(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 179 719 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
13.02.2002 Bulletin 2002/07

(51) Int Cl.7: **F28D 1/03**, F28F 3/04, B21C 37/08

(21) Application number: **01117658.3**

(22) Date of filing: **25.07.2001**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **08.08.2000 US 634037**

(71) Applicant: **Modine Manufacturing Company**
Racine Wisconsin 53403 (US)

(72) Inventors:
- **Heyse, Richard P.**
  Racine, Wisconsin 53406 (US)
- **Eggert, Jeffrey F.**
  Kenosha, Wisconsin 53142 (US)
- **Fox, Richard A.**
  Racine, Wisconsin 53406 (US)
- **Kaat, Ronald J.**
  Racine, Wisconsin 53404 (US)

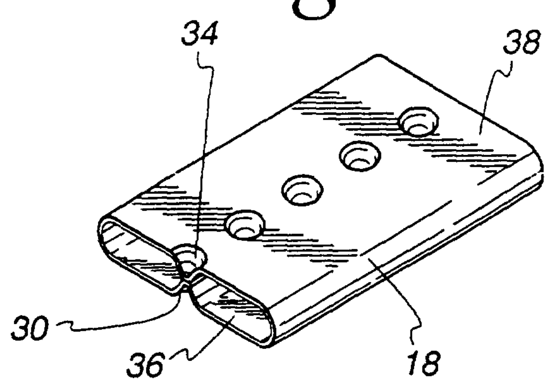
(74) Representative: **Heselberger, Johannes**
Bardehle, Pagenberg, Dost, Altenburg, Geissler, Isenbruck, Postfach 86 06 20
81633 München (DE)

(54) Method of making a tube for a heat exchanger

(57) Method for manufacturing dimpled, flattened tubes for heat exchangers including the steps of:

a) providing an elongated strip of aluminum based material (22) having opposed edges (24,26) and a braze alloy on only one side thereof;
b) forming dimples (30) in the strip (22) such that the dimples (30) project to the side of the strip (22) opposite the strip one side and the dimples (30) on one side of a predetermined fold line (28) located between opposed edges will align with the dimples (30) on the other side of the fold line (28);
c) placing slits (34) extending through the strip (22) at the apexes (44) of the dimples (30) on at least one side of the fold line (28);
d) folding the strip (22) along the fold line (28) and bringing the edges (24,26) into contact with one another while causing the apexes (44,46) of aligned ones of the dimples (30) to abut one another;
e) welding the edges (24,26) to each other to form a tube; and
f) causing the braze alloy to flow from the strip one side through the slits to the interior of the tube and braze the apexes (44,46) of the aligned dimples (30) together.

Fig. 3



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Description

FIELD OF THE INVENTION

[0001] This invention relates to heat exchangers, and more particularly, to so-called oval or flattened dimpled tubes employed in such heat exchangers and methods of making the same.

BACKGROUND OF THE INVENTION

[0002] So-called flattened or oval cross-section, dimpled tubes have long been employed in heat exchangers of various types. In such tubes, dimples are formed in the side walls of the tubes to extend partially or wholly across the interior of the tube in a direction across the tube minor dimension. In many cases, the dimples arc employed for the purpose of inducing turbulence in the heat exchange fluid flowing within the tube to thereby increase the rate of heat transfer. In other cases, opposed dimples are bonded to one another or dimples are bonded to the opposing side wall of the tube for the purpose of providing pressure resistance to the tubes.

[0003] More specifically, with weight being a concern in many applications, particularly in vehicular applications, and to reduce material costs, tubes of this sort arc made with extremely thin walls and consequently may be incapable of supporting the tube against distortion caused by pressure of the fluid within the tube. This is of particular concern when the tubes are used in higher pressure applications such as in condensers for refrigeration systems, etc. In particular, because the tubes are flattened, when subjected to pressure, they tend to "go round" unless they are supported against the forces causing such distortion. In some cases, plate fins are employed on the exterior of the tubes to girdle the tubes and prevent such distortion while in others, inserts are located within the tubes and bonded to opposed side walls for the same purpose. In still others, internally directed dimples are brazed to one another or to the opposite side wall of the tube to provide the required strength.

[0004] Because of its relatively low density and relative high thermal conductivity, aluminum is increasingly becoming the material of choice in forming such tubes. Aluminum tubes are easily brazed to other heat exchanger components such as headers and fins. Thus, commonly a dimpled, aluminum tube is formed by placing dimples in a strip used to form the tube while the strip is generally flat or planar. Through forming techniques of a conventional nature, the strip is formed into a generally round shape and the sides of the strip brought together. High frequency induction welding is employed along the edges that are in abutment to weld the strip into a closed tube. Further sizing of the tube from a basically round tube to the conventional flattened or oval cross-section shaped tube then takes place. Dimples formed in the strip while flat are brought into substantial abutment with one another.

[0005] The strip itself is formed of aluminum base metal and clad with an aluminum based braze alloy on both sides thereof. Brazing flux is introduced into the interior of the tube and when the tube is assembled into a heat exchanger and held in place by a fixture, and subject to a brazing operation, braze alloy material on the interior of the tube flows at the dimples and joins opposed dimples together.

[0006] One problem with forming dimpled tubes in this fashion is the fact that the strip of which the tube is formed must be braze clad on both sides thereof. Braze cladding on one side is required to assure the availability of braze alloy during the brazing process where the dimples are in contact with one another so as to bond the two together. It is also required on the opposite side of the strip which will be the exterior of the tube, to allow the strip to be brazed to headers, and even more particularly, to fins. Strip stock that is provided with braze cladding on both sides is more expensive than strip stock that is clad with braze alloy on only one side. However, according to present techniques, the former is required to achieve brazing of the internally directed dimples to one another.

[0007] Another difficulty is the fact that brazing flux must be present on the interior of the tube in order to assure that the dimples will braze to one another. Brazing fluxes typically employed in an aluminum brazing operation, such as the Nocolok® process leave residues after the brazing process is completed. These flux residues make it difficult to employ the process on tubes having passages of relatively small hydraulic diameter since the passages may become partially or wholly plugged by the flux residue. Moreover, introducing the flux residue into the interior of the tube can be challenging and the tube interiors may require a subsequent cleaning operation to minimize the accumulation of brazing flux therein.

[0008] The present invention is directed to overcoming one or more of the above problems.

SUMMARY OF THE INVENTION

[0009] It is the principal object of the invention to provide a new and improved method of forming a dimpled tube. It is also an object of the invention to provide a tube for a heat exchanger made according to the inventive method.

[0010] The highly preferred method of making a heat exchanger tube according to the invention includes the steps of:

a) providing an elongated strip of aluminum base material and having opposed edges and a braze alloy on only one side thereof;
b) forming dimples in the strip such that the dimples project to the side of the strip opposite the strip one side and the dimples on one side of a predeter-

mined fold line located between the opposed edges will align with the dimples on the other side of the fold line;

c) placing slits extending through the strip at the apexes of the dimples on at least one side of the fold line;

d) folding the strip along the fold line and bringing the edges into contact with one another while causing the apexes of aligned ones of the dimples to abut one another;

e) welding the edges to each other to form a tube; and

f) causing the braze alloy to flow from the strip one side through the slits to the interior of the tube and braze the apexes of the aligned dimples to one another.

[0011] Even more preferably, step f) is proceeded by the step of applying a flux to the strip one side at at least the vicinity of the dimples having the slits.

[0012] Preferably, the dimples are nominally frustoconical.

[0013] In some cases, perforations other than slits may be used while in others, dimples may be located on only one side of the fold line and brought into contact with the opposite internal side wall of the tube.

[0014] Also contemplated is a new and improved dimpled tube made by the method of the invention.

[0015] Other objects and advantages will become apparent from the following specification taken in connection with the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

[0016]

Fig. 1 is a side elevation of a typical heat exchanger employing dimpled tubes made according to the invention;

Fig. 2 is a perspective view of a section of aluminum sheet stock to be ultimately folded upon itself to form the tube;

Fig. 3 is a view similar to Fig. 2 but showing the section of sheet stock folded upon itself to form a completed tube section; and

Fig. 4 is an enlarged, sectional view of a dimpled tube made according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0017] The method of the present invention is intended to produce aluminum based tubes of so-called flattened or oval cross-section which include internally directed dimples. Tubes of this sort are ideally suited for employment in heat exchangers of various types and particularly those where internally directed dimples are employed for inducing turbulence within the interior of the tube and wherein the tube is required to have some degree of internal resistance to pressure of a heat exchange fluid passing through the tube. Typically, the tubes will be useful in the fabrication of vehicular radiators, charge air coolers, heat exchangers used in air conditioning or refrigeration systems, etc. However, it is to be particularly noted that no limitation to use of any of the foregoing listed heat exchangers is intended. It should be sufficient to note that the tubes are ideally suited for use in any heat exchanger application wherein dimples are employed for inducing turbulence and/or for providing pressure resistance.

[0018] With reference to Fig. 1, a typical heat exchanger made according to the invention includes opposed, spaced, parallel headers which may be in any known form. For example, the headers 10, 12 may be tubular, formed of one or more pieces. Alternatively, the headers 10 and 12 may be formed of header plates capped with tanks in a conventional fashion.

[0019] As shown in Fig. 1, an inlet is schematically indicated at 14 and extends to the header 10. An outlet, schematically illustrated at 16 extends from the header 12. A plurality of tubes 18, only some of which are shown, extend between the headers 10, 12 and are in fluid communication with the interior thereof. The tubes 18 will be of so-called or flattened or oval cross-section and extend through slots (not shown) in facing sides of the headers 10, 12 and brazed in place.

[0020] Serpentine fins 20 are located between adjacent ones of the tubes 18 and brazed thereto in a conventional fashion. However, it is to be particularly noted that plate fins could be used if desired.

[0021] All of the components are formed of an aluminum based material so that they may be brazed together in a conventional fashion as, for example, by the so-called Nocolok® process which employs potassium fluoro aluminate compounds as a brazing flux.

[0022] It should also be noted that while inlet 14 is indicated as extending to one of the headers 10 and the outlet 16 extends from the header 12, describing a so-called single pass heat exchanger, baffles may be placed in one or the other or both of the headers 10, 12 to provide as many different passes as may be desired. Thus, the inlet 14 and the outlet 16 may be located in a single one of the headers 10, 12 rather than in separate headers, depending upon the number of passes provided.

[0023] Turning to Fig. 2, tubes 18 are formed of an elongated strip 22 of aluminum based sheet stock. The strip 22 has opposed edges 24, 26 which may be curled upwardly in the same direction through about 90° at each of the edges 24, 26 as illustrated.

[0024] Generally centrally of the strip is a pre-determined fold line 28. In actuality, the fold line 28 is imaginary and represents an area on which the strip 22 will be bent along its length to bring the edges 24 and 26 into contact with one another. Of course, if desired, the fold line 28 could actually be located on the strip 22 by any suitable marking technique from scoring to the application of ink or the likc.

[0025] Between the fold line 28 and the edge 24, a series of dimples 30 are formed in at least one row that extends longitudinally of the strip 22. The dimples 30 are spaced from one another, nominally frusto-conical in shape, and according to a preferred embodiment, imperforate. They may be formed by any suitable stamping or drawing technique as the strip 22 is passed through forming equipment of a conventional nature employed to form the strip 22 into a completed tube.

[0026] A second row of spaced dimples 32 is formed between the fold line 28 and the edge 26. The dimples 32 are located so as to align with the dimples 30 when the strip is folded approximately 180° on the fold line 28. The dimples 32 are also generally frusto-conical in shape and their apexes are provided with openings 34.

[0027] The strip 22 is, as mentioned previously, aluminum based material. On its upper surface 36, bare aluminum is present. That is to say, the upper surface 36 is free of braze alloy, although the same may be oxidized somewhat as is well known. The opposite side of the strip 38 is clad in braze alloy which will typically be an aluminum based compound containing some silicon or other materials which lowers its melting point slightly below the melting point of the base aluminum of which the strip 22 is formed. This allows the braze alloy to become a liquid and flow before the aluminum of the base strip 22 softens and flows. The metallurgy of such a system is well known and will not be described further herein.

[0028] A section of completed tube is illustrated in Fig. 3. Here, the edges 24 and 26 have been brought into abutment with one another and bonded to each other as, for example, by high frequency induction welding. In addition, the apexes of the dimples 30 and 34 have been brought into contact with one another and, by means to be described in greater detail, bonded to one another. Of course, the tubes 18 will typically be substantially longer than that shown in Fig. 3 which represents only a short section of a completed tube 18.

[0029] Turning now to Fig. 4, the strip 22 is illustrated with its edges 24, 26 abutted against one another and with a weld 40 formed at the point of abutment to complete a tube. Also seen is the layer 42 of braze alloy on the side 38 of the strip 22. It will be noted that the side 36 is free of braze clad alloy.

[0030] The apex 44 of one of the dimples 32 has been brought into abutment with the apex 46 of one of the dimples 30.

[0031] It will be seen that the openings 34 in the apexes 44 thus align with the apexes 46. Fillets 48 of braze material bond the apexes 44, 46 together as well as seal the openings 34. The fillets 48 are formed by braze material from the layer 42 on the side 38 of the strip entering the interior of the tube through the openings 34 to wet the apex 46 of the dimples 30. Upon solidification, the fillets 48 are formed.

[0032] In the usual case, a strip 42 will be unwound from a coil or the like and run through a stamping or drawing machine to form the dimples 30, 32 as well as the curl at the edges 24 and 26. Through roll forming techniques or the like, the strip 22 is bent generally about the fold line and elsewhere to cause the edges 24, 26 to be brought into abutment with one another where they are subject to welding to form the weld 40. The resulting tube will be generally round in shape and may be flattened about the weld 40 and the fold line 46 to assume the configuration generally illustrated in Fig. 3, thereby bringing the dimples 30, 32 into contact with one another. In some cases, the imperforate dimple 30 may be omitted and the perforated dimples 32 brought into direct contact with the facing interior wall of the tube 18. The welding operation will generally occur before the dimples 30, 32 are abutted but can take place at the same time or afterwards as desired.

[0033] At this or any subsequent time, flux may be applied to the exterior of the tube at least in the vicinity of the dimples 30, 32 and the tube subject to a brazing operation. The braze clad material 42 on the surface 38 of the tube will liquify and, along with the flux, flow through the openings 34 to the interior of the tube and wet the apex 46 of the dimple 30 and ultimately form the fillets 48. Preferably, however, prior to that occurring, the tube is assembled in a fixture along with the headers 10, 12, subject to fluxing and then to brazing temperature to achieve the finished heat exchanger with the dimples 30, 32 bonded to one another.

[0034] While the openings 34 may take on a variety of shapes from circular to oval to other configurations, it is preferred to form them as slits such as the slits shown at 34 in the drawings. In the course of forming the strip 22 as mentioned previously, it has been determined that slits are substantially easier to form than circular openings such that the forming process need not be slowed down by any need to actually remove material to form the openings 34. That is to say, a slit opening is basically one that penetrates fully through the strip 22 at the apex 44 of the dimples 32 without the removal of any material. However, where some decrease in assembly line speed can be tolerated, the openings 34 may be formed by other than slitting with material actually removed at the apexes 44.

[0035] The openings 34 thus provide access to the interior of the tube in the vicinity of the apexes 46 on the dimples 30 to allow both the braze alloy from the layer 42 and flux to enter at the precise point where the bonding between dimples 30, 32 is to occur. As a consequence of the foregoing, the strips 22 need be braze clad only on one side rather than on both sides. Consequently, material costs for the tubes is reduced.

[0036] Furthermore, fluxing of the interior of the tube is avoided entirely since the flux flows into the joint from the exterior of the tube. Thus, problems associated with flux in the passages and the need to form a flux removing cleaning operation are avoided as well.

[0037] The resulting tube therefore provides the advantages of known dimpled, flattened tubes while being produceable at a lower cost and avoiding any problems associated with the flux residue. The dimples in the tube provide the desired turbulence and/or pressure resistance for many applications.

Claims

1. A method of making a heat exchanger tube comprising the steps of:

a) providing an elongated strip of aluminum based material having opposed edges and a braze alloy on only one side thereof;
b) forming dimples in said strip such that the dimples project to the side of the strip opposite said strip one side and the dimples on one side of a predetermined fold line located between the opposed edges will align with the dimples on the other side of the fold line;
c) placing slits extending through the strip at the apexes of the dimples on at least one side of said fold line;
d) folding the strip along said fold line and bringing said edges into contact with one another and causing the apexes of aligned ones of said dimples to abut one another;
e) welding said edges to each other to form a tube; and
f) causing said braze alloy to flow from said strip one side through said slits to the interior of the tube and braze the apexes of the aligned dimples together.

2. The method of claim 1 wherein step f) is preceded by the step of applying a flux to said strip one side at least in the vicinity of the dimples having said slits.

3. The method of claim 1 wherein said dimples are nominally frusto-conical.

4. A method of making a heat exchanger tube comprising the steps of:

a) providing an elongated strip of aluminum based material having opposed edges and a braze alloy on only one side thereof;
b) forming dimples in said strip such that the dimples project to the side of the strip opposite said strip one side and the dimples on one side of a predetermined fold line located between the opposed edges will align with the dimples on the other side of the fold line;
c) placing perforations extending through the strip at the apexes of the dimples on at least one side of said fold line;
d) folding the strip along said fold line and bringing said edges into contact with one another and causing the apexes of aligned ones of said dimples to abut one another;
e) welding said edges to each other to form a tube; and
f) causing said braze alloy to flow from said strip one side through said perforations to the interior of the tube and braze the apexes of the aligned dimples together.

5. A method of making a heat exchanger tube comprising the steps of:

a) providing an elongated strip of aluminum based material having opposed edges and a braze alloy on one side thereof;
b) forming dimples in said strip such that the dimples project to the side of the strip opposite said strip one side and the dimples on one side of a predetermined fold line located between the opposed edges will align with the dimples on the other side of the fold line;
c) placing perforations extending through the strip at the apexes of the dimples on at least one side of said fold line;
d) folding the strip along said fold line and bringing said edges into contact with one another and causing the apexes of aligned ones of said dimples to abut one another;
e) welding said edges to each other to form a tube; and
f) causing said braze alloy to flow from said strip one side through said perforations to the interior of the tube and braze the apexes of the aligned dimples together.

6. A tube for a heat exchanger and made by the method of claim 1,4 or 5.

7. A method of making a heat exchanger tube comprising the steps of:

a) providing an elongated strip of aluminum based material having opposed edges and a braze alloy on only one side thereof;
b) forming a protuberance on each side of a predetermined fold line located between said edges and projecting to the side of the strip opposite said strip one side with the protuberance on one side of the fold line alignable with the protuberance on the other side of the fold line;
c) perforating at least one of the protuberances;
d) folding the strip along the fold line to bring said edges in contact with each other while causing said protuberances to abut each other with the perforations in one protuberance opening toward the other protuberance;
e) welding said edges to each other to form a tube;

f) placing a brazing flux on said strip one side at least in the vicinity of said perforations; and
g) causing said braze alloy to flow from said strip one side through said perforations and braze said protuberances to one another.

8. The method of claim 7 wherein step c) is performed by placing slits in said at least one protuberance.

9. A method of making a heat exchanger tube comprising the steps of:

a) providing an elongated strip of aluminum based material having opposed edges and a braze alloy on one side thereof;
b) forming a protuberance on each side of a predetermined fold line located between said edges and projecting to the side of the strip opposite said strip one side with the protuberance on one side of the fold line alignable with the protuberance on the other side of the fold line;
c) slitting at least one of the protuberances;
d) folding the strip along the fold line to bring said edges in contact with each other while causing said protuberances to abut each other with the slits in one protuberance opening toward the other protuberance;
e) welding said edges to each other to form a tube;
f) placing a brazing flux on said strip one side at least in the vicinity of said slits; and
g) causing said braze alloy to flow from said strip one side through said slits and braze said protuberances to one another.

10. A method of making a heat exchanger tube comprising the steps of:

a) providing an elongated strip of aluminum based material having opposed edges and a braze alloy on one side thereof;
b) forming a protuberance on each side of a predetermined fold line located between said edges and projecting to the side of the strip opposite said strip one side with the protuberance on one side of the fold line alignable with the protuberance on the other side of the fold line;
c) slitting at least one of the protuberances;
d) folding the strip along the fold line to bring said edges in contact with each other while causing said protuberances to abut each other with the slits in one protuberance opening toward the other protuberance;
e) welding said edges to each other to form a tube; and
f) causing said braze alloy to flow from said strip one side through said slits and braze said protuberances to one another.

11. A method of making a heat exchanger tube comprising the steps of:

a) providing an elongated strip of aluminum based material having opposed edges and a braze alloy on only one side thereof;
b) forming dimples in said strip such that the dimples project to the side of the strip opposite said strip one side;
c) placing perforations extending through the strip at the apexes of at least some of said dimples;
d) forming the strip to bring said edges into contact with one another while causing the apexes of the slit containing dimples to abut said strip opposite side;
e) welding said edges together to form a tube; and
f) causing said braze alloy to flow from said strip one side through said slits to the interior of the tube to braze the apexes of the slit containing dimples to said strip opposite side where they abut one another.

Fig. 1

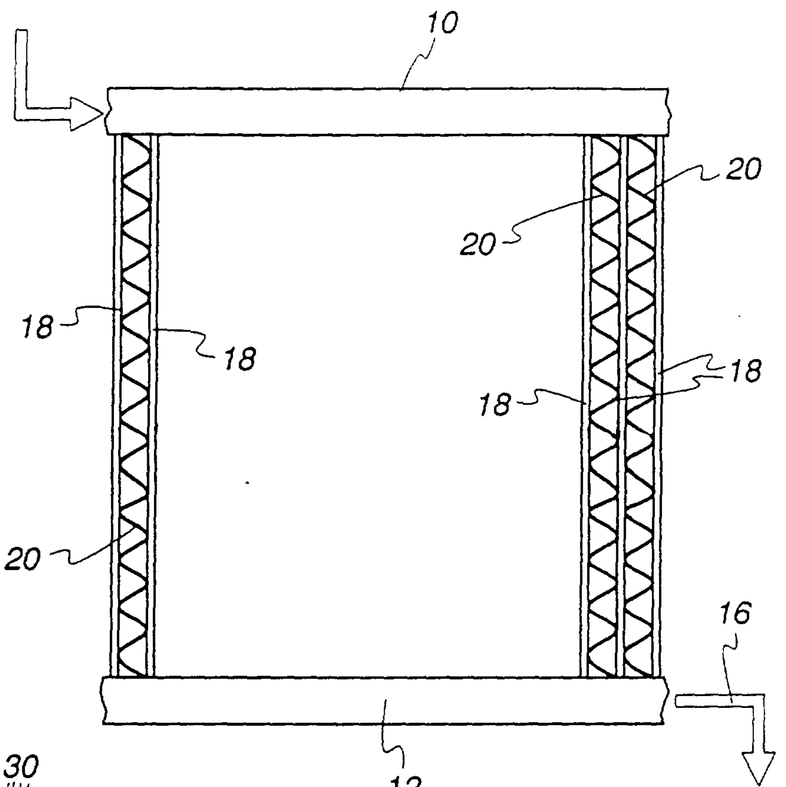

Fig. 2

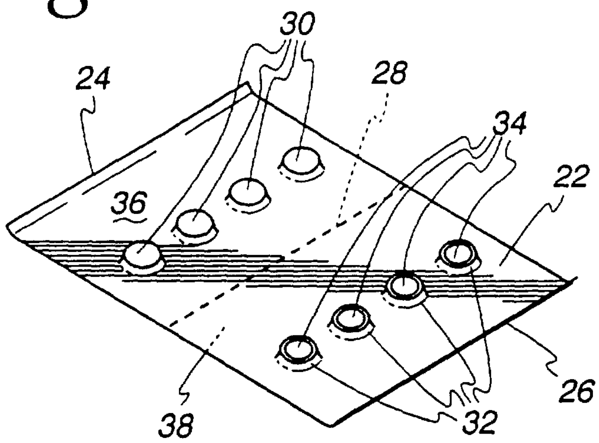

Fig. 3

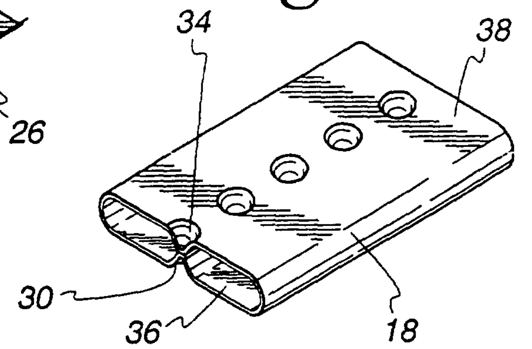

Fig. 4