

[54] **ARTICLE OF MANUFACTURE WITH TWISTED WEB**

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[22] Filed: **June 29, 1973**

[21] Appl. No.: **375,037**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 211,858, Dec. 27, 1971, abandoned, which is a continuation-in-part of Ser. No. 767,303, Oct. 14, 1968, abandoned.

[52] **U.S. Cl.**..... **29/191**, 29/6.1, 29/193, 29/193.5, 52/635

[51] **Int. Cl.**..... **B32b 15/02**, B22b 15/04

[58] **Field of Search** 29/193, 193.5, 6.1, 191; 113/116 A; 52/670-672, 635

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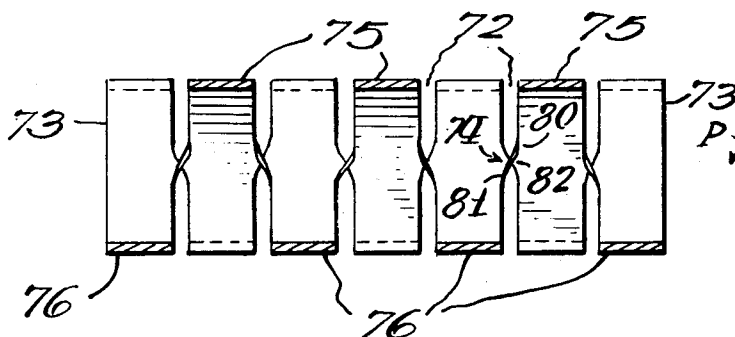
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Primary Examiner—Allen B. Curtis

[57] **ABSTRACT**

An article of manufacture wherein one or more pairs of spaced, parallel ribbons are connected by at least one integral web, with the webs connecting ribbon portions that are disposed in oppositely inclined planes. One end portion of each web is disposed in the plane of a first ribbon, and the opposite end portion of the web is disposed in the plane of a second ribbon, with the intermediate web portion being twisted throughout its length. The article is preferably fabricated from a sheet of metal or other suitable material with each of the ribbons being deformed to include alternating, longitudinally spaced crests and troughs, the crests on each ribbon being aligned with a trough on an adjacent ribbon. The article is fabricated by a process including the step of simultaneously imparting a multi-planar torsional deformation to each of the webs of the sheet while deforming the ribbons to form the crests and troughs.

41 Claims, 80 Drawing Figures



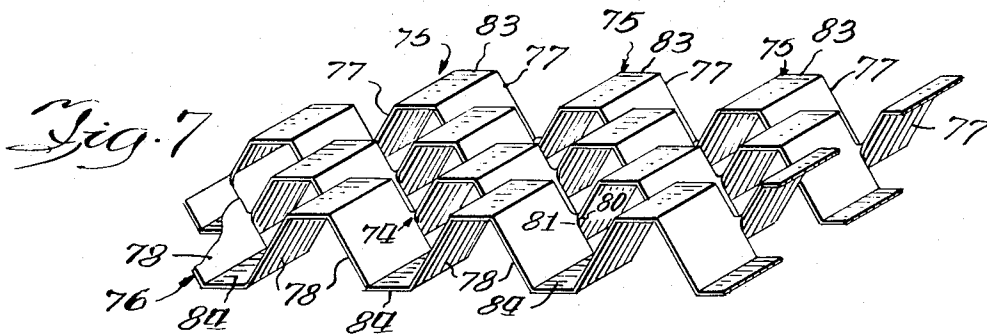
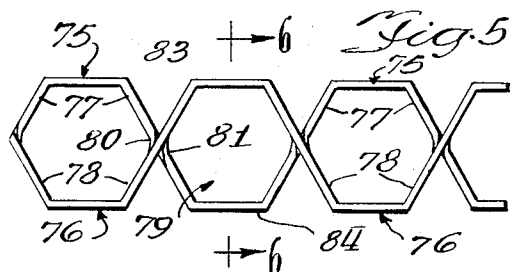
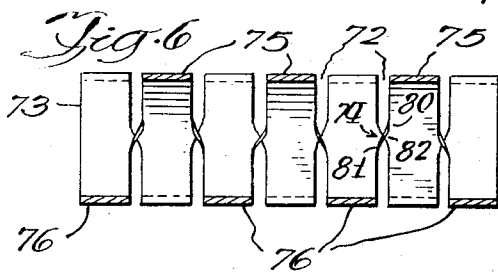
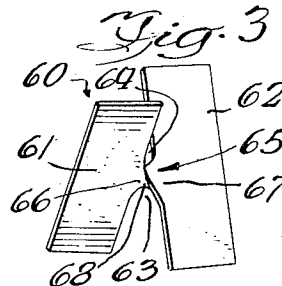
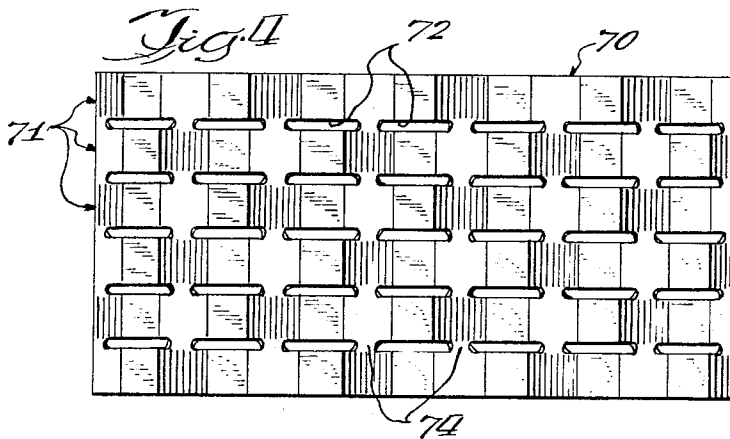
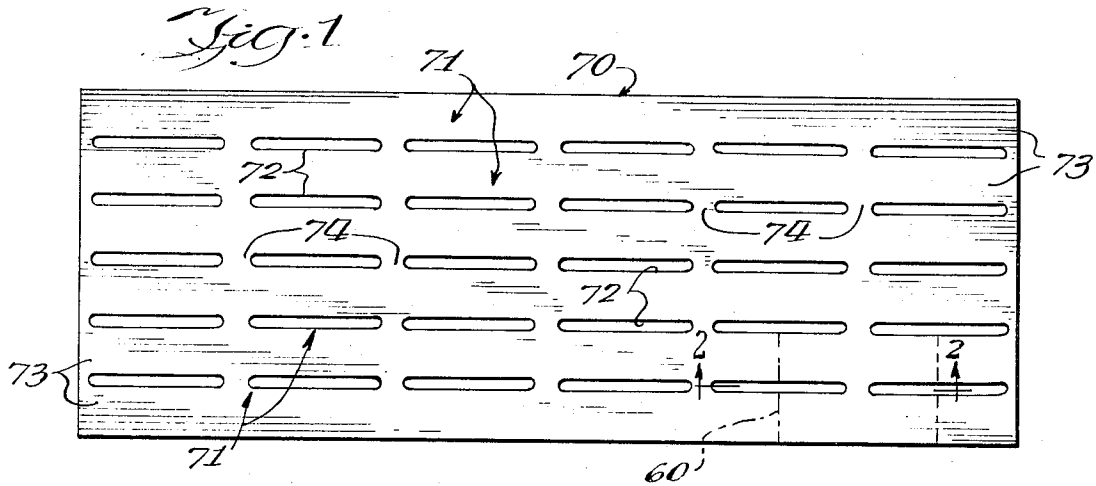


Fig. 8

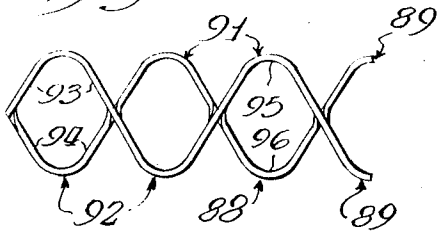


Fig. 9

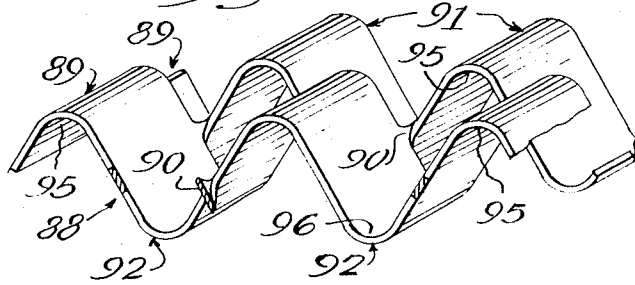


Fig. 10

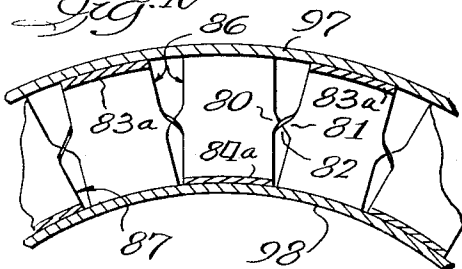


Fig. 11

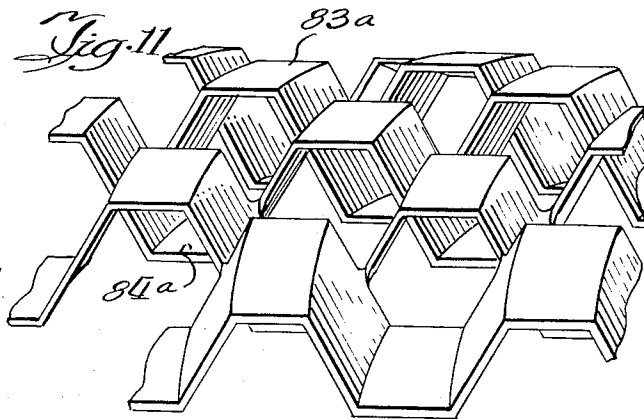


Fig. 12

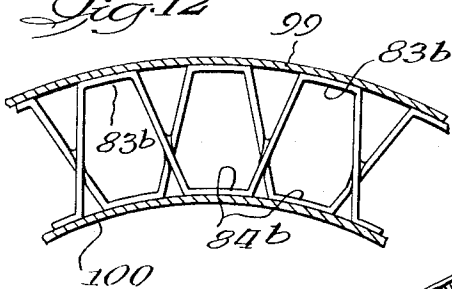


Fig. 13

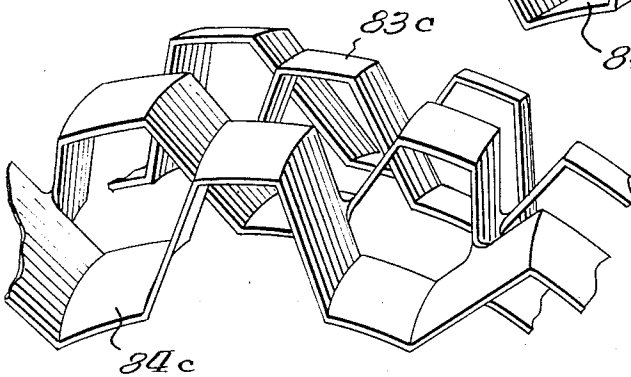
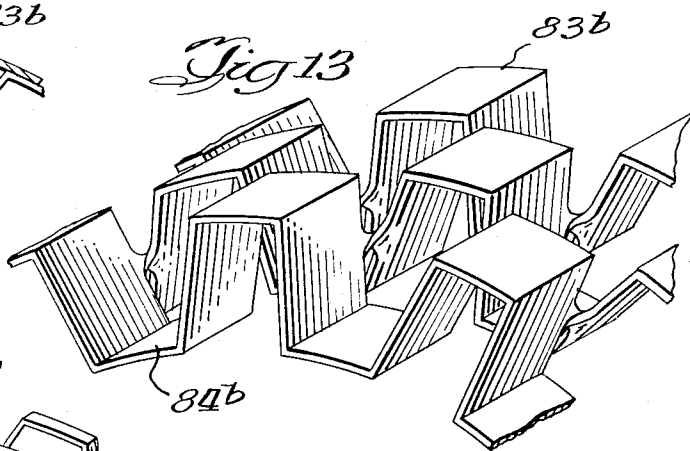


Fig. 14

Fig. 15

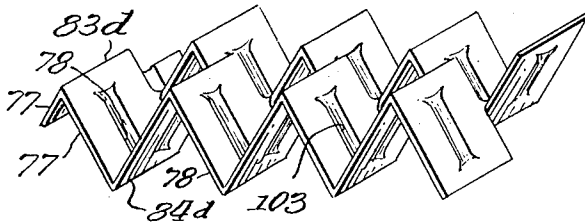


Fig. 16

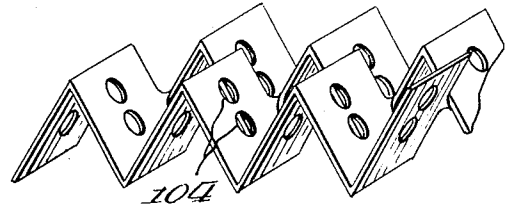


Fig. 17

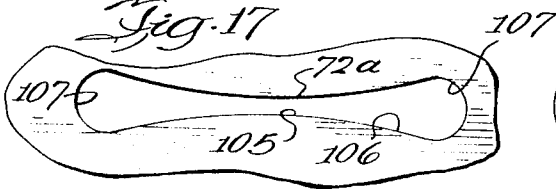


Fig. 20

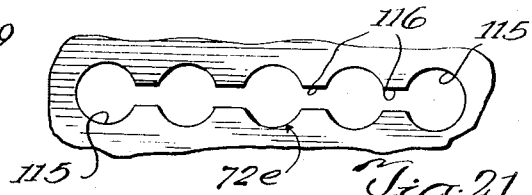
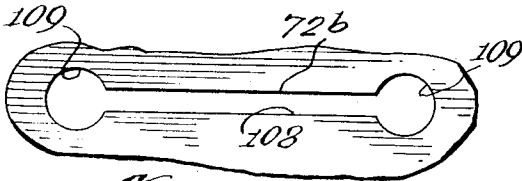
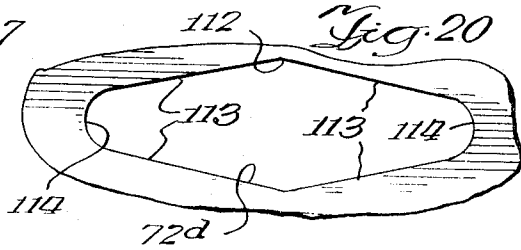


Fig. 18

Fig. 21

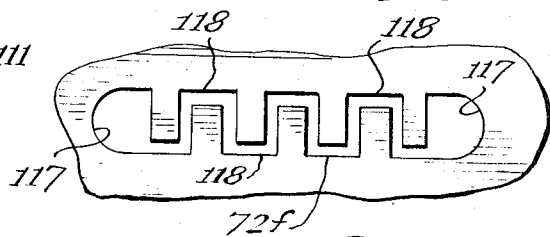
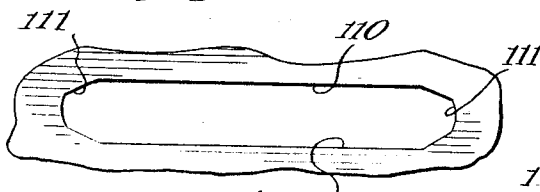


Fig. 19

Fig. 22

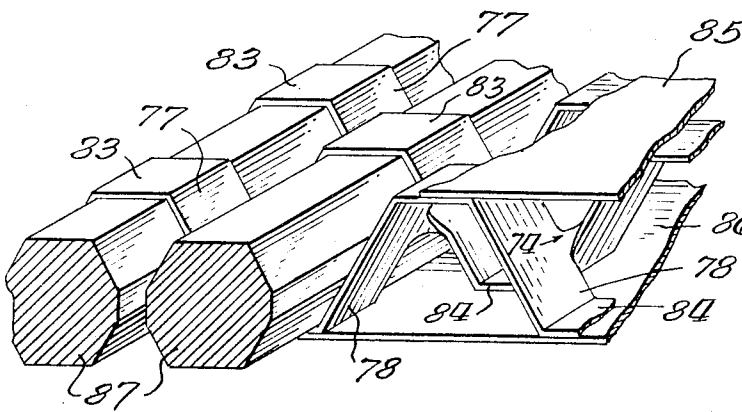


Fig. 23

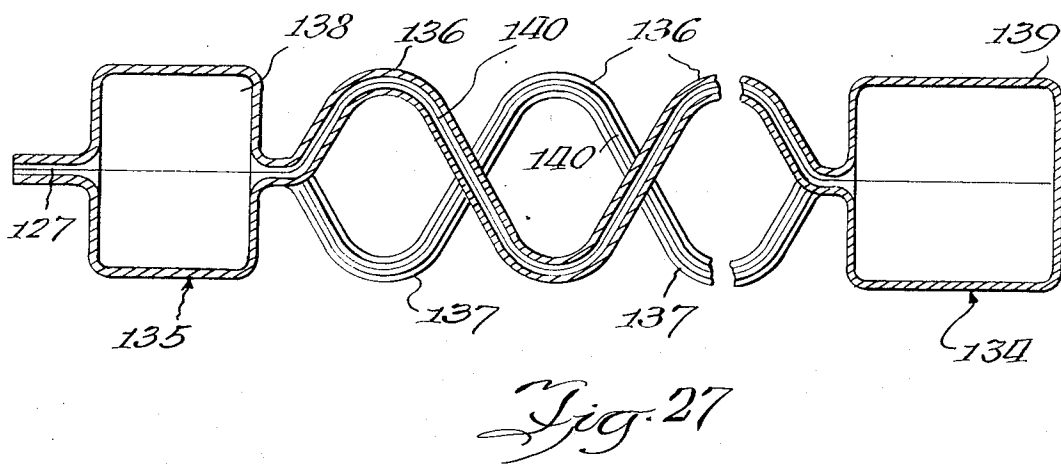
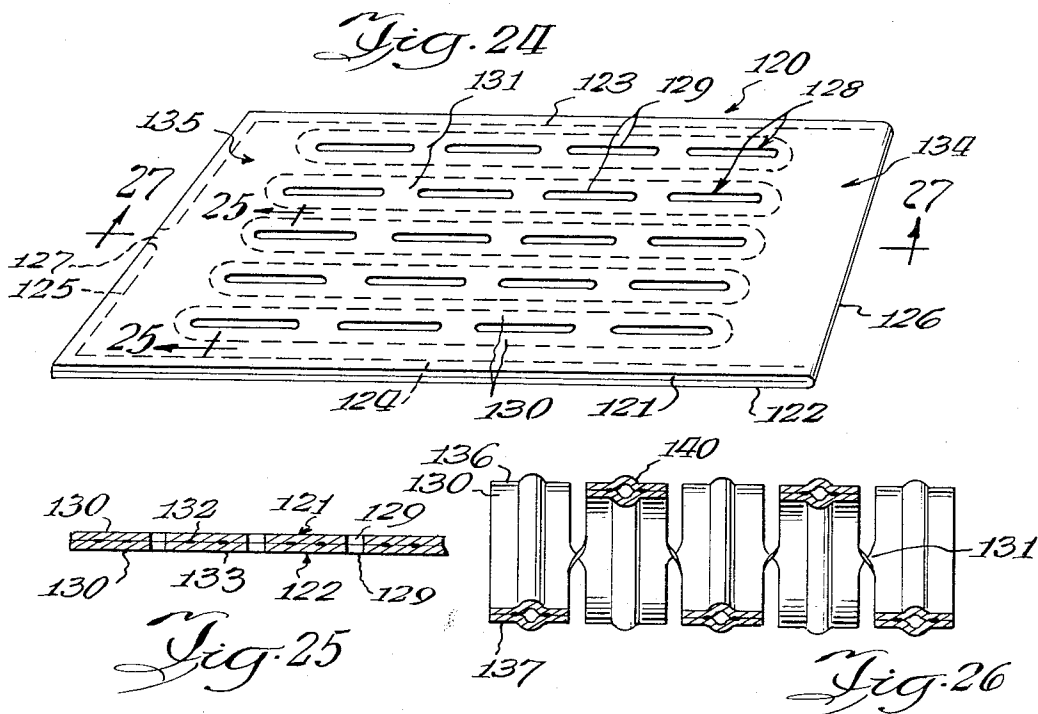
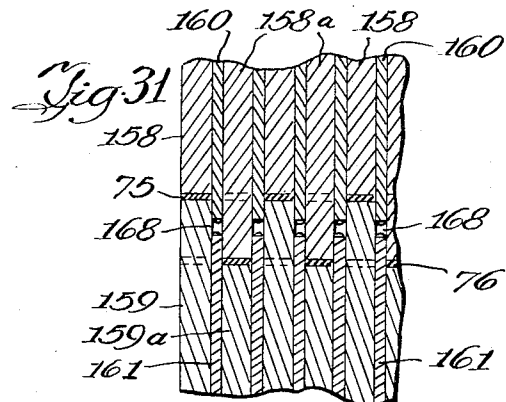
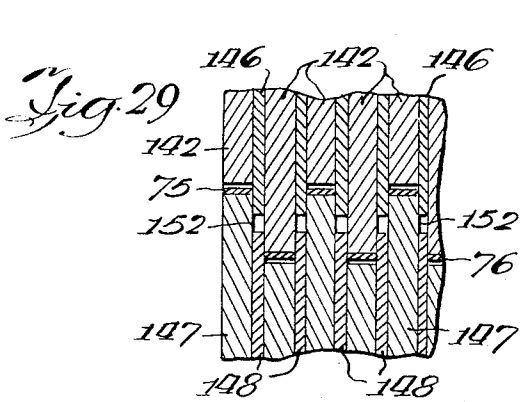
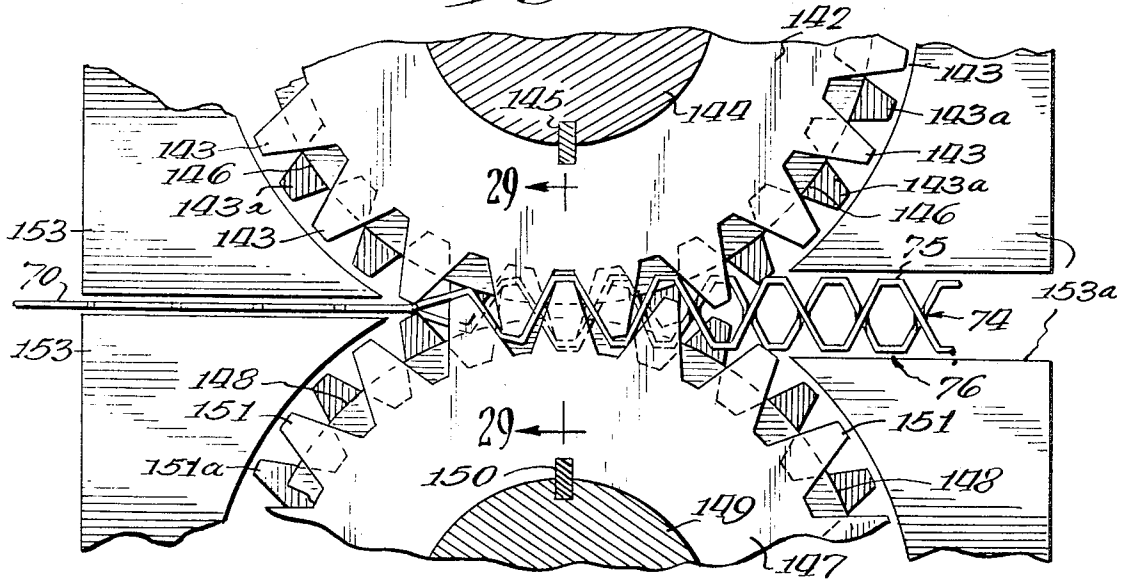
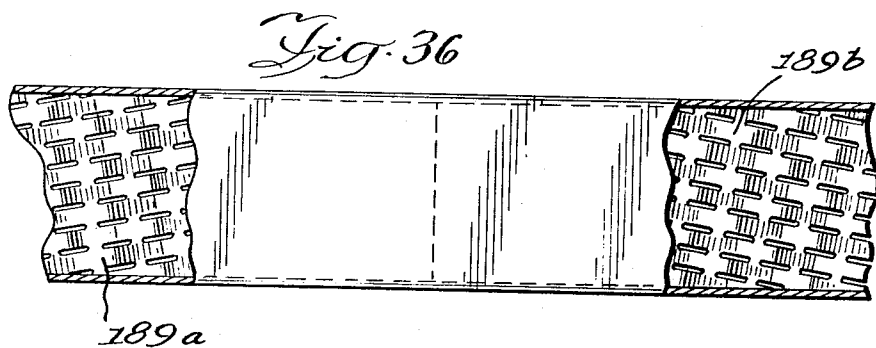
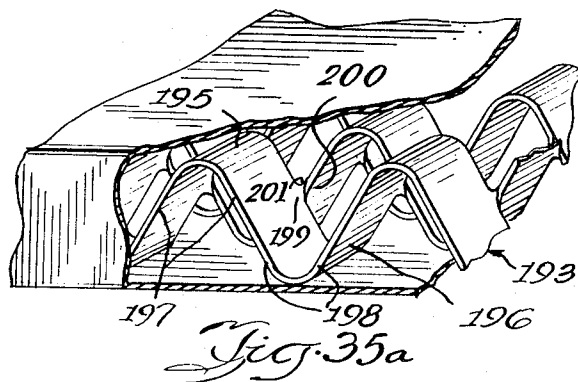
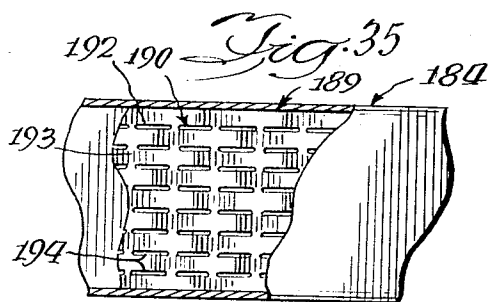
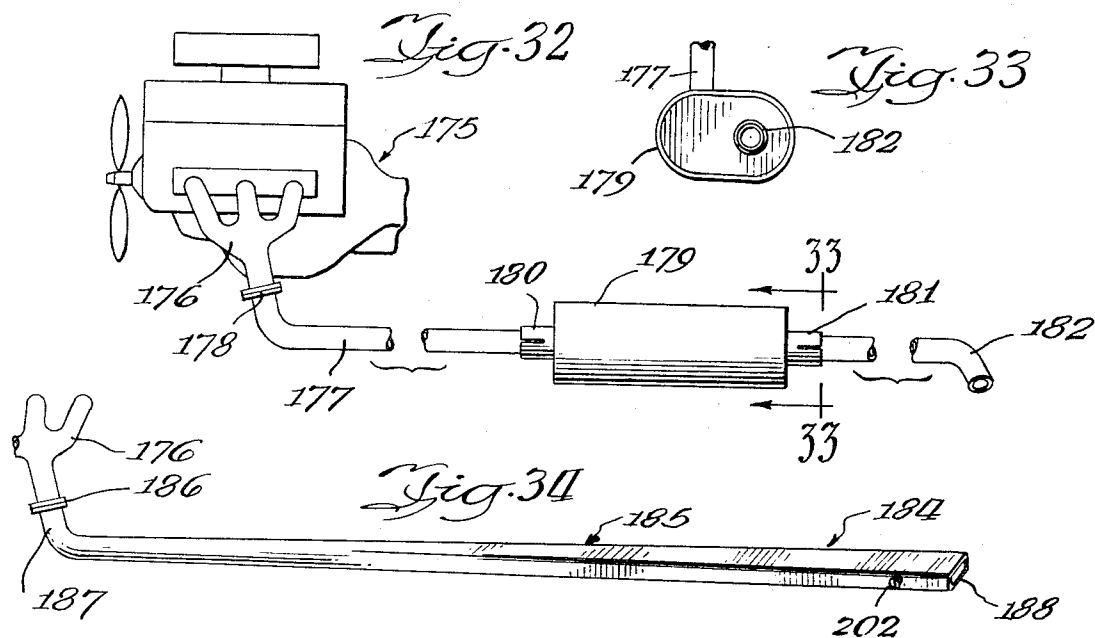
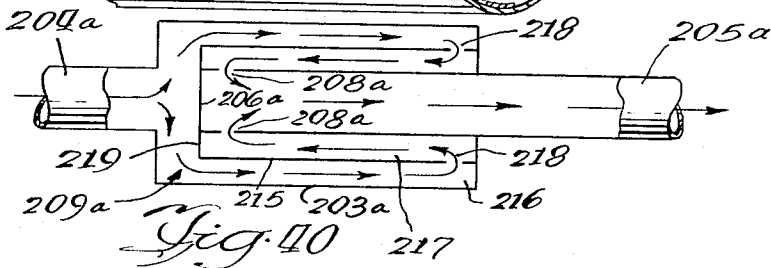
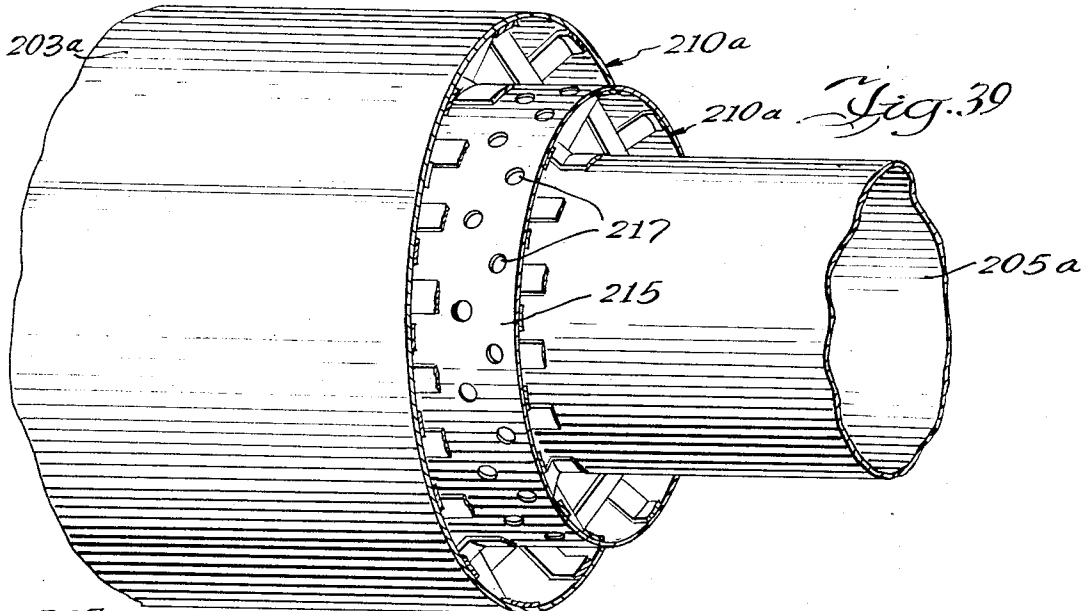
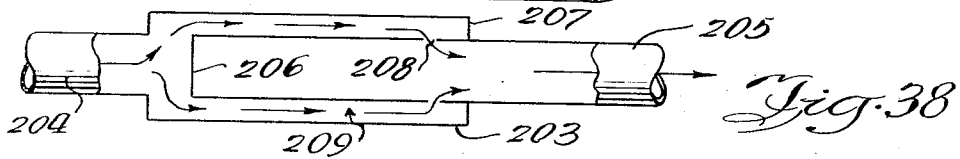
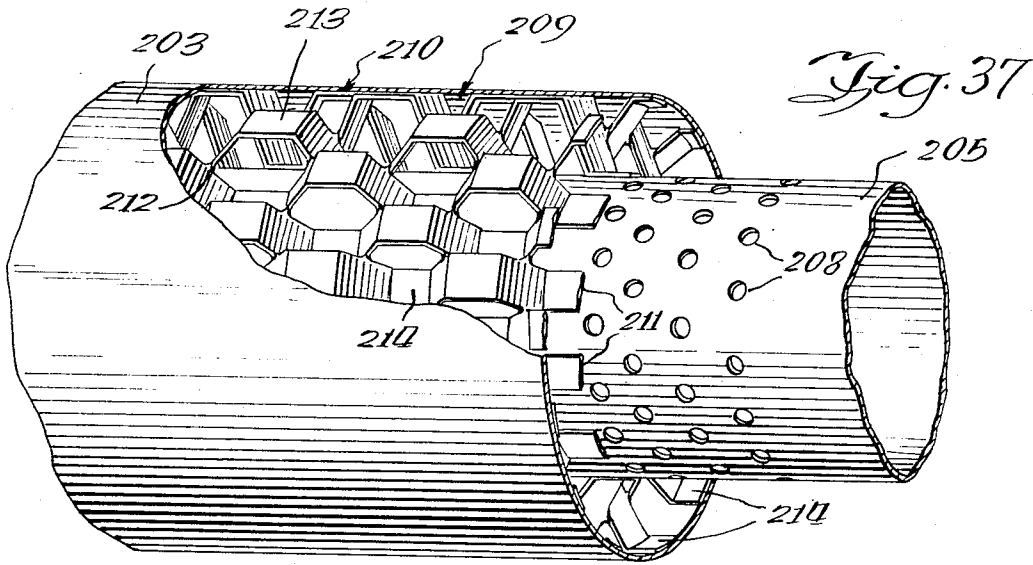


Fig. 28







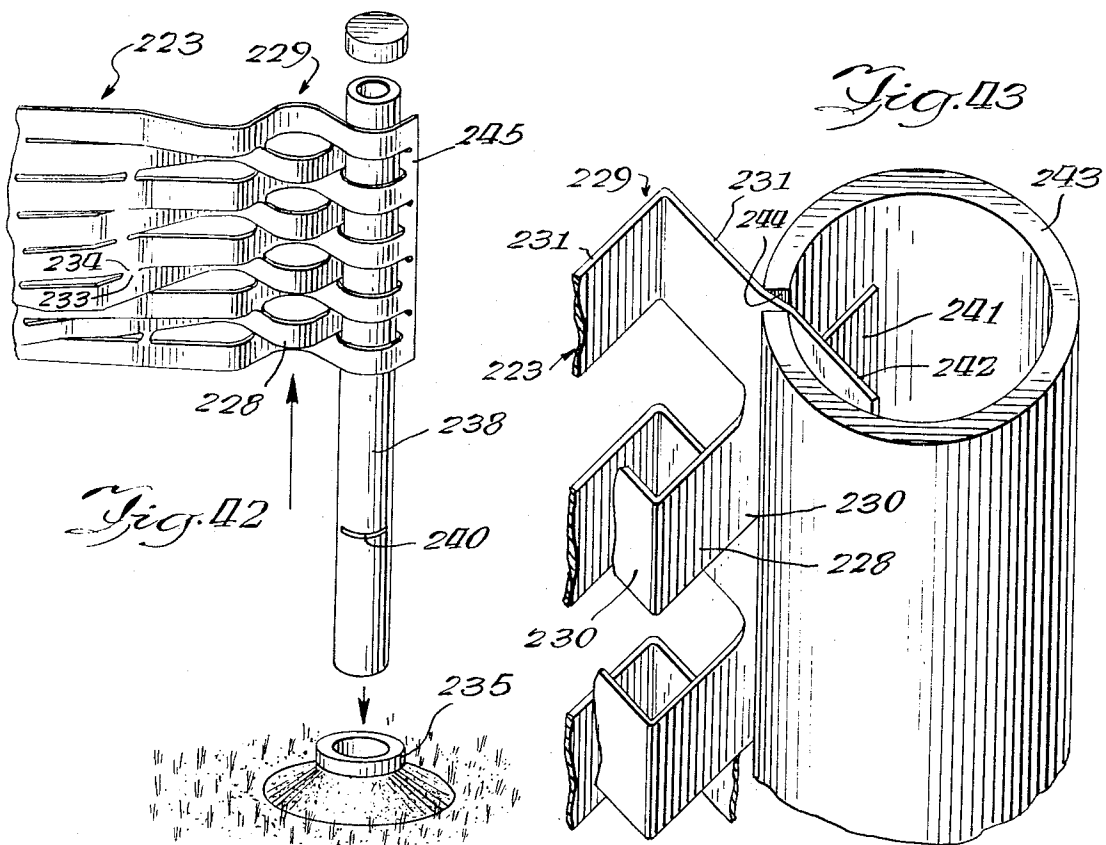
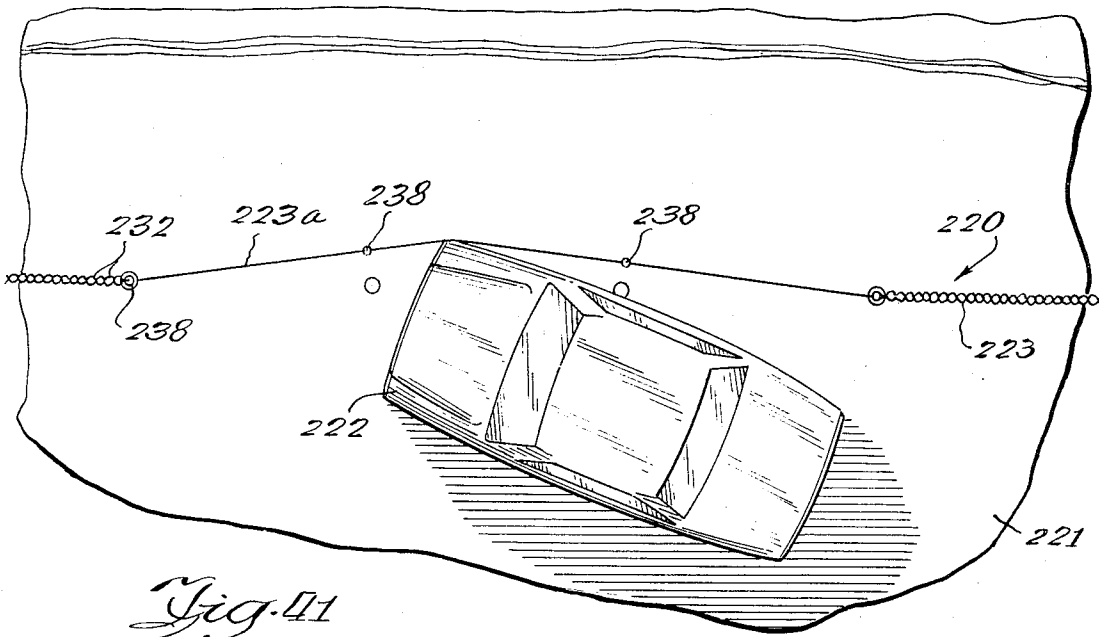


Fig. 44

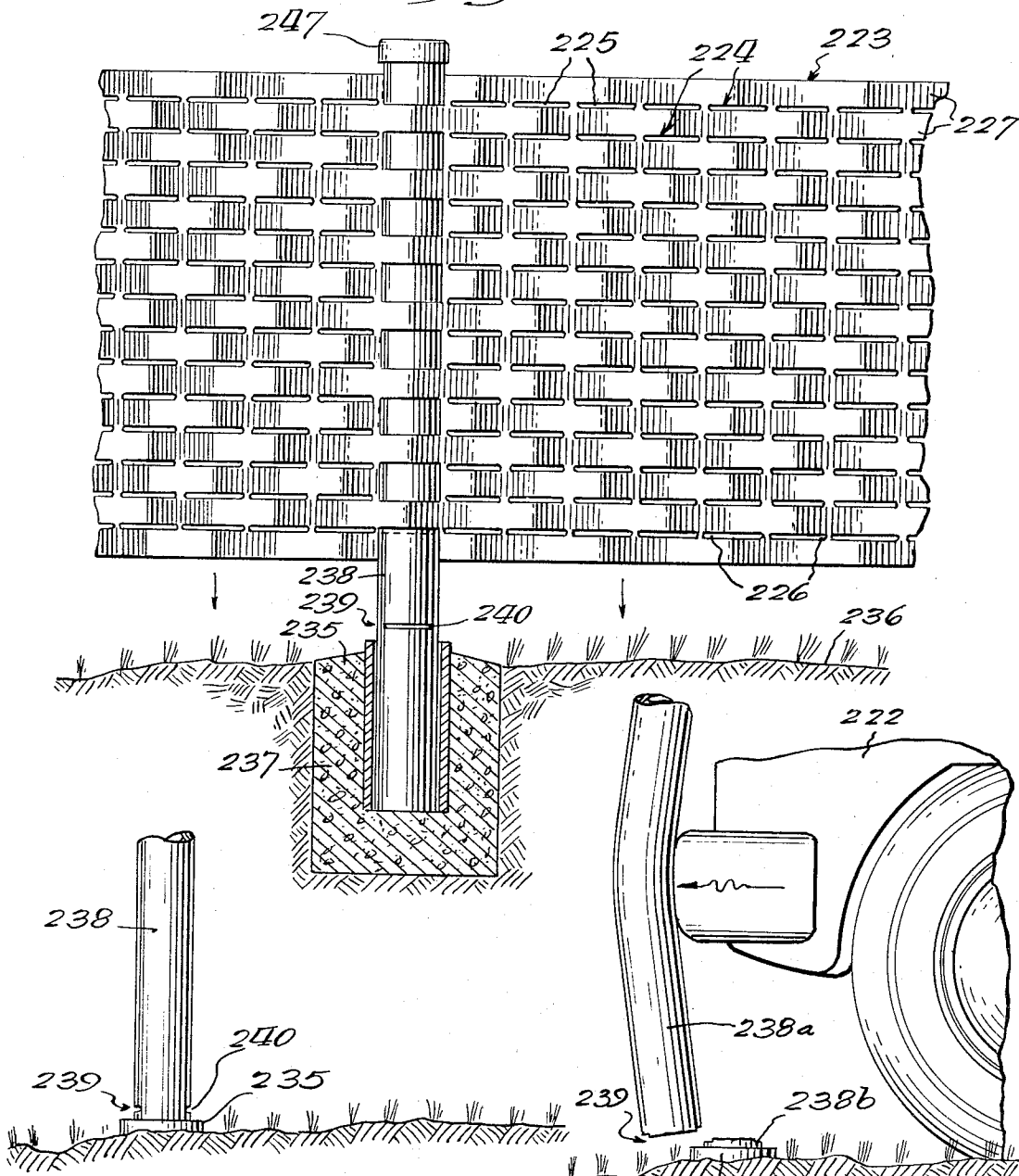
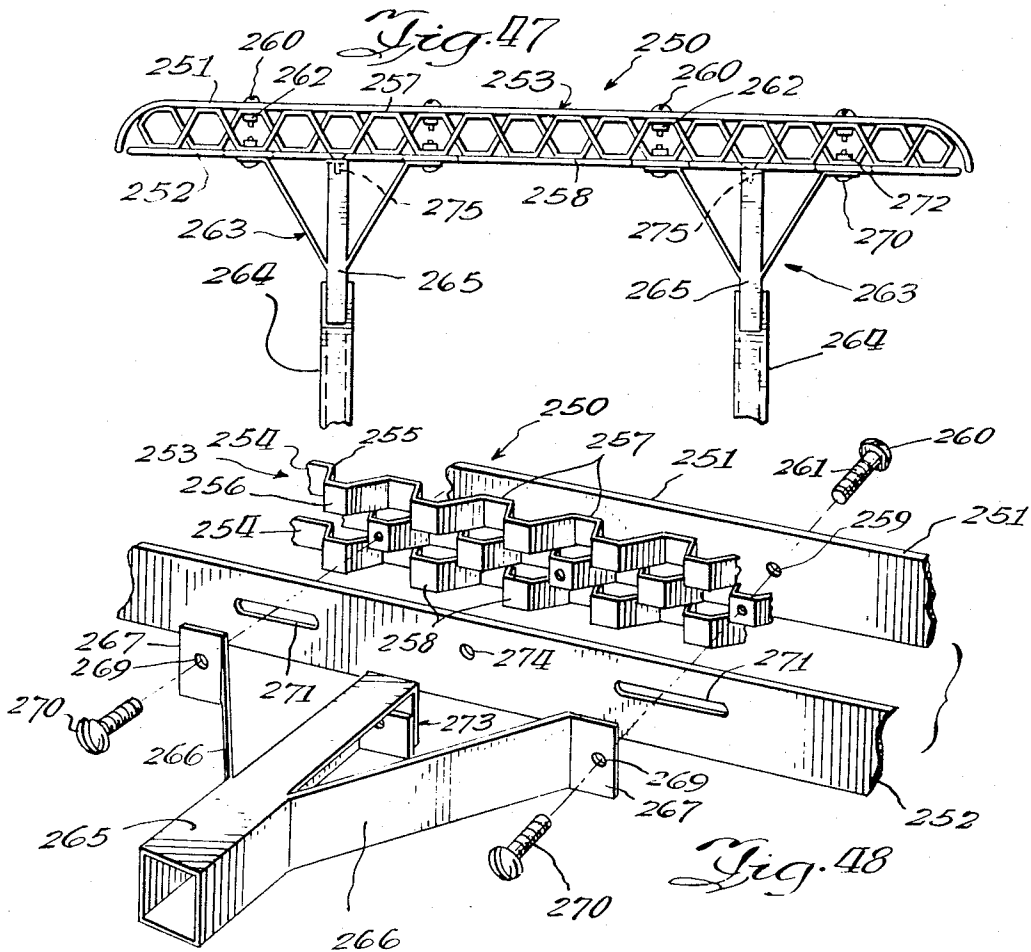
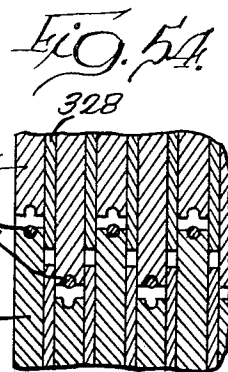
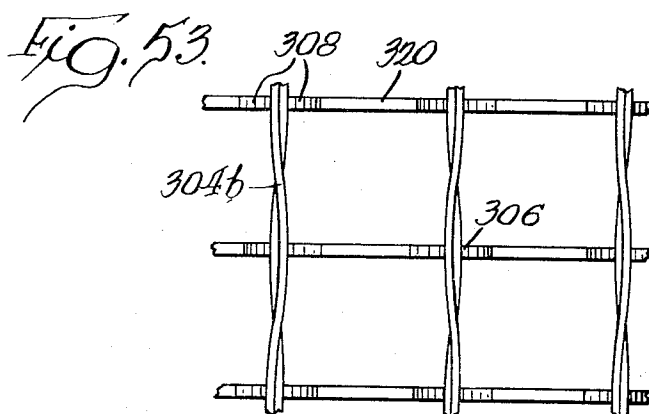
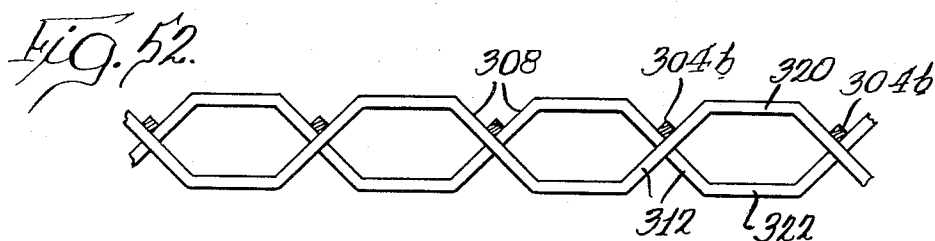
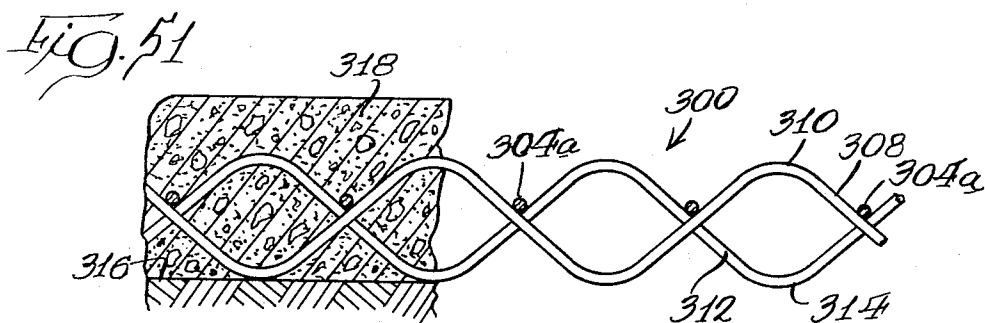
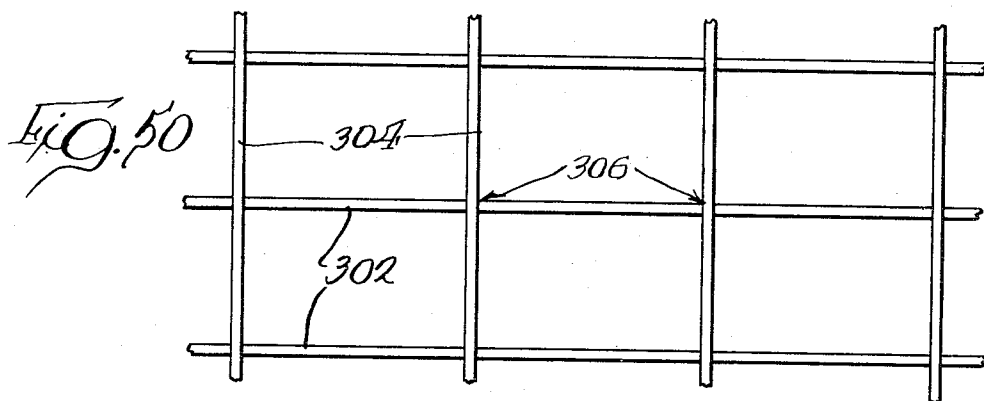
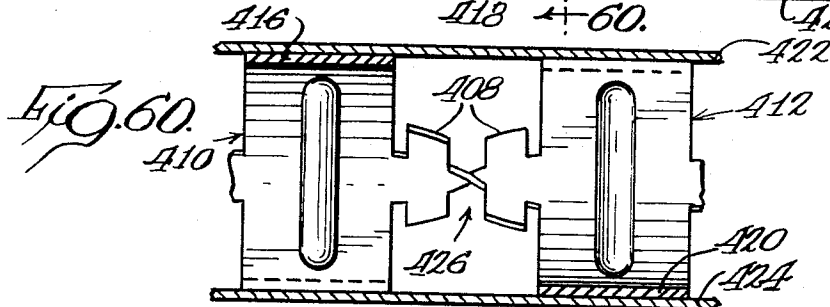
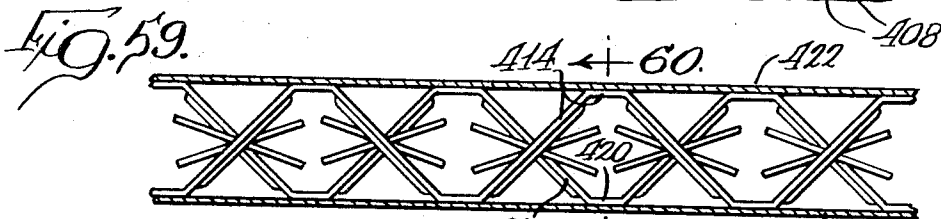
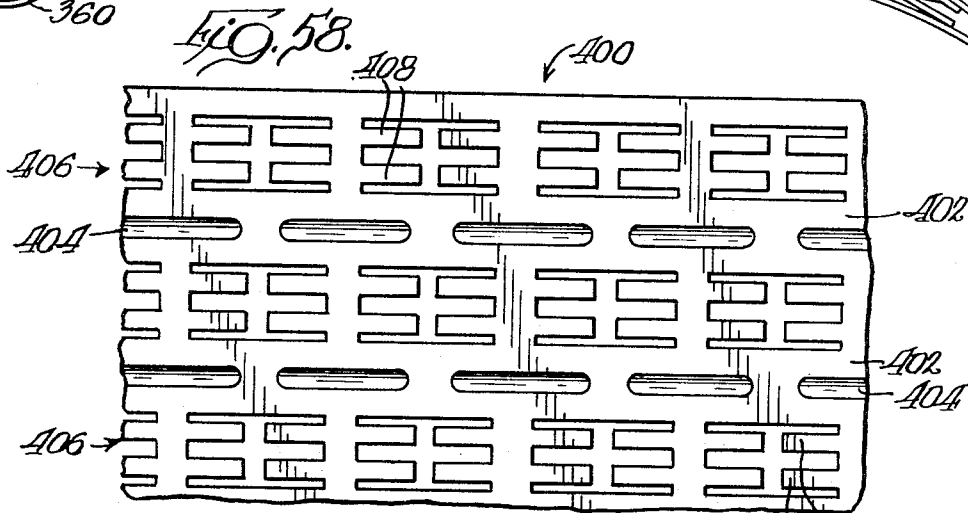
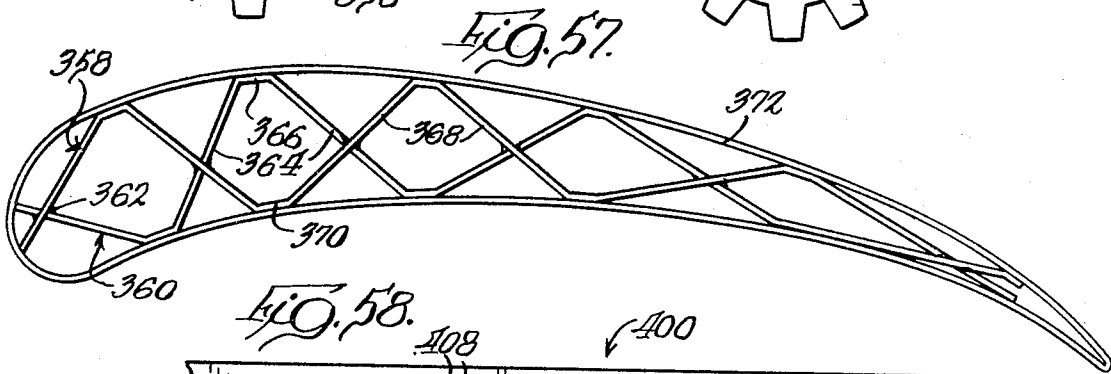
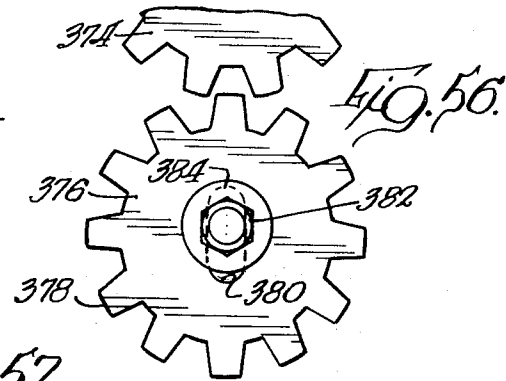
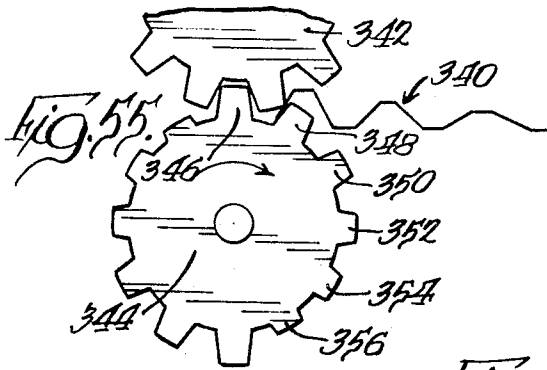


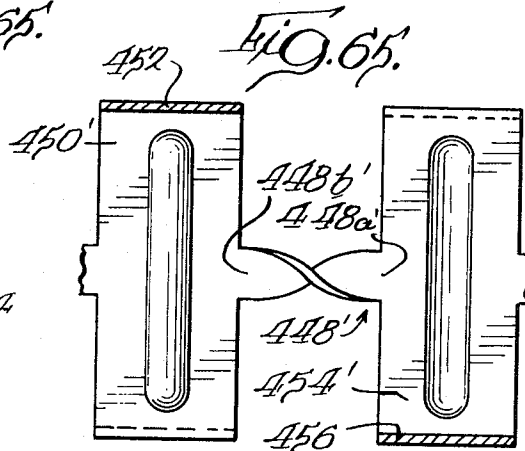
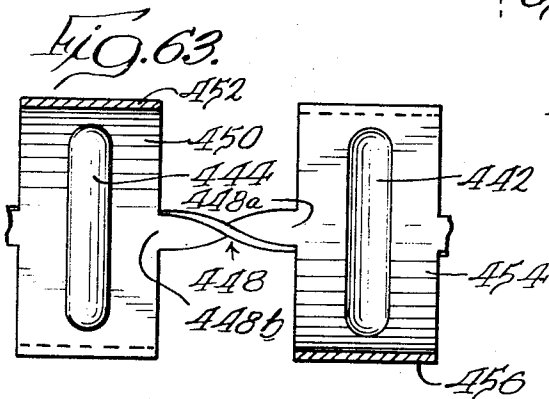
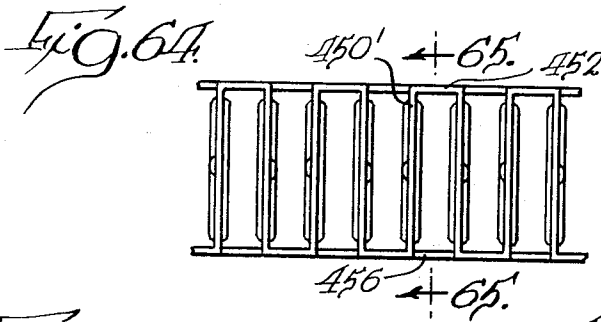
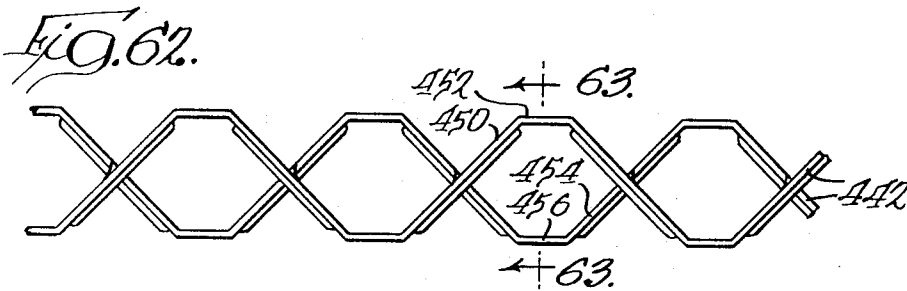
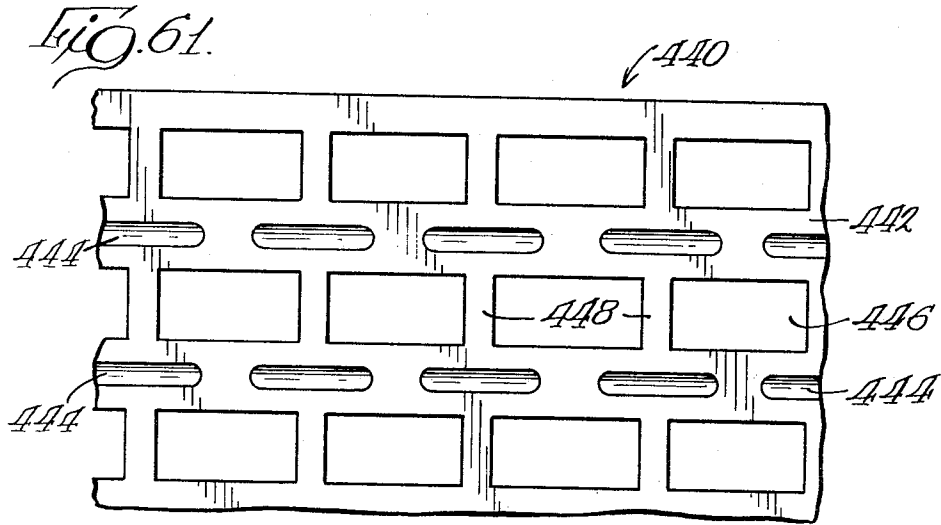
Fig. 45

Fig. 46









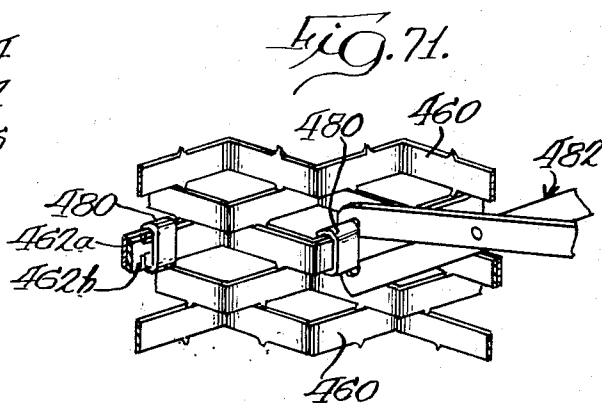
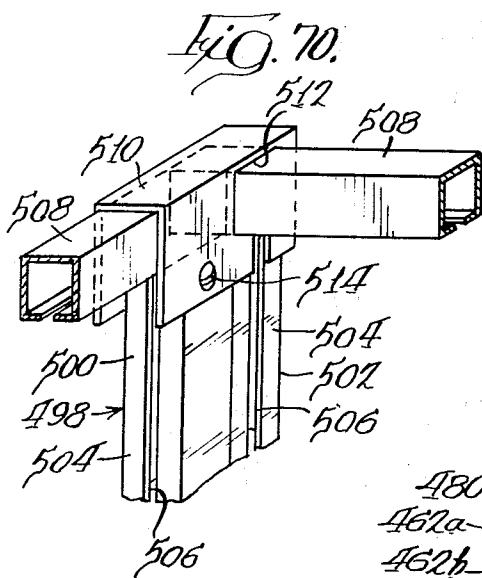
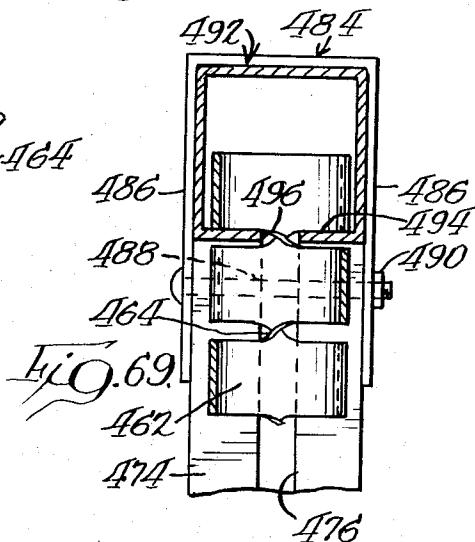
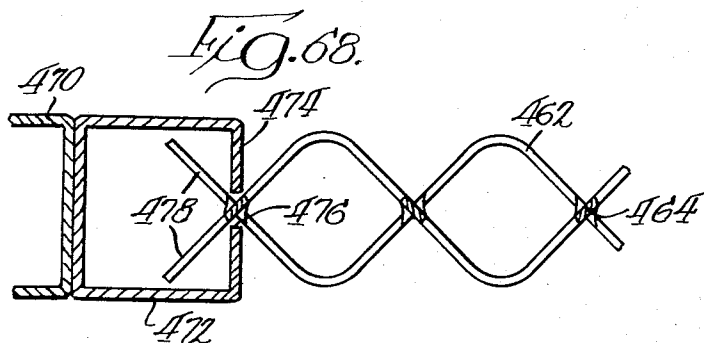
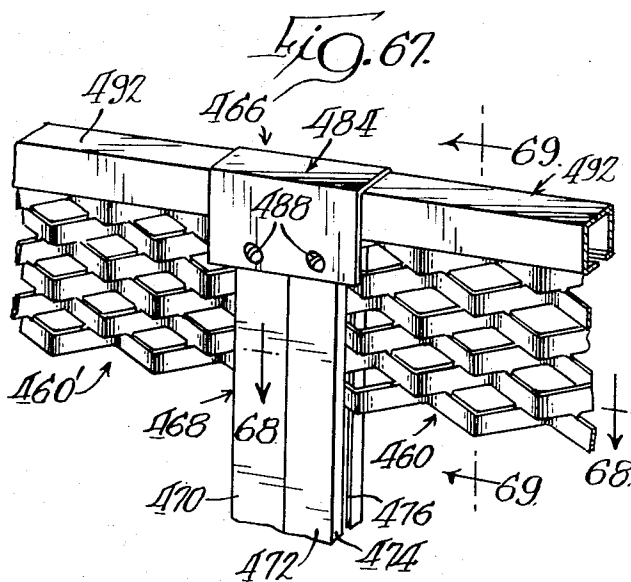
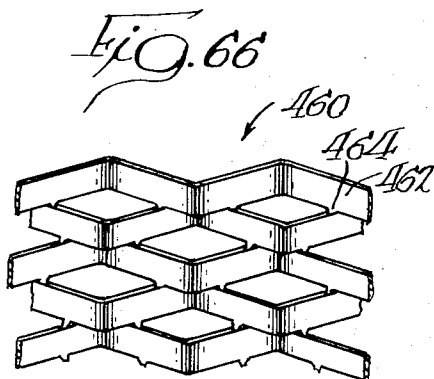


FIG. 72.

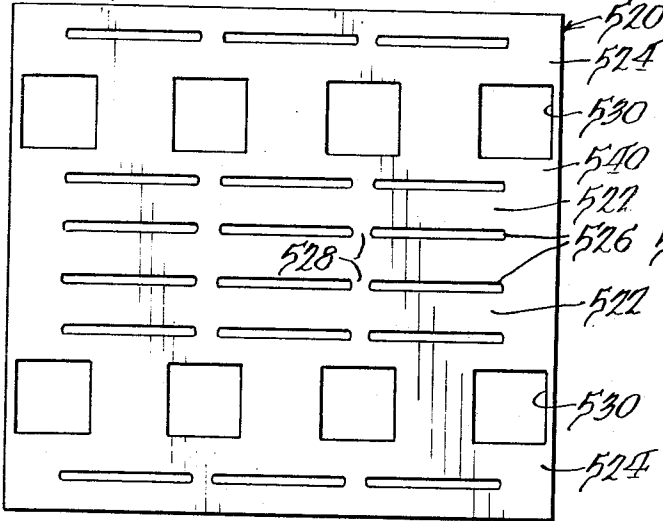


FIG. 76.

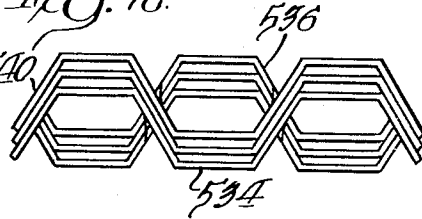


FIG. 73.



FIG. 74.

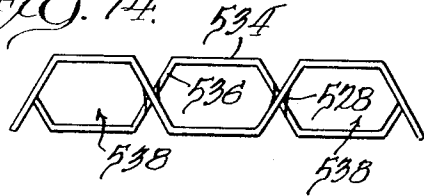


FIG. 75.

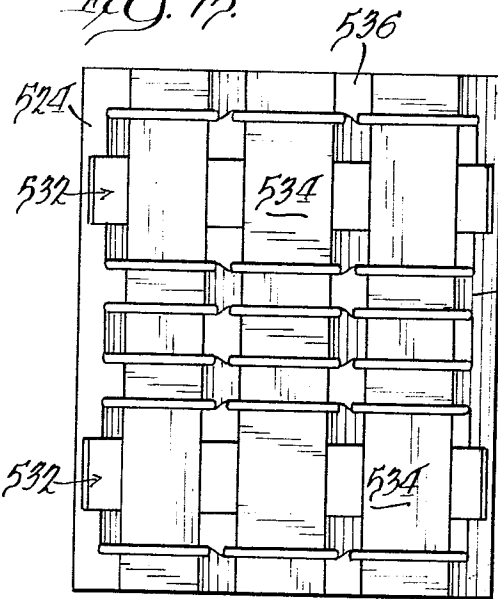


FIG. 77.

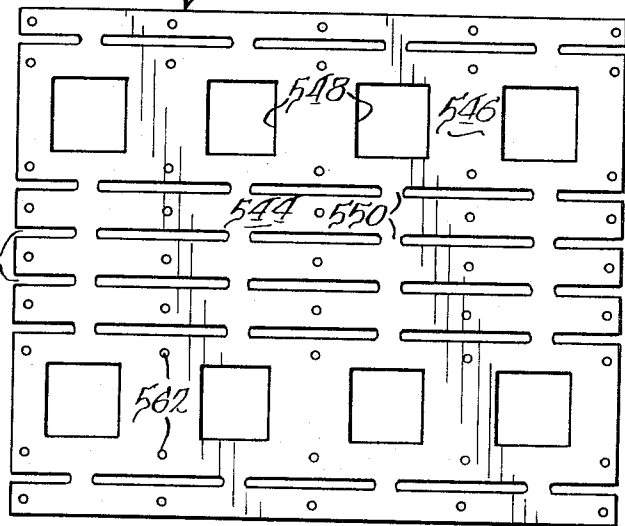


FIG. 78.

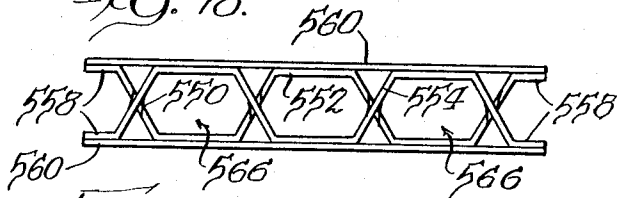
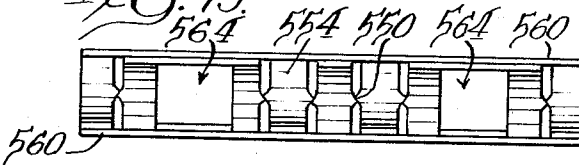


FIG. 79.



ARTICLE OF MANUFACTURE WITH TWISTED WEB

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of my application Ser. No. 211,858, filed December 27, 1971, now abandoned which was a continuation-in-part of my application Ser. No. 767,303 filed Oct. 14, 1968, now abandoned.

BACKGROUND OF THE INVENTION

The desirability of providing a structural material that has a high strength-to-weight ratio has been well recognized in the past. One well known expedient that has been used to fulfill this need is a honeycomb structure, which essentially consists of hexagonally shaped open cells interconnected by columnar webs. While such members have functioned satisfactorily in aircraft structures and the like, because of their inherent inflexibility, difficulty has been encountered in causing honeycomb structures to conform to curved surfaces, while at the same time retaining their column strength.

Many attempts have been made to provide a satisfactory structural material having multi-planar flexibility, but heretofore, the structures that have been proposed are either impractical to fabricate, or deficient in the strength required for the intended function. An example of a structural material that is difficult, if not impossible, to fabricate is that disclosed in Robb U.S. Pat. No. 3,227,598. As disclosed therein, a plurality of projections are struck outwardly in opposite directions from a sheet of material, so as to stretch the material between the projections to define saddle-shaped connecting portions. The Robb structure is extremely difficult to fabricate without piercing the material, and even if the material does not rupture, the connecting portions between the projections neck down sufficiently such that the material loses a significant portion of its structural integrity.

Corrugated metal structures that are formed by a simultaneous slitting and deforming step are also well known. An exemplary prior art arrangement is disclosed in Jones U.S. Pat. No. 1,067,521, and as described therein, a plurality of longitudinally spaced slits are cut into a sheet of metallic stock, while alternating portions of the sheet are simultaneously deformed to provide longitudinally spaced crests and troughs.

It is also well known to weld opposed sheets of metal together in preselected areas, and to force fluid under pressure between the welded areas to expand the metal to provide internal passages. Prior art methods and resulting articles are typified by those disclosed in Grenell U.S. Pat. No. 2,690,002, Fromson U.S. Pat. No. 2,828,533, Adams U.S. Pat. No. 2,859,509, Williams et al. U.S. Pat. No. 2,920,380, Meissner U.S. Pat. No. 2,922,344, Miller U.S. Pat. No. 2,932,491, Mack et al. U.S. Pat. No. 3,058,203 and Heuer U.S. Pat. No. 3,180,011. While the above mentioned patents illustrate the highly developed state of the art, heretofore no one has provided a completely satisfactory structure wherein undulating passages communicate with enlarged chambers, with the passages being provided in spaced ribbons that are interconnected by twisted webs.

SUMMARY OF THE INVENTION

The article of manufacture of the present invention

consists essentially of a plurality of spaced, parallel longitudinally extending ribbons that are corrugated to include longitudinally spaced alternating crests and troughs. Adjacent ribbons are interconnected by webs that are twisted throughout their length. The article is formed from an initial sheet, strip or plate having a plurality of transversely spaced rows of elongate, uniformly spaced openings, so that when the ribbons are deformed to form the crests and troughs, the webs are given a multi-planar torsional deformation. The article of the present invention has multi-planar flexibility, although the flexibility is not equal in all directions. Because of its flexibility, the article of the present invention has particular utility in environments where the material must conform to a curved surface. Furthermore, the article of the present invention is ideally suited for use in sandwich structures, where the inner and outer skins are curved, since the apexes of the crests and troughs of the ribbons can be readily given a curvature corresponding to the curvature of the adjacent outer skin.

Because relatively wide openings are provided in the initial sheet of material, the crests and troughs in the spaced ribbons can be struck downwardly from the plane of the sheet a substantial distance, so that the resulting article has a length that is substantially less than the initial sheet. This enables the sheet to have impact absorbing characteristics in that, when struck, the sheet will initially expand to its original length before the material itself undergoes deformation. Because of this characteristic, the sheet may be used in diverse environments as a spring, a safety fence, a vehicle bumper, etc.

The twisted web interconnecting the spaced ribbons makes the material of the present invention extremely useful in environments where radical changes in temperature are encountered. Because the webs are twisted from end to end during the fabrication of the material, the overall length of the webs is decreased, so that in a variable temperature environment, the twisted webs act as expansion joints interconnecting the ribbons. While the material of the present invention is hereinafter described as having specific utility in a muffler for attenuating engine exhaust noises, it will be appreciated that the material also has utility in variable temperature environments, such as heating elements, and the like.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a top plan view of a sheet of material from which an article of manufacture of the present invention is fabricated;

FIG. 2 is a sectional view taken generally along line 2—2 of FIG. 1;

FIG. 3 is a perspective view of the basic unit of an article of manufacture of the present invention;

FIG. 4 is a top plan view of the sheet of FIG. 1, after it has been fabricated in accordance with the process of the present invention;

FIG. 5 is a fragmentary side elevational view of the fabricated sheet of FIG. 4;

FIG. 6 is a sectional view taken generally along line 6—6 of FIG. 5;

FIG. 7 is a fragmentary top perspective view of the fabricated sheet of FIG. 4;

FIG. 8 is a side elevational view, similar to FIG. 5, and illustrating a modified article of manufacture;

FIG. 9 is a fragmentary top perspective view of the article of manufacture of FIG. 8;

FIG. 10 is a fragmentary sectional view of an arcuate sandwich structure formed in accordance with the teachings of the present invention;

FIG. 11 is a fragmentary perspective view of the arcuate sheet used in the sandwich structure of FIG. 10;

FIG. 12 is a fragmentary sectional view through a modified form of arcuate sandwich structure;

FIG. 13 is a fragmentary perspective view of the arcuate sheet used in the sandwich structure of FIG. 12;

FIG. 14 is a fragmentary perspective view of a still further sheet usable in a spherical sandwich structure;

FIGS. 15 and 16 are fragmentary perspective views of articles of manufacture formed in accordance with the teachings of the present invention, and illustrating different embodiments of weight reducing and strengthening means;

FIGS. 17-22 are enlarged fragmentary top plan views showing different configurations for the openings in the basic starting sheet of FIG. 1;

FIG. 23 is a fragmentary top perspective view of a modified sandwich structure;

FIG. 24 is a top perspective view of a composite sheet structure usable in the manufacture of a heat exchanger, or the like;

FIG. 25 is a sectional view taken generally along line 25-25 of FIG. 24;

FIG. 26 is a sectional view, similar to FIG. 25, but after fabrication of the article has been completed;

FIG. 27 is a sectional view taken generally along line 27-27 of FIG. 24 after the article has been fabricated;

FIG. 28 is a fragmentary side elevational view of a first form of apparatus for producing an article of manufacture in accordance with the process of the present invention;

FIG. 29 is a sectional view taken generally along line 29-29 of FIG. 28;

FIG. 30 is a fragmentary side elevational view of a second form of apparatus that is used to fabricate an article of manufacture in accordance with the process of the present invention;

FIG. 31 is a sectional view taken generally along line 31-31 of FIG. 30;

FIG. 32 is a broken schematic representation of an exhaust system for an internal combustion engine utilizing a typical prior art muffler structure;

FIG. 33 is a sectional view taken generally along line 33-33 of FIG. 32;

FIG. 34 is a view similar to FIG. 32, but illustrating a muffler formed in accordance with the teachings of the present invention;

FIG. 35 is an enlarged fragmentary top plan view of the muffler illustrated in FIG. 34, with the top portion of the outer muffler shell being removed;

FIG. 35a is an enlarged top perspective view of the muffler of FIG. 34, with a portion of the side and top of the outer muffler shell broken away;

FIG. 36 is a fragmentary top plan view of a modified muffler structure, with a portion of the top of the outer shell broken away;

FIG. 37 is a fragmentary perspective view of another muffler structure with a portion of the outer shell removed;

FIG. 38 is a schematic central sectional view through the muffler of FIG. 37, and illustrating the path of gas flow therethrough;

FIG. 39 is a fragmentary perspective view of still another muffler structure, with the outer and intermediate shells broken away;

FIG. 40 is a schematic central sectional view through the muffler of FIG. 39, and illustrating the path of gas flow therethrough;

FIG. 41 is a top plan view of an impact absorbing safety fence formed in accordance with the teachings of the present invention;

FIG. 42 is an enlarged perspective view of the fence of the present invention and illustrating the mounting post structure for supporting the fence;

FIG. 43 is an enlarged perspective view illustrating the cooperative action between a trim piece at the end of the fence and the sheet of fencing material;

FIG. 44 is a front elevational view of the fencing structure of the present invention during the erection of the fence;

FIG. 45 is a front elevational view of the fence post of the present invention and structure for supporting the same;

FIG. 46 is a view similar to FIG. 45, and illustrating fracturing of the fence post upon impact;

FIG. 47 is a top plan view of a bumper formed in accordance with the teachings of the present invention;

FIG. 48 is an exploded perspective view of the bumper structure of FIG. 47;

FIG. 49 is a top plan view of a modified bumper structure;

FIG. 50 is a fragmentary top plan view of a concrete reinforcing structure formed in accordance with the present invention;

FIG. 51 is a side elevational view of the structure illustrated in FIG. 50, with one end portion of the structure being shown embedded in concrete;

FIG. 52 is a side elevational view similar to FIG. 51, and showing a modified form of concrete reinforcing structure;

FIG. 53 is a fragmentary top plan view of the embodiment of FIG. 52;

FIG. 54 is a fragmentary cross-sectional view similar to FIGS. 29 and 30, and illustrating slightly modified apparatus that may be used to fabricate the embodiment of FIGS. 50 and 51;

FIGS. 55 and 56 are fragmentary side elevational views of apparatus that may be used to fabricate a formed shape as shown in FIG. 51;

FIG. 57 is a side elevational view of an air foil, or the like, wherein the core is formed by the apparatus shown in FIGS. 55 and 56;

FIG. 58 is a fragmentary plan view of a blank that is utilized to make the core of the structure of FIGS. 59 and 60;

FIG. 59 is a side elevational view of a sandwich structure incorporating a core made from the blank of FIG. 58;

FIG. 60 is an enlarged cross-sectional view taken generally along line 60-60 of FIG. 59;

FIG. 61 is a fragmentary plan view of a blank that is utilized to form a product that includes a web which is twisted approximately 180°;

FIG. 62 is a side elevational view of the blank of FIG. 61 following a first deformation step wherein the webs are twisted approximately 90°;

FIG. 63 is an enlarged cross-sectional view taken generally along line 63-63 of FIG. 62;

FIG. 64 is a side elevational view of the blank of FIG. 61 following a second deformation step wherein the webs are twisted approximately 180°;

FIG. 65 is an enlarged cross-sectional view taken generally along line 65—65 of FIG. 64;

FIG. 66 is a fragmentary perspective view showing a fencing section formed in accordance with the teachings of the present invention;

FIG. 67 is a fragmentary perspective view of two in-line fencing structures, and the mechanism for inter-connecting the same;

FIG. 68 is a sectional view taken generally along line 68—68 of FIG. 67;

FIG. 69 is a sectional view taken generally along line 69—69 of FIG. 67;

FIG. 70 is a perspective view illustrating the mechanism for connecting right angled fencing sections;

FIG. 71 is a perspective view similar to FIG. 66 but illustrating the method of joining two vertically adjacent fencing sections;

FIG. 72 is a plan view of a blank that is utilized to manufacture a nestable, four-way pallet formed in accordance with the teachings of the present invention;

FIG. 73 is an edge view of the blank shown in FIG. 72;

FIG. 74 is an edge view of the blank following fabrication;

FIG. 75 is a plan view of the fabricated structure shown in FIG. 74;

FIG. 76 is an end view illustrating a plurality of pallets nested with one another;

FIG. 77 is a plan view of a blank for forming a modified pallet structure; and

FIGS. 78 and 79 are side and end elevational views of the blank of FIG. 77 following fabrication and with the addition of spaced parallel support plates.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

While this invention is susceptible of embodiment in many different forms, there is shown in the drawings and will herein be described in detail a preferred embodiment of the invention and modifications thereof, with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the invention to the embodiments illustrated. The scope of the invention will be pointed out in the appended claims.

The basic unit of the present invention is illustrated at 60 in FIG. 3, and the unit includes a pair of spaced, parallel, generally planar ribbons 61 and 62 that are separated from one another by elongate openings 63 and 64. An integral web 65 connects ribbons 61 and 62, and the ribbons are disposed at an angle with respect to one another, so that one end 66 of the web 65 is disposed in the plane of ribbon 61, while the opposed end 67 of the web 65 is disposed in the plane of ribbon 62, with the intermediate portion 68 of the web being generally uniformly twisted between end portions 66 and 67.

A plurality of basic units 60 are formed during the fabrication of a unitary sheet 70, illustrated in FIG. 1 as including a plurality of transversely spaced rows 71 of longitudinally aligned, elongate openings 72. The rows of openings 72 divide the sheet 70 into a plurality of longitudinally extending, parallel ribbons 73, with the openings 72 being separated by a web 74, which in-

terconnects adjacent ribbons 73. The basic unit 60 would be formed from two adjacent ribbons 73, as is illustrated in broken lines in the lower right-hand corner of FIG. 1.

To form the article of the present invention, the sheet 70 is deformed by apparatus to be hereafter described in connection with FIGS. 28-31 to provide a series of alternating longitudinally spaced crests 75 and troughs 76 in each of the ribbons 73. As can be best seen in FIG. 5, the crests 75 are defined by upwardly converging ribbon portions 77, while the troughs 76 are defined by downwardly converging ribbon portions 78. The crests 75 on each ribbon 73 are aligned with troughs 76 on an adjacent ribbon, so that the crests and troughs define aligned, transversely extending openings 79, as is evident from FIG. 4. After the sheet 70 has been fabricated, the length thereof has been significantly reduced, and for purposes of example and not of limitation, the present invention contemplates that the reduction in length will be on the order of 25 percent.

As is also evident from FIG. 5, the transitional portions of the crests 75 and troughs 76, i.e., the merger between ribbon portions 77 and 78 adjacent the webs 74, are disposed on an angle with respect to the initial plane of the sheet indicated generally at P in FIG. 5, with the transitional portions of adjacent ribbons being disposed at oppositely inclined angles with respect to plane P. Webs 74 include a first end portion 80 disposed in the plane of the transitional portion of one ribbon, with the opposite end portion 81 of the web being disposed in the plane of a transitional portion on an adjacent ribbon, so that the midportion 82 of the web 74 is substantially uniformly twisted between the oppositely inclined web end portions 80 and 81.

The above described article has multi-planar flexibility, with the deformed sheet 70 being readily bendable about a longitudinal line through webs 74, and with the deformed sheet 70 also being readily bendable about a transverse line through webs 74. The deformed sheet 70 is also bendable about inclined lines through the webs 74, although it will be appreciated that the sheet 70 is not equally bendable in the above described directions. The sheet 70 must be relatively ductile to allow the webs 74 to undergo multi-planar torsional deformation during fabrication of the article, and while the sheet 70 may be formed of metal, the present invention is not limited to any specific material.

In the embodiment of FIGS. 1-7, the apexes of the crests 75 and troughs 76 are flattened, so as to define crest portions 83 and trough portions 84 that are spaced from, and parallel with, the initial plane P of the sheet 70. As is evident from FIG. 23, the embodiment of FIGS. 1-7 has particular utility as a truss-like structural element sandwiched between spaced, parallel outer skins or sheets 85 and 86. The cover sheets may have different thicknesses, if desired, and in some instances, only one cover sheet may be provided. While the deformed sheet 70 is illustrated in FIG. 23 between cover sheets 85 and 86, it is also contemplated that the deformed material may be bonded to solid articles, and the like. The crest surfaces 83 and trough surfaces 84 are joined to sheets 85 and 86 by any suitable process that is compatible with the material from which the sheets are formed. With metallic materials, the present invention contemplates that at least a plurality of the crest surfaces 83 and trough surfaces 84 will be bonded to the sheets 85 and 86, respectively, by welding, and

supporting members, such as those illustrated at 87 in FIG. 23, may be inserted in the openings 79 during the welding operation. The illustrated supporting members 87 are slidably inserted in the openings 79, and may be removed after the bonding operation has been completed, although the present invention also contemplates that the supporting members may be joined to the deformed sheet 70 to provide a reinforcement therefor, if desired.

The embodiment of FIGS. 8 and 9 is similar to the embodiment of FIGS. 1-7 in that the structural member 88 is formed from a thin, flat sheet having a plurality of transverse rows of elongate openings that divide the sheet into parallel ribbons 89 connected by twisted webs 90. As with the previously described embodiment, the ribbons 89 are deformed to provide crests 91 and troughs 92, with the crests 91 including upwardly converging surfaces 93, and with the troughs 92 including downwardly converging surfaces 94. The embodiment of FIGS. 8 and 9 differs essentially from the previously described embodiment in that the apexes 95 and 96 of the crests 93 and troughs 94, respectively, have an arcuate configuration, with the apexes being curved about centers that are spaced from and parallel with the plane of the initial sheet, with the centers being positioned along lines that are perpendicular to the length of the ribbons.

The embodiment of FIGS. 10 and 11 is similar to the embodiment of FIGS. 1-7, in that the apexes of the crests 75 and the troughs 76 are defined by relatively broad areas. However, in the embodiment of FIGS. 10 and 11, the apexes 83a of the crests 75, and the apexes 84a of the troughs 76, have an arcuate configuration, with the apexes 83a and 84a being curved about an axis that is parallel to the length of the ribbons 71. The deformed sheet of FIGS. 10 and 11 has particular utility as a structural element in an arcuate sandwich structure between an outer skin or sheet 87 and an inner skin or sheet 98. While the sheets 97 and 98 are illustrated in FIG. 10 as having only limited arcuate extent, the present invention contemplates that the members 97 and 98 will be concentric tubes that define an annular chamber therebetween, with crest apex 83a being rounded about a radius equal to that of tube 97 and with trough apex 84a being rounded about a radius equal to that of tube 98, so that the apexes will be positioned in face abutting engagement with the tubes to facilitate joining of the tubes to the deformed sheet.

The embodiment of FIGS. 12 and 13 is similar to the embodiment of FIGS. 10 and 11, in that the deformed sheet is bent to have an arcuate configuration, so as to be useful in an arcuate sandwich structure, as between concentric tubes 99 and 100. The embodiment of FIGS. 12 and 13 differs from the embodiment of FIGS. 10 and 11, in that the deformed sheet in FIGS. 12 and 13 is positioned at right angles with respect to the position of the deformed sheet in FIGS. 10 and 11. In the embodiment of FIGS. 12 and 13, the crest apexes 83b and the trough apexes 84b are curved about axes that are perpendicular with respect to the length of the ribbons 71, with the crest apexes 83b being disposed on a radius that is equal to the radius of tube 97, and with the trough apexes 84b being disposed on a radius that is equal to the radius of tube 100, so as to position the apexes in face abutting engagement with the adjacent tube surfaces.

The embodiment of FIG. 14 is similar to the embodiment of FIGS. 10 and 11 and FIGS. 12 and 13, except that the crest apexes 83c and trough apexes 84c have a generally spherical configuration, so that the embodiment of FIG. 14 can be used in a spherical sandwich structure. Flexible supporting members may be inserted in the arcuately deformed members to facilitate the bonding of the members to their outer sheets.

The deformed sheet embodiment illustrated in FIGS. 15 and 16 is similar to the previously described embodiments, except that the converging crest portions 77 and converging trough portions 78 merge with one another, so that the crest apexes 83d and the trough apexes 84d define a relatively sharp corner. The embodiment of FIG. 16 is illustrated as having weight reducing means in the form of a pair of circular openings 104 in the inclined portions of the ribbons, and in addition to lessening the weight of the structural material, such openings provide a means for attaching the material to cooperating structural element. As is illustrated in FIG. 15, the ribbons may include strengthening means in the form of an elongate rib 103 that is struck outwardly from the inclined portion of the ribbon. While the weight reducing openings and strengthening ribs have been illustrated in connection with the embodiment of FIGS. 15 and 16, it will be appreciated that such means could also be provided in the previously described embodiments.

FIGS. 17-22 illustrate various forms of openings that may be provided in sheet 70 in lieu of openings 72. Like openings 72, the openings 72a-72f, each has rounded end portions so as to minimize the stress concentration effects adjacent the webs 74 during the sheet deformation operation. The opening 72a in FIG. 17 includes a narrow midportion 105 with gradually outwardly flaring side portions 106 that merge with the rounded end portions 107. The opening 72b in FIG. 18 includes an elongate narrow midportion 108, with enlarged, generally circular end portions 109 being provided at opposite ends of portion 108. The opening 72c in FIG. 19 includes an enlarged midportion 110 terminating in rounded end portions 111 of reduced size. The opening 72d of FIG. 20 includes an enlarged midportion 112 with inclined sides 113 converging toward rounded end portions 114. The opening 72e of FIG. 21 includes a plurality of generally circular portions 115 connected by slots 116 of reduced width. The opening 72f of FIG. 22 includes rounded end portions 117 that are connected by a plurality of oppositely facing U-shaped slots 118.

A composite article 120 is illustrated in FIG. 24 and comprises a first sheet 121 folded upon a second sheet 122. Sheets 121 and 122 are bonded to one another, as by welding, at their longitudinal edges 123 and 124 and at the end 125 opposite from the fold line 126. The weld 125 is discontinuous, preferably at the center of the article 120, as shown at 127, to provide an opening, as will hereinafter appear. While the article 120 is illustrated as being formed from a single sheet, the present invention also contemplates that two identically shaped sheets may be placed upon one another and welded around the entire periphery thereof. Sheets 121 and 122 are similar to sheet 70, in that they incline a plurality of transverse rows 128 of elongate openings 129 that divide the sheets 121 and 122 into a plurality of longitudinally extending, parallel ribbons 130. The openings 129 are separated from one another by webs

131, which interconnect adjacent ribbons 130. As can be best seen in FIG. 25, the ribbons 121 are welded to one another in spaced parallel areas 132 and 133. The end portions 134 and 135 of the article 120 outwardly of ribbons 130 are not welded to one another.

The article 120 is deformed by apparatus illustrated in FIGS. 28 and 30 to provide alternating, longitudinally spaced crests 136 and troughs 137 in each of the ribbons 130. During the article deforming steps, the webs 131 are subjected to multi-planar torsional deformation so as to be twisted throughout their length, as previously described in connection with the embodiment of FIGS. 1-7. After the article 120 has been deformed to the shape best seen in FIGS. 26 and 27, fluid under pressure (or other suitable means) is forced between the sheets 121 and 122 through opening 127 to expand the unwelded areas 134 and 135 at the ends of the article 120 to provide chambers or manifolds 138 and 139 at opposite ends of the article, and to provide passages 140 in each of the ribbons 130 that communicate with chambers 138 and 139. The completed article illustrated in FIGS. 26 and 27 has utility as an automobile radiator, or similar article.

The above described articles may be manufactured by apparatus such as that illustrated in FIGS. 28 and 29. In this apparatus, a plurality of gear-like upper die members 142 are secured to a rotatable spindle 144 by a key 145, and the die members 142 have a plurality of circumferentially spaced toothlike dies 143 around the periphery thereof. As is evident from FIG. 28, the dies 143 have an external configuration corresponding to the article illustrated in FIGS. 1-7. Alternating die members 142 are offset circumferentially by one-half of the distance between adjacent die teeth 143, so that the die teeth 143 on one die member are positioned between the die teeth 143a on an adjacent member. The die members 142 are separated by spacer members 146 having an outer diameter slightly less than the outer diameter of the die teeth 143.

A plurality of gear-like lower die members 147 are secured to a rotatable spindle 149 by a key 150, and die members 147 are separated from one another by spacers 148. Like die members 142, die members 147 include a plurality of circumferentially spaced tooth-like dies 151 with the dies 151a on alternating members 147 being spaced between the dies 151 on adjacent members 147.

The die members 142 and 147 are positioned in intermeshing engagement with one another, and a sheet 70 is fed between a pair of vertically spaced guides 153 by counterclockwise rotation of the members 142 and by clockwise rotation of the members 147. The toothlike die members progressively deform the sheet 70 to provide the crests 75 and troughs 76 in the ribbons of the sheet and to simultaneously impart the multi-planar torsional deformation to the webs 74. The spacers 146 and 148 are spaced from one another so as to provide a clearance space 152 which allows the webs 74 to freely twist. Vertically spaced finish guides 153a are provided at an opposite side of the die members 142 and 147 from guide 153 to receive the finished product. Spindles 144 and 149 are designed to move vertically to permit various thicknesses of stock to be formed in the same tooling.

An alternate fabricating apparatus is illustrated in FIGS. 30 and 31, and includes a plurality of vertically movable die members for progressively forming the

crests 75 and troughs 76 in the sheet 70. The die members include an upper gripping die 154, a lower gripping die 155, a top forming die 156, a bottom forming die 157, a top preforming die 158, and a bottom preforming die 159. The lower portions of dies 154-159 are shaped to provide the flat topped crests and troughs of the embodiment of FIGS. 1-7. The dies 154-159 may be moved up and down by any suitable means, such a pneumatic, mechanical or hydraulic means. A plurality of sets of dies are provided, each set of dies being adapted to form the crests and troughs on adjacent ribbons, and as is evident from FIG. 30, the adjacent die members 154a-159a are offset from die members 154-159. As is evident from FIG. 31, the upper die members are separated from one another by spacers 160, while the lower die members are separated from one another by spacers 161. When the upper and lower dies are in their closed crest and trough forming position, the spacers 160 and 161 are spaced from one another, as shown at 168 in FIG. 31, to allow the webs to undergo the multi-planar torsional deformation.

The dies 154-159 and 154a-159a are sequenced for proper movement relative to one another by suitable means, not shown, to first grip the sheet 70, preform the crests 75 and troughs 76, and final-form the crests 75 and troughs 76 as the sheet 70 is sequentially fed through the machine. To this end, lower gripper die 155 and bottom forming die 157 are secured to one another for simultaneous movement, as by a transverse pin 169. The dies are sequenced such that the upper gripper die 154 first moves downwardly into engagement with a completed trough 76, whereupon the lower dies 155 and 157 move upwardly, with gripper die 155 moving into gripping engagement with a completed crest 75, and with forming die 157 completing the formation of an adjacent crest 75. Top forming die 156 then moves downwardly to complete the formation of trough 76 adjacent the gripped trough. Bottom preforming die 159 then moves upwardly to initially deform an incipient crest 75, and the top preforming die 158 then moves downwardly to initially form an incipient trough 76. The sheet 70 is fed through the die structure between strap guide members 172 at the sheet entrance end and finished guide members 173 at the opposite side of the die structure by a rotatable strip advancing wheel 170 having lugs 171 that extend radially outwardly therefrom into strip advancing engagement with the openings 72. The strip advancing movement is, of course, timed to take place when the dies 154-159 are raised.

Turning now to the muffler structure illustrated in FIGS. 32-40, a typical prior art arrangement is illustrated in FIGS. 32 and 33 as including an exhaust manifold 176 associated with an internal combustion engine 175, with a bent connecting tube 177 making a flanged connection 178 with the manifold 176. Tube 177 communicates with a muffler 179 through an exhaust gas inlet pipe 180, and a tail pipe 182 communicates with a gas outlet pipe 181 at the opposite end of muffler 179. Muffler 179 is a bulky device which extends a substantial distance below the vehicle to present a significant impediment when the vehicle is traversing a bumpy terrain.

A first embodiment of the muffler structure of the present invention is indicated generally at 184 in FIG. 34, and it will be readily apparent from a visual comparison with FIG. 32 that the muffler 184 is substan-

tially less bulky than the prior art muffler 179. The muffler 184 includes a thin-low profile outer shell 185 in the form of an elongate, unitary tubular member that has an upwardly bent gas inlet end 187 which makes a flanged connection 186 with an exhaust gas manifold 176. The gas inlet end 187 of the outer shell 185 has a circular cross section and the gas outlet end 188 at the opposite end of the shell 185 has a rectangular cross section. As is evident from FIG. 34, the circular cross section portion of the outer shell 185 is smaller in diameter than the width of the rectangular portion 188. In this manner, the circular portion of the shell presents an inwardly facing abutment for limiting axial movement of a sound attenuating member 189 toward the gas inlet end of the muffler 184.

The sound attenuating member 189 is formed from a flat, generally planar sheet having a plurality of transverse rows 191 of elongate openings 192 that divide the member 189 into a plurality of spaced longitudinally extending ribbons 193 that are connected by webs 194 between the openings 192. As can be seen in FIG. 35a, the sound attenuating member is deformed so as to provide alternating longitudinally spaced crests 195 and troughs 196 in each of the ribbons 193. The crests on the ribbons are aligned with troughs on an adjacent ribbon so as to define passages in the member that extend at right angles to the ribbons 193. The crests 195 are defined by upwardly converging ribbon portions 197, while the troughs 196 are defined by downwardly converging ribbon portions 198. In the embodiment of FIGS. 35 and 35a, the apexes of the crests and troughs are arcuate, and are curved about radii that are disposed on lines perpendicular to the length of ribbons 193. The webs 194 are provided at the transitional portion between the ribbon sections 197 and 198, and the webs 194 have a multi-planar torsional deformation, such that one end portion 199 of the web is disposed in the plane of the transitional portion of one ribbon 193, while an opposite end portion 200 of the web is disposed in the plane of the transitional portion of an adjacent ribbon, with the intermediate portion 201 of the web being generally uniformly twisted between the end portions 199 and 200.

As can be best seen in FIG. 35, the member 189 has a width which is substantially the same as the interior dimension of the rectangular portion 188 of outer shell 185, and the distances between the apexes of crests 195 and 196 is substantially the same as the height of the rectangular shell portion 188, as can be seen in FIG. 35a. The member 189 is slidably insertable within shell 185, with the ribbons 193 being parallel to the length of the shell in the embodiment of FIGS. 35 and 35a, and with the end of the member 189 bearing against the circular cross sectional portion on the shell. A fastener 202, such as a screw, extends laterally through the rectangular portion 188 of the shell adjacent the gas outlet end thereof, and through one of the transverse passages in the member 189, to prevent axial displacement of the member 189. The webs 194 act as expansion joints allowing the sound attenuating member 189 to move into snug engagement with the surrounding structure when the member is heated by the exhaust gases.

The ribbons 193 present a substantial barrier to the flow of exhaust gas through the muffler 184, thereby dampening the sound waves emanating from the engine 175. For an increased sound attenuating effect, the ribbons 193 may be positioned at an oblique angle with

respect to the length of muffler 184, as is shown in FIG. 36. The present invention contemplates that the sound attenuating member may be formed of a plurality of separate sections, such as shown at 189a and 189b in FIG. 36, with the ribbons 193 of adjacent sections being inclined oppositely with respect to one another to maximize the interference with the flow of exhaust gas through the muffler.

A modified muffler structure is illustrated in FIGS. 37 and 38, and the muffler illustrated therein includes an outer generally cylindrically shaped shell 203 having an inlet pipe 204 of reduced diameter in communication with the gas inlet end thereof. An inner tubular member 205 is telescoped within outer shell 203, and tubular member 205 has a closed end 206 adjacent the gas inlet end of the muffler, it being understood that the opposite end of member 205 is open to allow exhaust gases to pass outwardly therefrom. The end 207 of outer shell 203 remote from the gas inlet end is closed and is positioned in sealing engagement with inner member 205, and member 205 includes a plurality of openings 208 inwardly of shell end wall 207 to allow the exhaust gases to flow through the annular chamber 209 between members 203 and 205, through the openings 208, and to atmosphere.

A sound attenuating member 210 is positioned in the annular chamber 209 between members 203 and 205, and member 210 is similar to the previously described sound attenuating member 189 to the extent that it includes a plurality of spaced parallel ribbons 211 that are interconnected by integral webs 212 which are twisted throughout their length. As in the previously described embodiment, the ribbons 211 each include a plurality of alternating crests and troughs, but the sound attenuating member 210 differs from the sound attenuating member 189 in that the apexes 213 of the crests and the apexes 214 of the troughs present relatively broad surface areas that are positioned in face abutting engagement with members 203 and 205, respectively. Crest apexes 213 are curved about an axis that is parallel with the ribbons 211, with the radius of curvature being substantially equal to the radius of member 203; and in a like manner, the trough apexes 214 are curved about a radius that is parallel to the length of ribbons 211, with the radius being substantially equal to the radius of member 205. As with the previously described embodiment, the ribbons 211 present a substantial impediment to the flow of exhaust gases through the muffler, so as to dampen the sound of the engine to which the muffler is connected by dissipating the energy thereof. The longitudinally aligned twisted webs 212 allow the member 210 to be readily bent into an annular configuration, since the twisted portions 212 act as hinge joints allowing the ribbons 211 to be disposed at different orientations with respect to one another. As with the previously described embodiment, the twisted webs 212 act as expansion joints allowing the member 210 to expand into snug engagement with members 203 and 205 when heated by the exhaust gases.

The embodiment of FIGS. 39 and 40 is similar to the embodiment of FIGS. 37 and 38 so that the same reference numerals have been used to designate corresponding elements, with the subscript a having been added to the reference numerals in the embodiment of FIGS. 39 and 40. The muffler illustrated in FIGS. 39 and 40 differs essentially from that of FIGS. 37 and 38,

in that an intermediate cylindrical tubular member 215 is positioned in the chamber 209a between members 203a and 205a to divide the chamber 209a into an annular outer zone 216 and an annular inner zone 217. A plurality of openings 218 are provided in member 215 to establish communication between the zones 216 and 217. The end 219 of member 215 adjacent the gas inlet end of the muffler is closed, so that a tortuous flow path is provided for the exhaust gases through the outer chamber zone 216, through openings 218, through the inner chamber zone 217, through openings 208a, and to atmosphere through member 205a. Sound attenuating members 210a are slidably inserted in each of the chamber zones 216 and 217, as is evident from FIG. 39. As in the embodiment of FIGS. 37 and 38, the apexes of the crests and troughs of the ribbons in the sound attenuating members are curved so as to conform to the tubular surfaces against which they abut.

In each of the three above described muffler embodiments, at least a portion of the sound attenuating members is coated with a suitable substance for controlling the harmful effluent in the exhaust gases.

Turning now to the fencing structure illustrated in FIGS. 41-46, the fencing structure is illustrated generally at 220 in FIG. 41 as a road barrier adjacent a roadway 221; and as will be hereinafter explained, the fencing 220 is formed of one or more sheets of fencing material 223 having impact absorbing characteristics for arresting the motion of a vehicle 222. However, while the energy dissipating capability of the fencing material 223 makes the material particularly well suited for use in a roadway barrier, the fencing material is not limited to this specific use, since the material has other characteristics which make the material useful as a snow fence, a brakewater, or as an ordinary space divider.

The sheet of fencing material 223 is formed from an initially flat piece of material having a plurality of transverse rows 224 of elongate openings 225 that are separated from one another by webs 226. Spaced parallel ribbons 227 are defined between the rows 224, and the ribbons are connected by the webs 226. Each of the ribbons 227 is deformed to provide alternating, longitudinally spaced crests 228 and troughs 229 which extend outwardly from opposite sides of the plane of the initial sheet, with the crests 228 being formed by converging ribbon portions 230 and with the troughs 229 being formed by converging ribbon portions 231. The crests 228 on the ribbons 227 are longitudinally aligned with the troughs 229 on adjacent ribbons, so that the crests and troughs cooperate to collectively define parallel passages 232 in the fencing material 223 that are perpendicular to the length of the ribbons 227. The openings or slideways 232 allow the fencing material to be easily and quickly erected, since it is necessary only to slide the fencing material over vertical fence posts. Thus, the need for fasteners to secure the fencing material to the fence posts is eliminated.

When the crests 228 and troughs 229 are formed in the initial sheet material, the webs 226 are given a multi-planar torsional deformation, such that one end portion 233 of the web is disposed in the plane of the transitional section of one ribbon between ribbon portions 230 and 231, while the opposite end 234 of the web is positioned in the plane of the transitional section of an adjacent ribbon between the ribbon portions 230 and 231 thereon. The midportion of the webs 225 are generally uniformly twisted between the oppositely in-

clined end portions 233 and 234. In the fencing material 223 illustrated in FIG. 42, the apexes of the crests 228 and troughs 229 are rounded, so that the openings 223 are generally circular. In the modified structure 223' illustrated in FIG. 43, the ribbon portions 230 and 231 merge at a sharp angle, so that generally rectangularly shaped openings are defined therebetween. The fencing structure 223 is adapted to be used in connection with a tubular fence post having a circular cross-section, while the fencing structure 223' is adapted to be used with a fence post having a square or rectangular cross-section.

The fence post structure for mounting the fencing material 223 will be best understood from FIG. 44, and as illustrated therein, an upwardly opening tubular socket 235 is permanently embedded in the ground 236, preferably in concrete 237. A vertically extending tubular fence post 238 is slidably inserted within socket 235, preferably with a slight press fit to prevent unauthorized removal. The fence posts 238 preferably include weakening means 239 adjacent the lower end thereof, and the weakening means 239 may take the form of a circumferential groove 240 or a plurality of circumferentially spaced notches. The weakening means 239 allows the fence post 238 to shear into two sections 238a and 238b, when the post is struck by a vehicle 222, as is illustrated in FIG. 46.

When the sheet of fencing material is initially fabricated to provide the crests 228 and troughs 229, and to impart the multi-planar torsional deformation to the webs 226, the overall length of the material is significantly decreased, with the reduction in size being on the order of 25%. This allows the fencing material 223 to have built in energy absorbing characteristics, since when the fencing material 223 is engaged by a vehicle 222, as is shown in FIG. 41, the sheet will be stretched to the initial length, as shown at 223a, before a strain is imparted to the material itself. Obviously, if the material 223 is struck between fence posts 238 with only a slight impact, the material 223 will undergo only local deformation, and the fence posts 238 will not shear. As is illustrated in FIG. 41, the fencing material 223 preferably extends along a length including a plurality of fence posts 238, so that if a vehicle at high speed strikes the fencing 220 to shear the fence posts 238, several sections of fencing materials are brought into play to arrest the motion of the vehicle. In this manner, the energy of the moving vehicle is gradually dissipated, and the tendency of the vehicle to rebound off of the fencing is substantially eliminated.

As is shown in FIG. 43, the ends of the fencing material may be severed across the crests 228 and troughs 229 to provide oppositely inclined ribbon end portions 241 and 242. In such an arrangement, a split end tube 243 having opposed surfaces 244 may be slidably positioned over the web portions 226 to complete the fence, with the ribbon portions 241 and 242 cooperating to retain the end piece 243 upon the fencing material. Alternatively, the fencing material may have a straight line terminus, outwardly of the last openings 225 in the material 223, as is illustrated at 245 in FIG. 42. End caps 247 may be driven onto the upper ends of at least some of the fence posts 238 to prevent unauthorized removal of the fencing material, it being understood that the end caps are larger in size than the openings in the fencing material.

Referring now to FIGS. 47-49, a bumper 250 is illustrated therein, with a first embodiment of the bumper being shown in FIGS. 47 and 48 as including an impact absorbing sheet 253 sandwiched between an outer member 251 and an inner member 252. The member 253 is formed from a generally planar sheet of material having a plurality of transverse rows of elongate openings therein that separate the member 253 into a plurality of spaced, parallel ribbons 254, three such ribbons being illustrated in the embodiment of FIGS. 47 and 48. The webs between the openings connect the ribbons 254 at spaced positions therealong, and each of the ribbons 254 is deformed to provide alternating, longitudinally spaced crests 255 and troughs 256 between the webs. The apexes 257 of the crests 255 are flattened and parallel with the plane of the initial sheet, with the apexes 258 of the troughs 256 also being flattened and parallel with the plane of the initial sheet. As is evident from FIG. 47, crest apexes 257 are positioned in face abutting engagement with outer member 251, while trough apexes 258 are positioned in face abutting engagement with inner member 252.

The impact absorbing member 253 is secured to outer member 251 by shear bolt type fasteners 260, which pass through openings 259 in the member 251, and through openings in the crest apexes 257. Nuts 262 are threaded on fasteners 260 to positively secure the member 253 to the member 251, and fasteners 260 preferably are weakened, as by a circumferential groove 261, to provide a means allowing the fasteners to readily shear when the member 253 expands during impact.

Means 263 is provided for mounting the bumper 250 upon tubular vehicle chassis supports 264, and mounting means 263 are defined by a rectangular tubular mounting brackets 265 having outwardly diverging sides 266 that terminate in mounting feet 267. Mounting feet 267 are positioned in face abutting engagement with the outer surface of inner member 252, and mounting feet 267 include openings 269 that are positionable in alignment with elongate slots 271 in the inner member 252. Fasteners 270 impale openings 269, slots 271, and openings in the trough apexes 258, with nuts 272 being threaded upon the inner ends of fasteners 270 to secure the brackets 265 and the inner member 252 to the impact resisting member 253. Fasteners 270 are freely slidable along slots 271, so that when the member 253 expands during impact, the members 251 and 253 are free to move relative to inner member 252. The top and bottom of brackets 265 may be bent toward one another, as is shown at 273 in FIG. 48, with flush fasteners 275 extending through openings in the trough apexes 258 and through openings in the folded over bracket portions.

A modified bumper structure is shown at 250' in FIG. 49, and the bumper 250' is similar to the bumper 250, except that a plurality of impact absorbing members 253' are provided, with the apexes of the adjacent crests and troughs being secured to one another.

While both of the above described embodiments have been illustrated in connection with an outer member 250 or 250', the present invention contemplates that in certain instances the outer member may be eliminated to enhance the aesthetic appearance of the bumper.

Referring now to FIGS. 50-53, concrete reinforcing structures are illustrated therein which are formed in

accordance with the present invention. In the past, it has been well known, to use bars of reinforcing steel; or mesh, expanded metal, and welded wire type steel fabrics to reinforce concrete slabs, walls and partitions.

Fabric type reinforcing structures have proven unsatisfactory in several respects, and one of the primary drawbacks has been the inability to place the reinforcing structure at a uniform height within the concrete. Heretofore, the reinforcing structure is laid upon a prepared bed, and is pulled upwardly after the concrete has been poured. This results in different sections of the reinforcing material being located at a different position within the concrete, and gives the resulting structure unequal strength characteristics. A further deficiency of conventional reinforcing structures is that they are of limited thickness, and thus do not extend through a substantial portion of the thickness of the concrete material.

Turning now to FIG. 50, a plurality of longitudinally extending members or ribbons 302 are spanned by a plurality of transversely extending members or ribbons 304, and the members 302 and 304 are secured to one another at their junctions 306, as by welding, brazing, or by the use of other fasteners. The present invention contemplates that a mesh, such as that shown in FIG. 50, will be rolled into a relatively large coil, and transported by truck to the site at which the concrete is to be poured. At the site, apparatus formed in accordance with FIGS. 28-31 and 54, which may be carried by the truck, or separate therefrom, will deform the material into the configuration illustrated in FIGS. 51-53.

The members 302 and 304 may have the same or a different cross-sectional shape, and for example both members may be round as shown in FIGS. 50 and 51, square as shown in FIGS. 52 and 53, or one group of members can be round and the other group of members square. Also, it is not necessary that both members be formed of the same material, and different materials can be used to give the concrete structure properties that differ from one another in different directions.

In any event, when the blank of FIG. 50 is cold worked to form the structure shown in FIGS. 51 and 52, the longitudinally extending members 302 are provided with upwardly converging crests 308, and downwardly converging troughs 312. In the embodiment of FIG. 51, the crests and troughs are rounded as shown at 310 and 314, respectively. In the embodiment of FIG. 52, the crests and troughs are flattened, as shown at 320 and 322, respectively.

When the blank of FIG. 50 is cold worked, the portions of transversely extending members 304 that are located between longitudinally extending members 302 are subjected to torsional forces, and as a result, these portions, 304a in FIG. 51 and 304b in FIGS. 52 and 53, are twisted from end to end. The deforming members, such as gear-like dies 324 and 325, are provided with notches (FIG. 54) in their facing surfaces to confine the longitudinally extending members 302 as the blank is deformed. The spacers 328 between the die-like members 324 and 326 have an appropriate lateral dimension, which depends upon the transverse dimension between adjacent members 302.

In use, the reinforcing structure, after it is deformed on the site at which the concrete is to be poured, is placed on a prepared bed 316. It will be understood that the reinforcing structure rests upon the rounded portions 310, 314, or the flattened portions 320, 322,

to give the reinforcing structure a controlled thickness above the bed 318. Thus, when the concrete 318 is poured over the reinforcing structure, the reinforcing structure will project a uniform and substantial distance into the concrete 318. It should also be noted that the cold working of the reinforcing structure including members 302 and 304 gives the reinforcing structure additional strength, so as to improve the overall strength of the composite reinforced concrete.

Referring now to FIGS. 55-57, a formed member 340 is illustrated, which is similar to the product illustrated in FIGS. 4-6, but which differs therefrom in that the nodes on the core material progressively diminish in height from one end of the member to the other.

A first form of apparatus for producing member 340 is illustrated in FIG. 55, and the apparatus is similar to that illustrated in FIGS. 28 and 29. It will be understood that member 340 is formed from a blank, such as that shown at 70, in FIG. 1, and that the apparatus illustrated in FIG. 55 includes a plurality of pairs of gear-like die members 342 and 344, one pair of die members being provided for each ribbon of the blank. Each member 344 includes a plurality of circumferentially spaced teeth 346, 348, 350, 352 and 356 which extend outwardly from the periphery of member 344 by progressively decreasing amounts. Member 344 actually includes two sets of teeth 346-356, since the member 340 includes six nodes. As can be best seen in FIG. 57, the core material 340 that results from the action of forming members 342 and 344 includes a plurality of adjacent ribbons 358 and 360 that are interconnected by twisted webs 362, with ribbons 360 each including inclined truss-like portions 364 and flattened portions 366, and with ribbons 358 each including inclined trusslike portions 368 and flattened portions 370. The resulting member lends itself to inclusion in a tapered sandwich structure, such as air foil illustrated in FIG. 57, wherein the formed core is enclosed within a tapered skin 372 that may be bonded to the flattened portions 366 and 370 of the core.

An alternative means for producing member 340 is illustrated in FIG. 56 and includes a plurality of pairs of toothed members 374 and 376, with the teeth 378 on member 376 extending an equal amount outwardly of the center of the member. An elongate slot 380 is provided at the center of member 376, and is impaled by a drive shaft that drivingly connects each of the members 376. To this end, the shaft that extends through members 376 may have flattened portions to drivingly engage within slots 380. Nuts 382 may be threaded upon externally threaded outer portions of the drive shaft, to clamp holding members 384 against the outermost forming members 376. It will be understood that the members 376 can be adjusted so that the centers thereof are offset from the center of the drive shaft, so that the teeth 378 will be positioned eccentrically, and provide the member 340 with the tapered node construction.

Turning now to the embodiment of FIGS. 58-60, a blank 400 is shown in FIG. 58 and includes a plurality of laterally spaced, longitudinally extending ribbons 402 having longitudinally spaced reinforcing ribs 404 therein. Ribbons 402 are separated from one another by openings 406 with webs 426 extending between adjacent ribbons. A plurality of fins 408 extend outwardly from opposite sides of each web 426 for a purpose to be hereafter described.

As with the previous embodiments, blank 400 is subjected to a forming operation, as by the apparatus illustrated in FIGS. 28-31, to produce the configuration illustrated in FIG. 59 wherein one ribbon 410 includes inclined portions 414 spanned by flattened portions 416, while an adjacent ribbon 412 includes inclined portions 418 spanned by flattened portions 420. During the deforming action, the web 426 is given a multi-planar torsional deformation as with each of the previous embodiments, and it will be noted that the fins 408 which extend outwardly from opposite sides of the webs 426 are positioned at angles with respect to one another. The resulting member may be sandwiched between parallel skins 422 and 424 that may be secured to flattened portions 416 and 420, and the resulting structure may be used as a conduit in which liquid or gas mixing is to take place. It will be understood that the inclined fins 408, as well as the remainder of the structure, will enhance the mixing of the fluid passing through the conduit. The finned member also has particular utility in environments where added heat transfer is important.

Turning now to the embodiment of FIGS. 61-65, a structure is disclosed wherein the webs that connect adjacent ribbons are twisted substantially 180°. In each of the previously described embodiments, the transitional portion of adjacent ribbons, i.e., the portions of the ribbons that pass through the plane of the initial blank, are inclined oppositely with respect to one another, and since the ends of the webs merge with the transitional portions of adjacent ribbons, the webs are twisted by an amount corresponding to the angular orientation of the transitional ribbon portions.

A blank 440 is illustrated in FIG. 61, and blank 440 includes a plurality of longitudinally spaced, longitudinally extending ribbons 442 having a plurality of longitudinally spaced reinforcing ribs 444 thereon. A plurality of longitudinally spaced openings 446 are provided between each adjacent ribbon 442, to provide webs 448 which interconnect the ribbons. As with the previous embodiments, the blank 440 is subjected to a forming action, as by the apparatus illustrated in FIGS. 28-31, to produce the configuration illustrated in FIG. 62. As shown therein, each ribbon 442 includes crests formed by upwardly converging portions 450 spanned by flattened portions 452, and troughs formed by downwardly converging portions 454 spanned by flattened portions 450. As is evident from FIG. 63, webs 448 are given a multi-planar torsional deformation, with the end portions 448a and 448b merging with the aligned transitional portions of adjacent ribbons and disposed at an angle with respect to one another.

To produce the final end product, i.e., wherein the web 448 is given a complete 180° twist, the product illustrated in FIGS. 62 and 63 is subjected to a secondary forming operation to produce the configuration in FIG. 64 wherein the formerly inclined ribbon portions are drawn into parallelism with one another, as illustrated at 450' and 454'. With this arrangement, the opposite ends 448a' and 448b' of the web 448' are disposed in a common plane with the intermediate portion of the web being twisted a full 180°. It will be understood that because of the right angular disposition between members 450' and 454' in the embodiment of FIG. 64, the resulting structure will have particular utility in environments where high compressive strengths are required.

Each of the above described members may be formed of any suitable material, and may be given a polymer coating, if desired. The present invention contemplates that the members may be coated in any suitable fashion, depending on the size and shape of the article, and coating methods, such as dipping, spraying, electro-plating, and electrostatic powder coating are within the contemplation of the present invention. Various coating materials may be used, such as polyolefins, polyesters, epoxies and urethanes.

Referring now to FIGS. 66-71, a novel connecting system is illustrated therein which is useable with fencing structures of the type illustrated in FIGS. 41-46. With reference to FIG. 66, a section 460 of material is illustrated therein which includes a plurality of parallel ribbons 462 which are connected to one another by twisted webs 464, as described above. Member 460 may be formed of any suitable material such as metal, plastic, or metal coated with plastic.

FIGS. 67-69 illustrate a connecting means 466 which is utilized to connect two fencing sections 460 and 460' in alignment with one another. The connecting means includes a vertical fencepost 468, which is formed of two separate box-like tubular members 470 and 472. Members 470 and 472 each include spaced wall portions 474 at oppositely facing sides thereof which define a narrow vertical passage 476. As can be best seen in FIG. 68, member 460 is severed along a line perpendicular to ribbons 462 to provide oppositely inclined retention portions 478. The width of passage 476 is slightly in excess of the dimension of web 464, but much smaller than the distance between retention portion 478, so that fencing member 470 can be positively secured to the fencepost element 472 by positioning the webs 464 immediately above passage 476, and then vertically moving the fencing member 460 relative to the fencepost 470 to insert the retention portions 478 inwardly of fencepost element 472.

In the event that fencing members 460 are not co-extensive in dimension with fencepost member 470, more than one fencing member 460 may be utilized, as shown in FIG. 71, with the adjacent ribbons 462a and 462b of the adjacent fencing members 460 overlapping one another in inter-nested relationship. C-shaped clips 480 may be cinched around overlapping ribbons 462a and 462b if desired to positively interconnect the adjacent fencing members. A suitable tool 482, including a pair of pivotally mounted jaws, is illustrated in FIG. 71 for cinching clips 480.

Fencepost elements 470 and 472 may be connected directly to one another, if desired, but in the preferred embodiment, a separate inverted U-shaped connecting member 484 is utilized with the downwardly extending legs 486 thereof embracing the upper ends of fencepost elements 470 and 472. A pair of screws 488 extends through aligned clearance openings in legs 486 and fencepost elements 470 and 472, with nuts 490 being threaded on screws 488 to unit fencepost elements 470 and 472 and clips 484.

Top rail members 492 may also be provided, if desired, with reference to FIG. 69, it will be noted that top rail members 492 are tubular box-like members including spaced wall portions 494 having a narrow passage 496 in one side thereof. Top rail members 492 are preferably similar in dimension to, or the same in dimension as, fencepost elements 470 and 472 to reduce inventory requirements. To this end, passage 496 has

a dimension that is slightly in excess of the dimension of webs 464, but substantially in excess of the dimension of the fabricated ribbons 462. As is also evident from FIG. 69, when clips 484 are utilized to connect fencepost elements 470 and 472, the top rail members 492 are inserted beneath the clips 484.

FIG. 70 illustrates a connecting system similar to that described above, but having utility for connecting two fencing sections at right angles to one another. To this end, a corner post 498 is provided that is comprised of two box-like tubular elements 500 and 502. Elements 500 and 502 have spaced wall portions 504 on one side thereof, that define narrow passageways 506. As described above, to minimize inventory requirements, the corner fencepost elements may be identical in dimension to those utilized to connect in-line fencing sections, but with the passage 506 being disposed at right angles to one another. Again, generally identical top rail members 508 may also be utilized, and to accommodate the perpendicular fence sections, an inverted U-shaped clip 510 is utilized which has a rectangular opening 512 in one leg thereof. The wall portion of clip 510 opposite opening 512 is preferably left solid so that the perpendicular top rail 508 may be butted thereagainst. As described above, one or more screws 514 may be utilized to connect the clip 510 to the corner fencepost elements 500 and 502.

Turning now to FIGS. 72-79, a novel pallet or skid structure is shown therein which minimizes or completely eliminates utilization of wood structural members. Referring first to FIG. 72, a blank 520 is shown therein having a plurality of spaced parallel relatively narrow ribbons 522 in the mid-portion thereof, and relatively wider ribbons 524 adjacent the side marginal edges thereof. As previously described, the ribbons are separated from one another by parallel rows of elongate openings 526, so that upon fabrication to the configuration of FIGS. 74 and 75, the webs 528 against adjacent ribbons become twisted from end to end.

As can be best seen in FIGS. 72 and 75, a row of relatively large, generally square openings 530 are provided in widened ribbons 524. Openings 530 are located with their midportions aligned with the mid-portion of the webs 528 connecting ribbons 524 to laterally adjacent ribbons. As is clear from FIGS. 72 and 75, openings 530 are positioned in longitudinal alignment with one another, and when the blank 520 is fabricated to the configuration shown in FIGS. 74 and 75, openings 530 cooperate to collectively define access passages 532.

As can be seen by comparing FIGS. 74 and 75, when the blank 520 is fabricated, the nodes of the crests and troughs of the ribbons 522 are flattened, as shown at 534, and disposed in spaced parallel planes to collectively define a material support surface. Openings 530 are substantially co-extensive in length with the inclined portions 536 of the ribbons so that the passages 532 which open to opposite sides of the pallet, are substantially co-extensive in dimension to the height of the pallet so that the tines of a fork lift truck can have easy access to the pallet from the side. As is also evident from FIG. 74, when the blank 520 is fabricated to the illustrated configuration, relatively large passages 538 are provided at the front and back of the pallet between the configured ribbons 522 and 524, so that the pallet is readily accessible from all four sides.

The pallet structure illustrated in FIGS. 74 and 75 may be readily nested for compact storage as shown in FIG. 76. To this end, the last openings 526 in each row of openings are spaced inwardly of the side marginal edges of the blanks 520 to leave a solid blank portion 540 at each side of the blank. The solid portions 540 are also of significant importance in spanning the openings 530 at the sides of the pallet, in that they tie the relatively large areas of material on opposite sides of the openings 520 together to prevent any spreading of the ribbons of the pallet, as might otherwise tend to occur under heavy loading. The inclined portions 536 of the pallet are all formed at the same angle so that the ribbons inter-fit with one another in the compact manner illustrated in FIG. 76.

In certain instances where nestability is not critical, and when it is desired to provide a pallet with a continuous product support surface, the structure illustrated in FIGS. 77-79 may be utilized. The blank 542 of FIG. 77 is similar to blank 520 in that it includes a plurality of relatively narrow central ribbons 544 in the mid-portion of the blank, with relatively wider ribbons 546 being provided outwardly thereof. Again, generally square openings 548 are provided in ribbons 546 in alignment with the webs 550 that connect adjacent ribbons. Also, crests and troughs of the ribbons are flattened, as shown at 552 and inter-connect by inclined portions 554, as can be best seen in FIG. 78.

The blank 554 and the pallet which results upon fabrication, differs from that illustrated in FIGS. 72-76 in that the longitudinally extending openings 556 between adjacent ribbons extend to the marginal side edges of the blank, as is clear from FIG. 77. In this manner, flattened shelves 558 are provided at the ends of the ribbons upon fabrication. Flattened portions 558 cooperate with flattened portions 552 to effectively define a parallel planar surface to which rectangular support members 560 may be secured. To facilitate the connection of support members 560 to the fabricated blank, a plurality of connector openings 562 may be formed in portions 552 and 558 of the blank prior to fabricating the blank to the configuration shown in FIGS. 78 and 79. As with the previous embodiment, openings 548 have a dimension which corresponds essentially to the height of the pallet so that enlarged passages 564 (FIG. 79) are provided at opposite ends of the pallet which are readily accessible to the tines of a fork lift truck. As is also evident from FIG. 78, enlarged passages 566 are also provided at right angles to passage 564 so that the pallet is readily accessible from all four sides thereof.

Each of the above described pallet structures have high strength-to-weight ratios by virtue of the truss-like structures resulting from inclined portions 536 and 554. The pallets are preferably formed of metal, although it is within the contemplation of the invention that other materials may be utilized. It should also be noted that blanks such as those shown in FIGS. 72 and 77, or structural equivalents thereof, can be produced in continuous lengths or coiled stock, and severed from one another immediately prior to, or subsequent to, forming.

I claim:

1. An article of manufacture comprising: a ductile member having a plurality of transversely spaced generally longitudinally extending rectilinear, ribbons, adjacent ribbons being parallel with one another and co-

operating to define a pair of ribbons and said member including a plurality of such pairs, said ribbons being continuous in length and having opposite longitudinally extending edges, the edges on adjacent ribbons being spaced from one another by a finite distance at spaced locations along their respective lengths to define a row of longitudinally spaced and longitudinally aligned openings between adjacent ribbons of each pair, the openings which define slots in plane section in each row being separated by a web portion that extends transversely and perpendicularly between ribbons of a pair of ribbons, each ribbon including alternating, longitudinally spaced crests and troughs, the crests extending upwardly from a reference plane and the troughs extending downwardly from the reference plane, the transitional portion of each ribbon between the crests and troughs being undeformed and extending at an angle with respect to the reference plane, the crests on each ribbon being aligned with a trough on the adjacent ribbon of its pair of ribbons whereby the aligned transitional portions of adjacent ribbons of each pair of ribbons are disposed at angles that are positioned oppositely with respect to said reference plane, each of said webs being continuous and having a finite length which extends from a first end portion merging with a transitional portion of one ribbon of its pair of ribbons to a second end portion merging with the aligned transitional portion of the adjacent ribbon of its pair of ribbons, the dimensions of said webs being selected such that the intermediate portion of each web between its end portions is twisted throughout its length.

2. An article of manufacture as set forth in claim 1 wherein said ribbons have openings therein.

3. An article of manufacture as set forth in claim 1 wherein said crests and troughs are defined by converging ribbon portions that merge at an acute angle.

4. An article of manufacture as set forth in claim 1 wherein said crests and troughs are defined by converging ribbon portions, the apex of said crests and troughs being arcuately shaped.

5. An article of manufacture as set forth in claim 4 wherein the radius of the crest apexes is different than the radius of the trough apexes.

6. An article of manufacture as set forth in claim 4 wherein said apexes are curved above axes that are parallel to one another and to said reference plane.

7. An article of manufacture as set forth in claim 6 wherein the axes of said apexes are parallel to the length of said ribbons.

8. An article of manufacture as set forth in claim 6 wherein the axes of said apexes are perpendicular to the length of said ribbons.

9. An article of manufacture as set forth in claim 4 wherein the apexes of said crests and troughs are spherically shaped.

10. An article of manufacture as set forth in claim 1 wherein said crests and troughs are defined by converging ribbon portions spanned by a flat ribbon portion that is parallel to said reference plane.

11. An article of manufacture as set forth in claim 1 wherein said member is sandwiched between a pair of cover members.

12. An article of manufacture as set forth in claim 11 in which at least some of said crests are secured to one of said cover members and at least some of said troughs are secured to the other of said cover members.

13. An article of manufacture as set forth in claim 11 in which said cover members are parallel to one another and to said reference plane, and wherein said crests and troughs are defined by converging ribbon portions spanned by a flat ribbon portion that is positioned in face abutting engagement with a cover member, at least some of said flat ribbon portions being secured to said cover members.

14. An article of manufacture as set forth in claim 11 wherein said cover members and sheet are curved.

15. An article of manufacture as set forth in claim 14 wherein said cover members are concentric tubes.

16. An article of manufacture as set forth in claim 15 wherein said ribbons extend circumferentially around the axes of said tubes.

17. An article of manufacture as set forth in claim 15 wherein said ribbons extend longitudinally, parallel to the axes of said tubes.

18. An article of manufacture as set forth in claim 1 wherein said webs have arcuate side edges to provide rounded portions at the ends of said longitudinally spaced openings.

19. An article of manufacture as set forth in claim 1 wherein the edges of adjacent ribbons that are spaced from one another to define said longitudinally spaced openings are generally parallel with one another, whereby said openings are of generally equal width throughout their length.

20. An article of manufacture as set forth in claim 1 wherein the edges of adjacent ribbons that are spaced from one another to define said longitudinally spaced openings are spaced a greater distance from one another adjacent the web at each end of the openings than at the midportion of the openings.

21. An article of manufacture as set forth in claim 1 wherein the edges of adjacent ribbons that are spaced from one another to define said longitudinally spaced openings are spaced a greater distance from one another adjacent the midportion of the openings than adjacent the web at each end of the openings.

22. An article of manufacture as set forth in claim 1 wherein said ribbons are wider than said openings.

23. An article of manufacture as set forth in claim 1 wherein said webs are integral with said ribbons.

24. An article of manufacture as set forth in claim 1 wherein said webs are provided by parts that are separate and distinct from said ribbons and which extend generally perpendicularly with respect thereto, said parts being secured to said ribbons at the intersections therebetween.

25. An article of manufacture as set forth in claim 1 in which the transitional portions of adjacent ribbons are disposed substantially perpendicularly with respect to said reference plane, and wherein the end portions of said webs are twisted substantially 180° relative to one another.

26. An article of manufacture as set forth in claim 1 wherein the crests and troughs progressively decrease in height from one end of the member to the other.

27. An article of manufacture as set forth in claim 26 wherein said member is positioned within a tapered enclosure.

28. An article of manufacture as set forth in claim 1 wherein each ribbon includes a plurality of longitudinally spaced reinforcing ribs.

29. An article of manufacture as set forth in claim 1 wherein at least one fin extends outwardly from one side of each web.

30. An article of manufacture as set forth in claim 29 wherein a plurality of fins extend outwardly from each side of each web.

31. An article of manufacture as set forth in claim 1 wherein said articles is coated with a plastic material.

32. An article of manufacture as set forth in claim 1 in which at least two of said ribbons include openings in alignment with the webs connecting the ribbons to adjacent ribbons, said openings being in alignment with one another and cooperating to define passageways in said at least two ribbons.

33. An article of manufacture as set forth in claim 32 in which the apexes of the crests and troughs are flattened and cooperate to define generally flat surfaces at opposite sides of said member.

34. An article of manufacture as set forth in claim 33 in which thin parallel support sheets are secured to said generally flat surfaces.

35. An article of manufacture as set forth in claim 1 in which a pair of said members are positioned along side one another with said members including adjacent edge portions facing one another, said edge portions being perpendicular to the length of said ribbons and each extending through a crest and trough of the ribbons of its respective member to provide oppositely inclined retention portions; and wherein rail means is provided for interconnecting said pair of members, said rail means including first and second sets of wall portions spaced from one another, the distance between the wall portions of said first and second sets being greater than the dimension of the twisted webs adjacent said retention portions and less than the dimension of the free ends of said retention portions, each member of said pair of members being connected to said rail means by inserting the twisted webs adjacent the retention portions of each of said pair of members between the wall portions of one of said first and second sets.

36. An article of manufacture as set forth in claim 35 in which said rail means includes first and second separate rail members, each rail member having one of said sets of separate wall portions, and wherein an inverted generally U-shaped clip is positioned over the free ends of said rail members, with fastening means securing said clip to at least one rail member.

37. An article of manufacture as set forth in claim 35 wherein the members of said pair of members are positioned in line with one another.

38. An article of manufacture as set forth in claim 35 wherein the members of said pair of members are positioned at a right angle with respect to one another.

39. An article of manufacture comprising: first and second generally identically shaped sheets positioned in face abutting engagement with one another, each sheet having a plurality of transversely spaced generally longitudinally extending ribbons, adjacent ribbons cooperating to define a pair of ribbons and said sheet including a plurality of such pairs, said ribbons being continuous in length and having opposite longitudinally extending edges, the edges on adjacent ribbons being spaced from one another at spaced locations along their respective lengths to define a row of longitudinally spaced openings between adjacent ribbons of each pair, the openings in each row being separated by a web portion, each ribbon including alternating, longi-

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itudinally spaced crests and troughs, the crests extending upwardly from a reference plane and the troughs extending downwardly from the reference plane, the transitional portion of each ribbon between the crests and troughs extending at an angle with respect to the reference plane, the crests on each ribbon being aligned with a trough on the adjacent ribbon of its pair of ribbons whereby the aligned transitional portions of adjacent ribbons of each pair of ribbons are disposed at angles that are inclined oppositely with respect to said reference plane, said webs each having a first end portion merging with a transitional portion of one ribbon of its pair of ribbons and a second end portion merging with the aligned transitional portion of the adjacent ribbon of its pair of ribbons, the intermediate portion of each web between its end portions being twisted throughout its length, means bonding at least one ribbon of said first sheet to a ribbon of said second

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sheet in laterally spaced longitudinally extending areas, the ribbon material between the bonded areas of each sheet extending away from one another to define a longitudinally extending passage between said bonded areas.

40. An article of manufacture as set forth in claim 39 wherein said first and second sheets are sections of a single member, said member being folded to place said sheets in face abutting engagement with one another.

41. An article of manufacture as set forth in claim 39 wherein the edges of said first and second sheets are bonded to one another around the periphery thereof, the ends of said sheets inwardly of said bonded edges and outwardly of said ribbons being spaced from one another to define chambers communicating with the passages in said ribbon.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,869,778
DATED : March 11, 1975
INVENTOR(S) : Raymond W. Yancey

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 10, line 9, "such a" should be -- such as --.

Column 12, line 66, "theembodiment" should be -- the
embodiment --.

Column 13, line 66, "webs 225" should be -- webs 226 --.

Column 17, line 45, "us" should be -- is --.

Column 18, line 37, "thereon" should be -- therein --.

Column 18, line 56, insert -- illustrated -- after
"configuration".

Column 19, line 32, "portion 478" should be -- portions 478 --

Column 19, line 61, "desired, with" should be -- desired.
With --.

Column 20, line 39, "against" should be -- between --.

Column 21, line 5, "blanks 520" should be -- blank 520 --.

Column 21, line 10, "520" should be -- 530 --.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

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Patent No. 3,869,778 Dated March 11, 1975

Inventor(s) Raymond W. Yancey

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 21, line 49, "to passage" should be -- to passages --.

Column 21, line 66, "rectilinear, ribbons" should be
-- rectilinear ribbons, --.

Column 24, line 8, "articles is" should be -- article is --.

Signed and sealed this 15th day of July 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks