially perpendicular to the main planar body. The fourth primary stiffening rib **240** s positioned on the support device **200** such that it snugly contacts in assembly position the lateral inside portion of at least one of the chords **2**, **4**, while the bridging structures **210** are oriented across the web **3**.

[**0086**] The support device **200** further features angulated holes **221** protruding through and positioned in a fold between the main planar body and the fourth primary stiffening rib **240**. In that way, the said support device **200** may be attached with fastener **300** along an angle **222** through the angulated holes **221** to the I-joist **1**, **1**B, **1**C. In assembled position where the main planar body snugly contacts the web **3** and where the fourth primary stiffening rib **240** snugly contacts the inside of one of the chords **2**, **4**, the angulated holes **221** point directly onto a corner line **12**. Corner lines **12** exist along the boundaries between the web **3** and the chords **2**, **4**.

[**0087**] The corner line **12** provides thereby for a centering of the fasteners **300** avoiding a slipping of them along a surface of the I-joist **1**, **1**B, **1**C prior to surface penetration. In addition, the angular penetration of the fasteners **300** along the corner line **12** keeps a splicing risk of the chord(s) **2**, **4** to a minimum. Also, the angular fastening direction provides for an easy access of the fasteners during their placement.

[**0088**] Further, the angular fastening direction provides for a simultaneous contact pressure of the main planar body and the fourth primary stiffening rib **240** with the opposing surfaces of the I-joist **1**, **1**B, **1**C. Hence, by initially attaching the support device **200** on the I-joist **1**, **1**B, **1**C via the fasteners **300** and through the angular holes **221**, the support device is brought into a tight, snug contact position with both the web **3** and one the bottom chord **2**. In case the support device **200** is attached with the spacing structure **220** above the hole **15**, the fourth stiffening **240** snugly contacts the top chord **4**.

[**0089**] The bridging structures **210** are directly attached to the web **3** via primary attachment holes **212**. The bridging structures **210** operate similar like bridging structures **110** except that they provide the buckling opposing interface with the remainder of the web **3** without inclusion of the support structure **20**. A support device **200** in accordance with the fifth embodiment is shown in top view in **FIG. 15A**, in perspective view in **FIG. 15B**, in side view in **FIG. 15C**, which is in protrusion direction of the I-joist **1**, 1B, **1**C, and in front view in **FIG. 15D**, which is in direction of the reference plane **11**.

[**0090**] **FIGS. 9A and 9B** illustrate a sixth embodiment in which secondary fourth stiffening ribs **241** span across the bridging structures **210** opposite the fourth primary stiffening rib **240**. Angular holes **223** protrude through the fold between secondary fourth stiffening rib **241** and the bridging structures **210** in an angle **224**. Fasteners **301** may be attached in a fashion similar as described in the above for the angular holes **221** and the fasteners **300**.

[**0091**] A height of the support device **200** is selected in correspondence with varying dimensional standards of the web height **8**. Consequently, fourth stiffening ribs **240**, **241** nugly contact both chords **2**, **4** and provide for a direct transmission of an eventual compressive force between the chords **2**, **4** resulting from a load carrying deflection of the I-joist **1**, 1B, **1**C. The web **3** may be consequently supported and/or relieved from compressive peak loads, which additionally reduces the web's **3** buckling tendency. A support device **200** in accordance with the sixth embodiment is shown in top view in **FIG. 16A**, in perspective view in **FIG. 168**, in side view in **FIG. 16C**, which is in protrusion direction of the I-joist **1**, 1B, **1**C, and in front view in **FIG. 16D**, which is in direction of the reference plane **11**.

[**0092**] **Figs. 10A and 10B** show a seventh embodiment in which a fifth stiffening rib **230** protrudes along the inside U-shaped edge of the support device **200**. The fifth stiffening rib **230** protrudes perpendicular from the main planar body in direction of either of the fourth stiffening ribs **240**, **241**. In case, the support device **200** features a fourth secondary stiffening rib **241**, the fifth stiffening rib **230** may be fully, partially or not directly connected to the rib **241**. The fifth stiffening rib **230** may have flaps extending at its ends (not shown). The flaps may be bent into an orientation parallel to the rib(s) **240** as is well known for enforcing three plane-corner regions of folded sheet metal parts.

[**0093**] An offset **231** between the horizontal portion of the fifth stiffening rib **230** and the fourth primary rib **240** may correspond to the chord height **10**. In that fashion, the support device **200** may be assembled with the main planar body being coplanar to the reference plane **11** and with the stiffening ribs **230**, **240** or **241** pointing towards the web **3**; the spacing structure **220** may operate thereby similar to the chord embedding structure **120**. A support device **200** in accordance with the seventh embodiment is shown in top view in **FIG. 17A**, in perspective view in **FIG. 17B**, in side view in **FIG. 17C**, which is in protrusion direction of the I-joist **1**, 1B, 1C, and in front view in **FIG. 17D**, which is in direction of the reference plane **11**.

[**0094**] A support device **200** in accordance with an eight embodiment is shown in top view in **FIG. 18A**, in perspective view in **FIG. 18B**, in side view in **FIG. 18C**, which is in protrusion direction of the I-joist **1**, 1B, **1**C, and in front view in **FIG. 18D**, which is in direction of the reference plane **11**. In the eight embodiment, the support device **200** features sixth stiffening ribs **250** that protrude from the outside edges of the bridging structures **210** perpendicular from the main planar body in direction of either of the fourth stiffening ribs **240**, **241**. The sixth stiffening ribs **250** may be fully, partially or not connected to either or both of the stiffening ribs **240**, **241**. The sixth stiffening ribs **250** may have flaps extending at either or both of its ends. The flaps may be bent into an orientation parallel to the rib(s) **240**, **241** as is well known for enforcing three-plane corner regions of folded sheet metal parts.

[**0095**] A support device **200** in accordance with a ninth embodiment is shown in top view in **FIG. 19A**, in perspective view in **FIG. 19B**, in side view in **FIG. 19C**, which is in protrusion direction of the I-joist **1**, 1B, **1**C, and in front view in **FIG. 19D**, which is in direction of the reference plane **11**. In the ninth embodiment, the fourth stiffening ribs **240**, **241** include a back folded support angle featuring first wings **243**, **245** and second wings **244**, **246**. First wings **243**, **245** are continuations of the fourth stiffening ribs **240**, **241** that are bent backwards at their peripheral ends and brought into substantially parallel orientation. The second wings **244**, **246** are parallel to the main planar body. The angulated holes **221**, **223** protrude all the way through the support angles. The support angles substantially increase a bending stiffness of said fourth stiffening ribs **240**, **241** as may be well appreciated by anyone skilled in the art.

[**0096**] A support device **200** in accordance with a tenth embodiment is shown in top view in **FIG. 20A**, in perspective view in **FIG. 20B**, in side view in **FIG. 20C**, which is in protrusion direction of the I-joist **1**, 1B, **1**C, and in front view in **FIG. 20D**, which is in direction of the reference plane **11**. In the tenth embodiment, the fourth stiffening ribs **240**, **241** feature at their peripheral ends stiffening flanges **242**, **247**. Similarly, fifth and sixth stiffening ribs **230**, **250** may also feature stiffening flanges (not shown). The stiffening flanges **242**, **247** provide additional buckling stiffness to the ribs from which they extend.

[**0097**] Also, the stiffening flanges **242**, **247** may be bent opposite to the direction indicated in the **FIGS. 20A-20D**. In that fashion, the stiffening flanges **242**, **247** may wrap around the chord(s) **2**, **4**. Eventual additional flanges (not shown) may be provided at the peripheral ends of the stiffening flanges **242**, **247** such that the chord(s) **2**, **4** islare embraced from three sides by sheet metal.

[**0098**] Finally, a support device **200** in accordance with an eleventh embodiment is shown in top view in **FIG. 21A**, in perspective view in **FIG. 21B**, in side view in **FIG. 21C**, which is in protrusion direction of the I-joist **1**, 1B, **1**C, and in front view in **FIG. 21D**, which is in direction of the reference plane **11**. In the eleventh embodiment, the support device **200** features seventh stiffening ribs **260**, **270** indented in the main planar body.

[**0099**] A practical test of a wooden I-joist, commercially available under the specification 9½" LPI **200** with a maximal shear load or nominal load of 1125 lb under standardized conditions was reinforced by a single support device **200** according to the seventh embodiment made from 16 gage standard sheet metal. A hole was cut into the web portion of the tested I-joist. The cut hole extended in vertical direction from top chord to bottom chord and in horizontal direction from side to side up to the vertical portions of the inside U-shaped contour of the support device **200**. The practical test resulted in tested failure load of 2370 lb, which corresponds to a maximum allowable shear load of 790 lb after applying a safety factor of 3 as is well known in the art. This is about 70% of the nominal load. Testing conditions complied with standards established by the World I-joist

Manufacturer Association (WIJMA) for shear load testing of I-joists with web holes as is well known in the art.

[0100] The support devices **100**, **200** are preferably fabricated from sheet metal by bending, deep drawing, hydro forming and/or other well-known sheet metal forming operations.

[0101] The scope of the invention includes embodiments in which the two bridging structures **110** are combined by two opposing chord embedding structures **120** and/or in which the two bridging structures **210** are combined by two opposing spacing structures **220**. In that cases, the outside contour of the support devices **100**, **200** in view onto the reference plane **11** is approximately that of a square. The inside contour has thereby an approximately O-shape. In that cases, stiffening ribs **130**, **230** follow the O-shape contour.

[0102] The scope of the invention includes embodiments, in which more than two bridging structures **110**, **210** are combined by alternately arrayed structures **120**, **220**.

[0103] The support device **100** may be provided as a repair means for erroneously cut holes **15**. The support device **100** may also be configured for providing a cutting mask to prevent erroneously hole cutting.

[0104] The support devices **100**, **200** may be part of an originally fabricated I-joist **1**, **1B**, **1C** for the purpose of providing increased buckling resistance and/or bending resistance at a given section of the I-joist **1**, **1B**, **1C**. This may be particularly advantageous, where it is desirable to keep the all over dimensions of an I-joist **1**, **1B**, **1C** to a minimum regardless an eventual peak load at identified sections of the I-joist **1**, **1B**, **1C**.

[0105] Referring to **FIGS. 22-42**, additional findings and inventive steps of the present invention are described in the following. Characteristics unique for wooden I-joists **1**, **1B**, **1C** include dissimilar stiffness properties of web **3** and chord **2**, **4** material, which result in peaks of well known I-joist shear loads in the glue connection between the web spigots **33** and the chord grooves **21**, **41** (see **FIG. 22**). During additional testing this unique characteristic became apparent due to glue connection failure in more than 90% of the tests. Because at least of the above wooden I-joist **1**, **1B**, **1C** characteristic the reinforcement bracket **200** is particularly suited for wooden I-joists **1**, **1B**, **1C** as will be more apparent in the below.

[0106] Another characteristic of wooden I-joist **1**, **1B**, **1C** as described further above is the splicing tendency of its chords **2**, **4**, which is addressed by the angulated attachment holes **221** along the overall width **202**. The attachment angle **222** of the angulated holes **221** is preferably smaller than spigot taper angle **332** such that the fasteners **300** mainly penetrate web **3** material extending via the spigots **33** into grooves **21**, **41** of the chords **2**, **4** while the reinforcement bracket **200** is attached to the wooden I-joist **1**, **1B**, **1C** via the angulated holes **221** in a corner line along the boundary between the web **3** and one of the cords **2**, **4**. The attachment angle **222** is a symmetry angle between planar body and fourth stiffening rib **240** such that the fasteners **300** apply a balanced tightening force via their respective heads once the fasteners **300** are tightened. For a preferred perpendicularly protruding fourth stiffening rib **240** the attachment angle **222** is about 45 degree. The spigot taper angle **332** is conventionally larger than 60 degrees.

[0107] The additional testing of reinforcement bracket **200** in combination with a variety of brands of wooden I-joists **1**, **1B**, **1C**, commercially available under the brand names Trus Joist™, APA™, Lousiana Pacific™, Boise™ in standardized total heights 5 of 9½ inches, 11⅞ inches, 14 inches and 16 inches revealed for increasing total heights **5** and decreasing bearing distance **17L** (see **FIG. 24**) increasing contour stress peaks and stress gradients particularly in an interface **290** (see **FIGS. 22, 23**) between the bridging structure **210** and the spacing structure **220**. Contour stress peaks and stress gradients increase together with I-joist shear load communicated onto the bridging structure **210** across the bridging height **210H** in dependence on the rigidity of the bridging structure's **210** attachment to the web **3**. It was discovered that the communicated shear load resulted particularly in an angular displacement between the bridging structure **210** and the spacing structure **220** as is illustrated in **FIG. 27**. To oppose the shear load while flattening stress gradients and minimizing contour stress peaks, the interface **290** was stiffened by adding a transition radius **290R** of at least about half the bridging height **210H**. The transition radius **290R** is placed between a first width contour **229** of the spacing structure **220** and an adjacent height contour **219** of the bridging structure **210**. First width contour **229** and adjacent height contour **219** are introduced in this application for the purpose of unambiguously locating the transition radius **290R** and a contour recess described in the below. It is clear to anyone skilled in the art that the transition radius **290R** may have a dimension such that first width contour **229** and/or adjacent height contour **219** are of zero length.

[0108] The stiffening configuration of the interface **290** may also include a curved rib island **271** in an approximately concentric offset to the transition radius **290R**, which assists in flattening the contour stress gradient away from the transition radius **290R** as can be seen in **FIGS. 34, 37, 40**. The curved rib island **271** assists also in opposing secondary buckling forces resulting from the stress peaks and stress gradients in the planar sheet metal body of the interface **290** as may be well appreciated by anyone skilled in the art. The curved rib island **271** is particularly feasible in case of the reinforcement bracket **200** being made of sheet metal.

[0109] The bridging structure **210** has a bridging height **210H** and a bridging width **210W** within which an attachment face **218** is facing in direction opposite the protrusion direction of the ribs **230**, **240**, **250**. The attachment holes **212** are arrayed within the attachment face **218** such that contact pressure from fasteners tightened through the attachment holes **212** on the web **3** provide a contact pressure between the attachment face **218** and the web **3** in a balanced fashion.

[0110] The resulting contact friction between the attachment face **218** and the web **3** assists in conjunction with the attachment hole fasteners in transferring shear loads between the web **3** the buckling structure **210**. The bridging structure **210** has a buckling opposing configuration in direction

[0111] The bridging structure **210** has a buckling opposing configuration in direction along its bridging height **210** reinforcing the web **3** at the attachment location of the bridging structure **210**. In case of the reinforcement bracket

200 being made of sheet metal, the buckling opposing configuration indudes sixth stiffening rib 260 and/or a central bridging rib island 261.

[0112] The spacing structure 220 has a spacing height 220H and a spacing width 220W. The spacing height 220H is a fraction of the bridging height 210H and the spacing width is a multiple of the bridging width 210W. The spacing width 220W is preferably larger than the bridging height 210H. The overall width 202 of the reinforcement bracket 200 includes the spacing width 220W and the bridging width 210W.

[0113] Referring to FIGS. 23, 24, preferably two bridging structures 210 are angularly combined oppositely the spacing structure 210 such that the spacing structure 210 extends with its spacing width 220W between the adjacent height contours 219. A contour recess having a clearance width 201 and a recess height 203 is thereby defined between the adjacent height contours 219, the first spacing width contour 229 and the transition radii 290R.

[0114] The reinforcement bracket 200 of FIGS. 23, 24 is preferably monolithically made of sheet metal having a thickness of 16 gage respectively about 1.5 mm in approximate dimensional ranges listed in Table 1 below. The reinforcement brackets 200 of Table 1 are preferably attached to wooden I-joist having a height 5, a web hole 15 of up to modified boundary circle 17D down to a bearing distance 17L listed in Table 1 adjacent the respective reinforcement bracket 200 dimensions. Fasteners 300 and fasteners for attaching the bridging structures 210 preferably conform to ANSI Specification B18.6.4-1981. Heights of ribs 230, 240, 250, 261, 271 are about 0.5 inches. Dimensions of Table 1 are approximate inches dimensions.

[0116] Reinforcement brackets 200 may be attached at a web hole 17 on both sides of the web 3 as depicted in FIG. 22 such that the attachment faces 218 are facing each other. In the more particular case, where the reinforcement brackets 200 are oppositely attached such that their respective outside contours are substantially collinear in direction perpendicular to their attachment faces 218, spacing holes 213 may be alternately inter arrayed with the attachment holes 212, such that attachment holes 212 of a first of the opposing reinforcement brackets 200 face a spacing hole of a second of the opposing reinforcement brackets 200. In that way, fasteners penetrating through the attachment holes 212 and the web 3 are prevented from pushing the opposing attachment face 218 away. In that way the full web width 9 may be utilized in combination with the fasteners'in thread, while a well known conical Up portion of the fastener may emerge unimpeded by the opposite reinforcement bracket 200. The conical tip portion is necessary for the fastener to bite into the solid web 3 as is well known in the art for a maximum connection strength between web 3 and bridging structure 210.

[0117] Also in conjunction with oppositely aligned reinforcement brackets 200 attached with their angulated holes adjacent a single chord 2 or 4, the angulated attachment holes 221 may be positioned along the outside width contour 209 such that a first angulated attachment hole 221 of a first reinforcement bracket 200 is in a splicing opposing safety offset to a second angulated attachment hole 221 of a second reinforcement bracket 200.

[0118] The color plots of FIGS. 25-27, 30-42 illustrate the teachings described in reference to FIGS. 22-24. For that purpose, representative finite element analyses where computed with a computer program commercially available under the trade name ProMechanica. The I-joist 1C with dimensions approximately corresponding to a standardized wooden I-joist of Table 1 having an approximate height 5 of about 9.5 inches was analyzed. For the purpose of simplicity, the I-joist 1C was assumed monolithic with isotropic material properties of web 3 and chords 2, 4, evenly loaded on the chord top 42 and supported via bearings 22. Web enforcers 35 as are common in architectural constructions were also considered part of the monolithic I-joist 1C. FIG. 25 shows a portion AJ of the I-joist 1C without web hole 17 as a reference stress plot. Test data of I-joist 1C without web hole 17 as nominal reference values was obtained from manufacturers. The color offsets between chords 2, 4 and web 3 show steep stress gradients even for a monolithic I-joist 1C of isotropic material. This demonstrates clearly the increased shear stress in the glue interface between web spigots 33 and chord grooves 21, 41.

TABLE 1

Bridging height 210H	Overall width 202	Bridging width 210W	Transition radius 290R	Clearance distance 201	Recess Height 203	I-joist height 5	Boundary diameter 17D	Bearing distance 17L
6.4	15.1	3.6	3.3	7.9	4.7	9.5	6	18
8.8	17.6	3.6	4.5	10.4	6.6	11.5	8.4	18
10.9	19.6	3.6	5.5	12.4	9.2	14	10.5	18
12.9	21.6	3.6	6.5	14.4	11.2	16	12.5	18

[0115] In case the reinforcement bracket 200 is made of sheet metal, the fifth stiffening rib 230 protruding along the first width contour 229, the transition radius or radii 290R and the adjacent height contour(s) 219 assists in increasing buckling opposing strength of the bridging structure 210. The fifth stiffening rib 230 assists also in increasing shearing opposing strength of the interface 290 and secondary buckling opposing strength of the interface 290 and the spacing structure 210. Secondary buckling may result from the shear loads exerted onto the interface structure 290 and spacing structure 210. The fourth stiffening rib 240 and curved rib island 271 may also strengthen the interface 290 and the spacing structure 210 against secondary buckling. Due to the substantially perpendicular rib protrusion of the rib islands 261, 271, bridging structure 210 and interface 290 are significantly strengthened against buckling compared with further above described indented ribs 260, 270. The fourth stiffening rib 240 may also provide stiffness against a tertiary buckling of an adjacent chord 2, 4 under compressive load.

[0119] FIG. 26 shows the I-joist 1C portion AJ with web hole 17 prescribed within the web hole boundary diameter 17D. Stress maxima are clearly identifiable around the contour of hole 17. Stress gradients in the web/chord interfaces are significantly steeper in the vicinity of the web hole 17 particularly demonstrating the necessity for reinforcement of the web/chord interface in the web hole 17 vicinity. Practical testing of has demonstrated about 40% ultimate nominal strength of an I-joist 1, 1B, 1C having a hole similar to web hole 17.

[0120] FIG. 27 shows the internal displacement of the reinforcement structure 200 in general and the angular displacement of the bridging structure 210 with respect to the spacing structure 220 in particular, both resulting from the shear loads communicated between bridging structures 210 and the web 3 across the bridging height 210H.

[0121] Front and Back views of the reinforcement bracket of FIG. 22 under stress are shown in FIGS. 31, 32. Due to the missing curved rib island 271 the stress gradients along the transition radius 290R is particularly steep at the reinforcement bracket 200 the bridging structure 210 of which is facing away from the web enforcer 35. Spacing structures 210 span across both web/chord interfaces in the vicinity of the web hole 17 reducing peak stresses in both web/chord interfaces as illustrated in FIGS. 32, 33.

[0122] The stressed reinforcement bracket 200 of FIG. 23, 24 is depicted in FIG. 34 solely attached to the I-joist 1C via attachment holes 212. Friction between attachment faces 218 and web 3 is not considered. Shear load transfer is relatively low compared to attachment configurations of FIGS. 37 and 40. Stress peaks around the web hole 17 remain high and the stress gradients of the web/chord interface in the vicinity of the web hole 17 remain also at high levels as depicted in FIGS. 35, 36.

[0123] The stressed reinforcement bracket 200 of FIG. 23, 24 is depicted in FIG. 37 solely attached to the I-joist 1C via attachment holes 212 with friction between attachment faces 218 and web 3. The friction condition is approximated in the simulation by defining the attachment holes 212 and respective screw holes in the web 3 as rigidly connected. Shear load transfer is improved compared to attachment configuration of FIGS. 34 resulting in higher stress loads on the reinforcement bracket 200. As stresses increase in the reinforcement bracket 200, the curved rib islands 271 increasingly assists in flattening the stress gradients and lowering contour stress peaks in particular along the transition radii 290R. Corresponding stress peaks around the web hole 17 as well as stress gradients of the web/chord interface in the vicinity of the web hole 17 are depicted in FIGS. 38, 39 lower than in FIGS. 35, 36. From comparing FIGS. 35, 36 with FIGS. 38, 39 the significance of a rigid attachment of the bridging structure(s) 210 with the web 3 and consequently the significance of spacing holes 213 is clearly demonstrated.

[0124] The stressed reinforcement bracket 200 of FIG. 23, 24 is depicted in FIG. 38 attached to the I-joist 1C via attachment holes 212 and angulated holes 221 with friction between attachment faces 218 and web 3 and friction between fourth reinforcement rib 240 and chord 2. The friction condition is approximated in the simulation by defining the attachment holes 212, 221 and respective screw holes in the web 3 as rigidly connected. Shear load transfer is improved also along the outside with contour 209 compared to attachment configuration of FIG. 37 resulting in more leveled stress loads on the reinforcement bracket 200 and flatter stress gradients in the web/chord interface in the vicinity of the outside width contour 209. As shown in FIGS. 41, 42, stress peaks around the web hole 17 as well as stress gradients of the web/chord interface in the vicinity of the web hole 17 are lowest compared to FIGS. 35, 36, 38, 39. From comparing FIGS. 35, 36, 38, 39, 41, 42 the significance of a rigid attachment of the outside width contour 209 with the web/chord interface and consequently the significance of angulated holes 221 is clearly demonstrated.

[0125] Chords 2, 4 are commonly made of stress graded wood with grain orientation substantially parallel to the I-joists' 1, 1B, 1C, protrusion direction. Practical testing has demonstrated about 10% higher ultimate strengths for identical test setups except the reinforcement bracket 200 being attached once with a u-shape and once with an n-shape. This may be attributed to the fourth stiffening rib 240 opposing tertiary buckling forces of the compressed top chord 4 in chase in an n-shape type attachment of the reinforcement bracket 200. Practical testing has demonstrated about 90% ultimate nominal strength of an I-joist 1, 1B, 1C having a hole similar to web hole 17 reinforced with a reinforcement bracket in n-shape attachment orientation. Practical testing has demonstrated about 80% ultimate nominal strength of an I-joist 1, 1B, 1C having a hole similar to web hole 17 reinforced with a reinforcement bracket in u-shape attachment orientation. The test results of reinforcement brackets 200 including the stiffening interface 290 demonstrated an approximate 10% increased failure load under otherwise substantially identical testing conditions.

[0126] Accordingly, the scope of the invention described in the Figures and the above Specification is set forth by the following claims and their legal equivalent.

1. A reinforcement bracket for reinforcing a wooden I-joist against shear failure, said reinforcement bracket comprising a bridging structure angularly combined with a spacing structure via a stiffening interface of said spacing structure, wherein:

a. said bridging structure features a bridging height, a bridging width, and an attachment face with attachment holes, said bridging structure having a buckling opposing configuration in direction along said bridging height;

b. said spacing structure has a spacing height and a spacing width, said spacing height being a fraction of said bridging height and said spacing width being a multiple of said bridging width; and

c. wherein said stiffening interface includes a transition radius between a first width contour of said spacing structure and an adjacent height contour of said bridging structure, said transition radius being at least about half of said bridging height.

2. The reinforcement bracket of claim 1, wherein said stiffening interface includes a curved rib island in an approximately concentric offset to said transition radius.

3. The reinforcement bracket of claim 1, wherein two of said bridging structure being said angularly combined oppositely said spacing structure such that said spacing structure

extends with its spacing width between said adjacent height contours of said two bridging structures and such that a contour recess is defined between two of said adjacent height contours, said first spacing width contour and two of said transition radius.

4. The reinforcement bracket of claim 3, wherein:

a. said bridging height is about 6.4 inches;

b. an overall width is about 15.1 inches, said overall width including twice said bridging width of about 3.6 inches and including said spacing width of about 7.9 inches;

c. said transition radius is about 3.3 inches;

d. a clearance distance of said contour recess equals said spacing width and a contour recess height is about 4.7 inches; and

e. said reinforcement bracket is attached to a wooden I-joist with fasteners via said attachment holes, said wooden I-joist having an I-joist height of down to about 9.5 inches

5. The reinforcement bracket of claim 4, wherein said wooden I-joist has a web hole with a modified boundary circle of up to about 6 inches in a bearing distance of down to about 1 foot 6 inches, and wherein said reinforcement bracket is attached to said I-joist with said two bridging structures flanking said web hole.

6. The reinforcement bracket of claim 2, wherein:

a. said bridging height is about 8.8 inches;

b. an overall width is about 17.6 inches, said overall width including twice said bridging width of about 3.6 inches and including said spacing width of about 10.4 inches;

c. said transition radius is about 4.5 inches;

d. a clearance distance of said contour recess equals said spacing width and a contour recess height is about 6.6 inches; and

e. said reinforcement bracket is attached to a wooden I-joist with fasteners via said attachment holes such that said buckling load communication and said shear load communication includes at least a web of said I-joist, said wooden I-joist having an I-joist height of down to about 11.5 inches.

7. The reinforcement bracket of claim 6, wherein said wooden I-joist has a web hole with a modified boundary circle of up to about 8.4 inches in a bearing distance of down to about 1 foot 6 inches, and wherein said reinforcement bracket is attached to said I-joist with said two bridging structures flanking said web hole.

8. The reinforcement bracket of claim 2, wherein:

a. said bridging height is up to about 10.9 inches;

b. an overall width is up to about 19.6 inches, said overall width including twice said bridging width of up to about 3.6 inches and including said spacing width of up to about 12.4 inches;

c. said transition radius is about 5.5 inches;

d. a clearance distance of said contour recess equals said spacing width and a contour recess height is up to about 9.2 inches; and

e. said reinforcement bracket is attached to a wooden I-joist with fasteners via said attachment holes such that said buckling load communication and said shear load communication includes at least a web of said I-joist, said wooden I-joist having an I-joist height of down to about 14 inches.

9. The reinforcement bracket of claim 8, wherein said wooden I-joist has a web hole with a modified boundary circle of up to about 10.5 inches in a bearing distance of down to about 1 foot 6 inches, and wherein said reinforcement bracket is attached to said I-joist with said two bridging structures flanking said web hole.

10. The reinforcement bracket of claim 2, wherein:

a. said bridging height is about 12.9 inches;

b. an overall width is about 21.6 inches, said overall width including twice said bridging width of about 3.6 inches and including said spacing width of about 14.4 inches;

c. said transition radius is about 6.5 inches;

d. a clearance distance of said contour recess equals said spacing width and a contour recess height is about 11.2 inches; and

e. said reinforcement bracket is attached to a wooden I-joist with fasteners via said attachment holes such that said buckling load communication and said shear load communication includes at least a web of said I-joist, said wooden I-joist having an I-joist height of down to about 16 inches.

11. The reinforcement bracket of claim 10, wherein said wooden Ijoist has a web hole with a modified boundary circle of up to about 12.5 inches in a bearing distance of down to about 1 foot 6 inches, and wherein said reinforcement bracket is attached to said wooden I-joist with said two bridging structures flanking said web hole.

12. The reinforcement bracket of claim 1 being monolithically fabricated.

13. The reinforcement bracket of claim 1, wherein an outside width contour features an angulated attachment hole.

14. The reinforcement bracket of claim 13, wherein said reinforcement bracket is attached to a wooden I-joist via said angulated hole in a corner line along a boundary between a web and a chord of said wooden I-joist.

15. The reinforcement bracket of claim 13, wherein said angulated attachment hole is positioned along said outside width contour such that a first of said angulated attachment hole of a first of said reinforcement bracket is in a splicing opposing safety offset to a second of said angulated attachment hole of a second of said reinforcement bracket while said reinforcement brackets are positioned with their respective attachment faces facing each other and while edge contours of said reinforcement brackets are substantially collinear in direction perpendicular said attachment faces.

16. The reinforcement bracket of claim 1 being fabricated from sheet metal.

17. The reinforcement bracket of claim 16, wherein said bridging structure and said spacing structure feature a fourth stiffening rib protruding along an outside width contour of said reinforcement bracket.

18. The reinforcement bracket of claim 17, wherein said outside width contour features an angulated hole providing an attachment angle being a symmetry angle between a planar body of said reinforcement bracket and said fourth stiffening rib.

19. The reinforcement bracket of claim 18, wherein said reinforcement bracket is attached with fasteners via said angulated hole to a wooden I-joist along a corner line between a web and a chord of said wooden I-joist, and wherein said attachment angle is substantially smaller than a spigot taper angle of a web spigot extending and glued into a groove of said chord, and wherein said fasteners mainly penetrate material of said web spigot.

20. The reinforcement bracket of claim 16, further comprising a fifth stiffening rib protruding along said first width contour, said transition radius and said adjacent height contour.

21. The reinforcement bracket of claim 16, wherein said buckling opposing configuration includes a sixth stiffening rib along an outside height contour of said bridging structure, said outside height contour being oppositely said adjacent height contour.

22. The reinforcement bracket of claim 16, wherein said buckling opposing configuration includes a central bridging rib island in direction along said bridging height.

23. The reinforcement bracket of claim 1, further comprising spacing holes alternately inter arrayed with said attachment holes on said attachment face, such that said attachment holes of a first of said reinforcement bracket face said spacing holes of a second of said reinforcement bracket while said reinforcement brackets are positioned with their respective attachment faces facing each other and while outside contours of said reinforcement brackets are substantially collinear in direction perpendicular to said attachment faces.

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