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(54) Title of the Invention: **Frangible tube heat exchanger**
Abstract Title: **Method of separating tube portions of a continuously formed heat exchange tube**

(57) A method of manufacturing a tube for a heat exchanger comprises extracting a first web of material 202 from a spool and weakening a portion of it along a first separation line 213 which divides the web into a first 202a and second 202b portions. Subsequently, a corrugated portion in the web is formed, it is received within a tube outer body, and the first web portion is frangibly separated from the second web portion along the separation line 213. The weakening may comprise a discontinuity along the entire width of the material and the discontinuity may comprise scoring a portion corresponding to an apex of the corrugation and/or perforating 226 a portion corresponding to an unbent part of the corrugation between apexes. Separation may be effected by pulling apart the first and second portions using corresponding carriages or pairs of rollers. The tube outer body may be formed from a second web of material which is similarly weakened and separated along a second separation line. The first and second separation lines may be formed simultaneously and aligned, to preferably be within 2mm of each other, before simultaneous separation along them. The second web material may be thicker than the first.

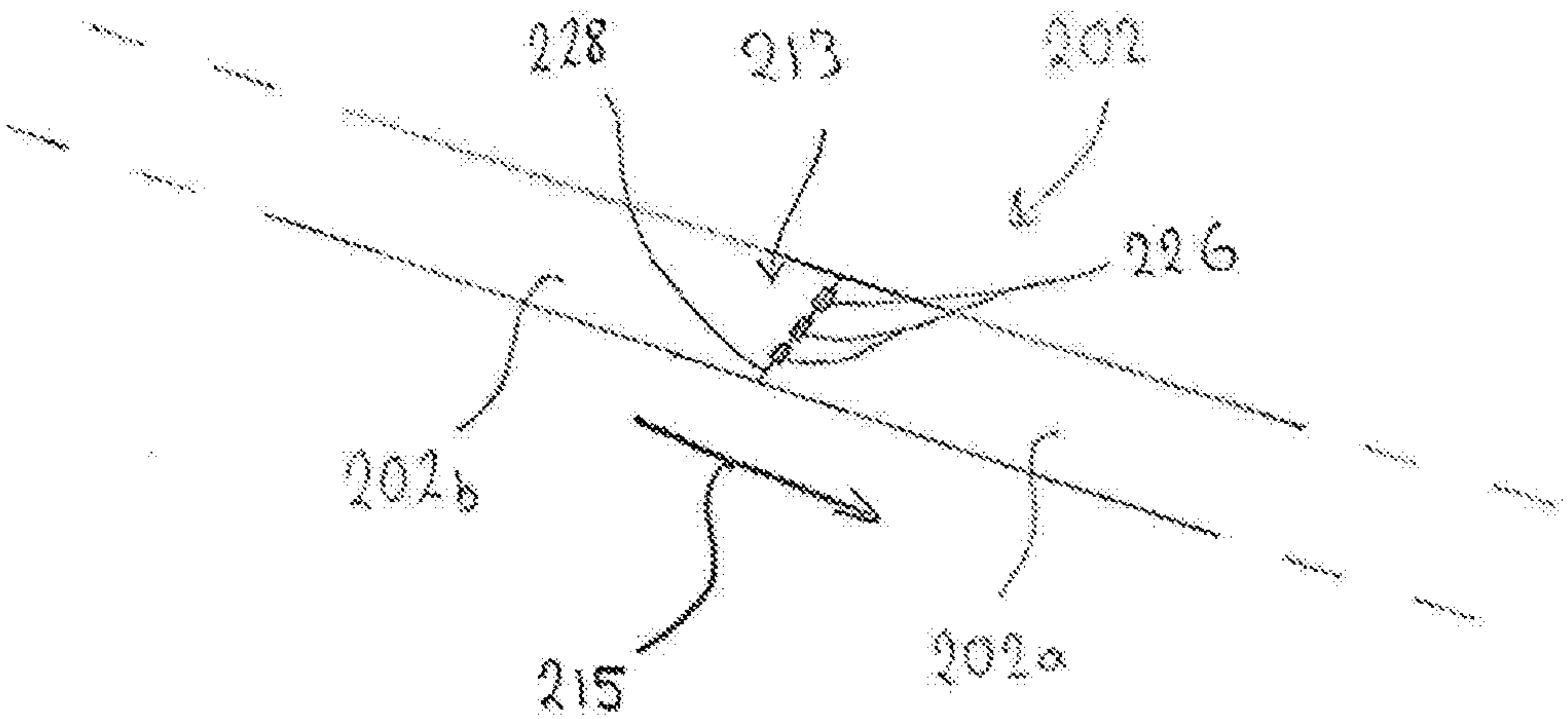

Figure 3

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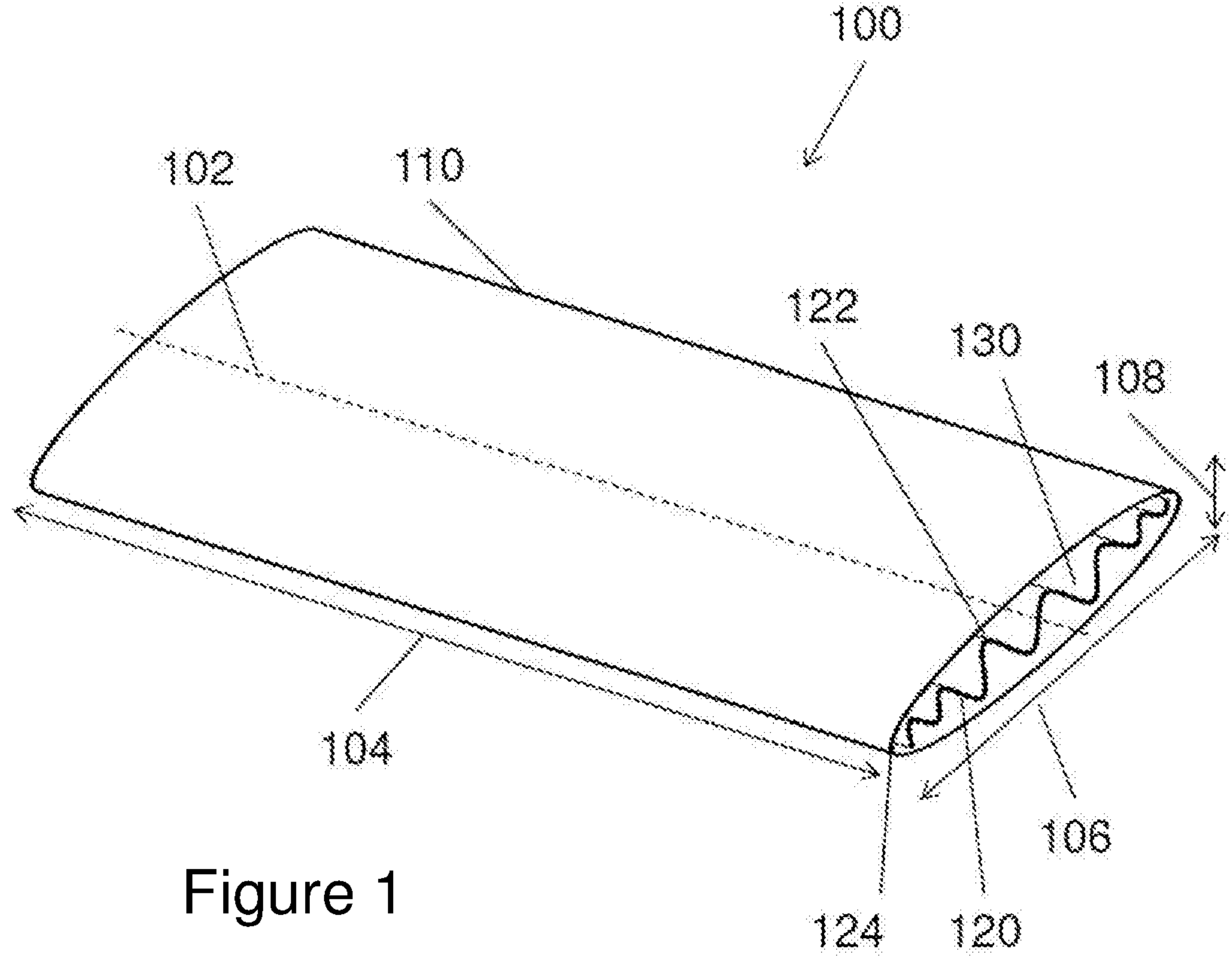

Figure 1

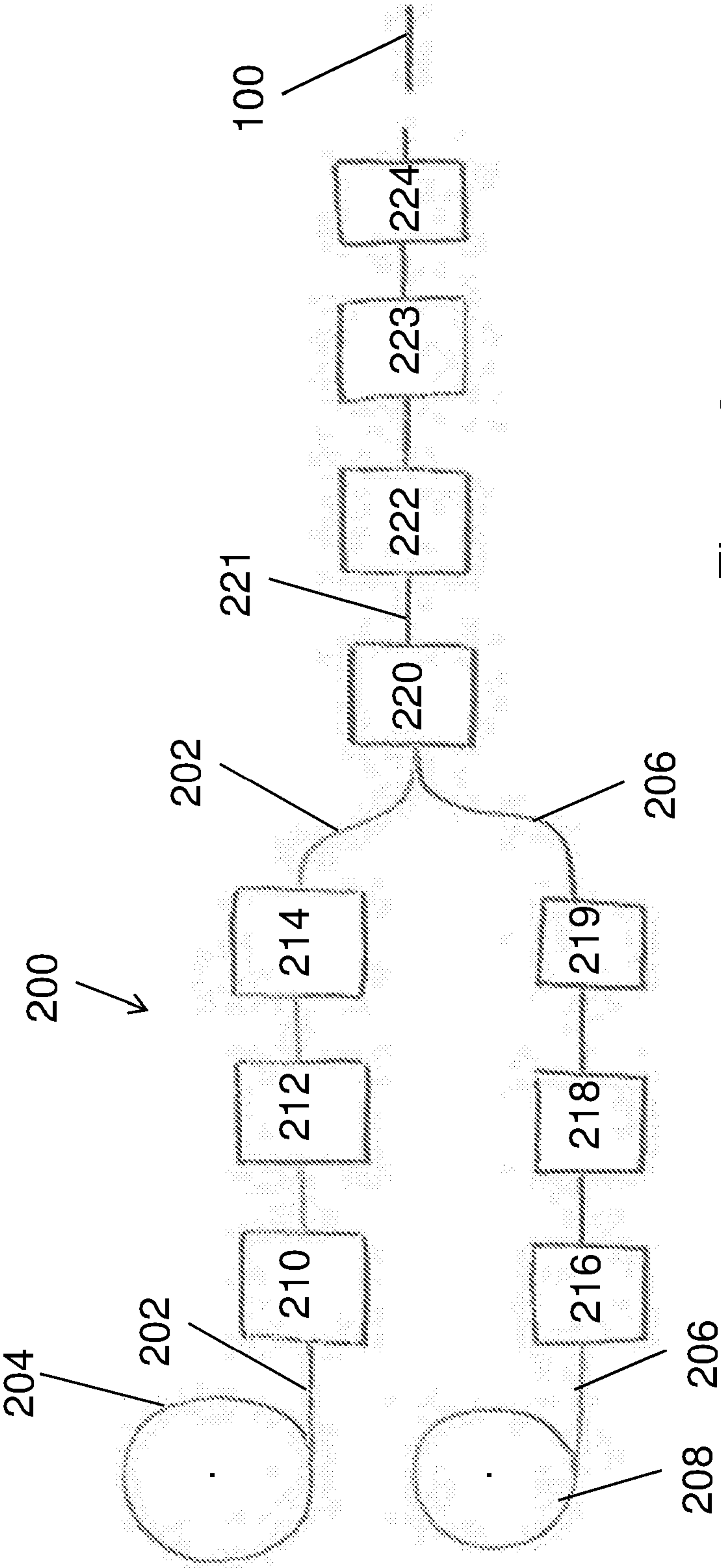
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Figure 2

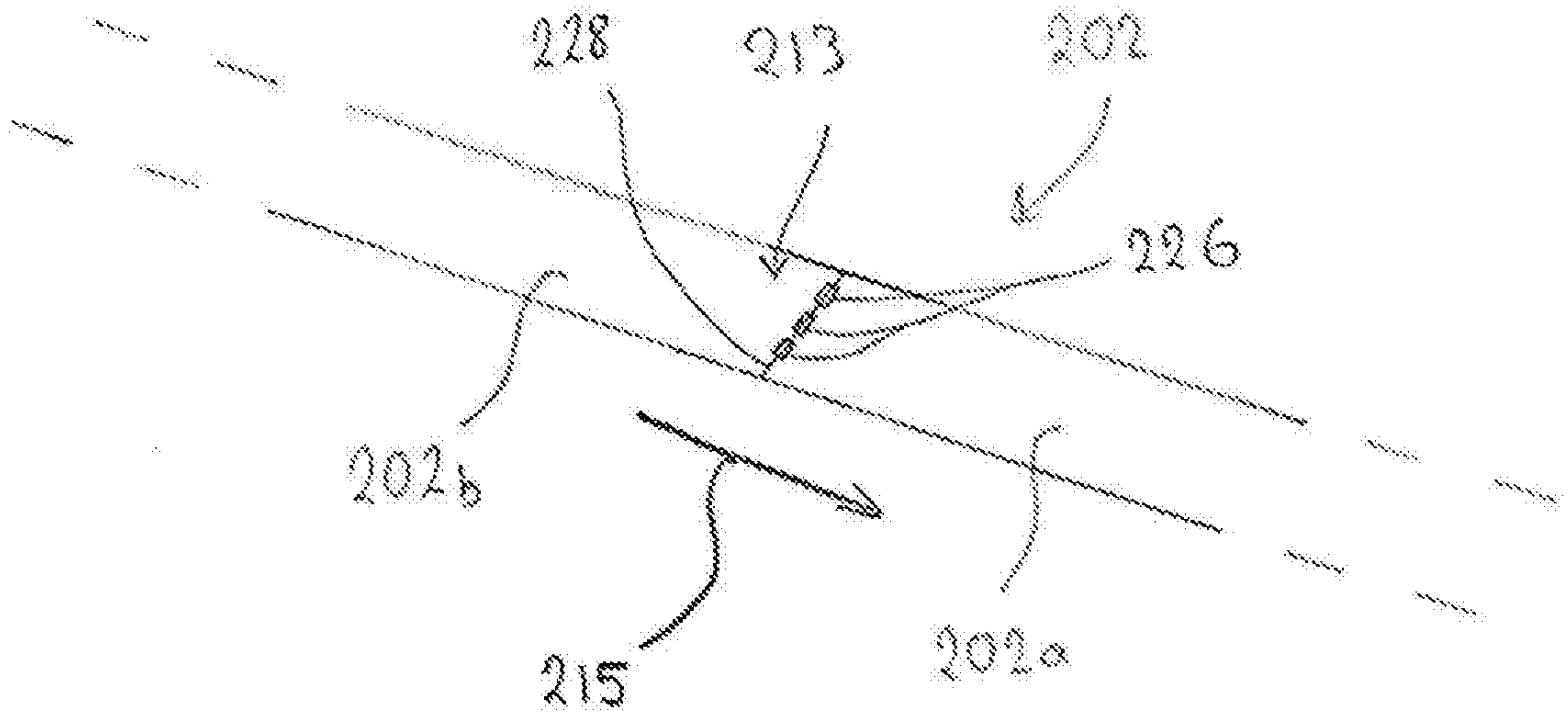

Figure 3

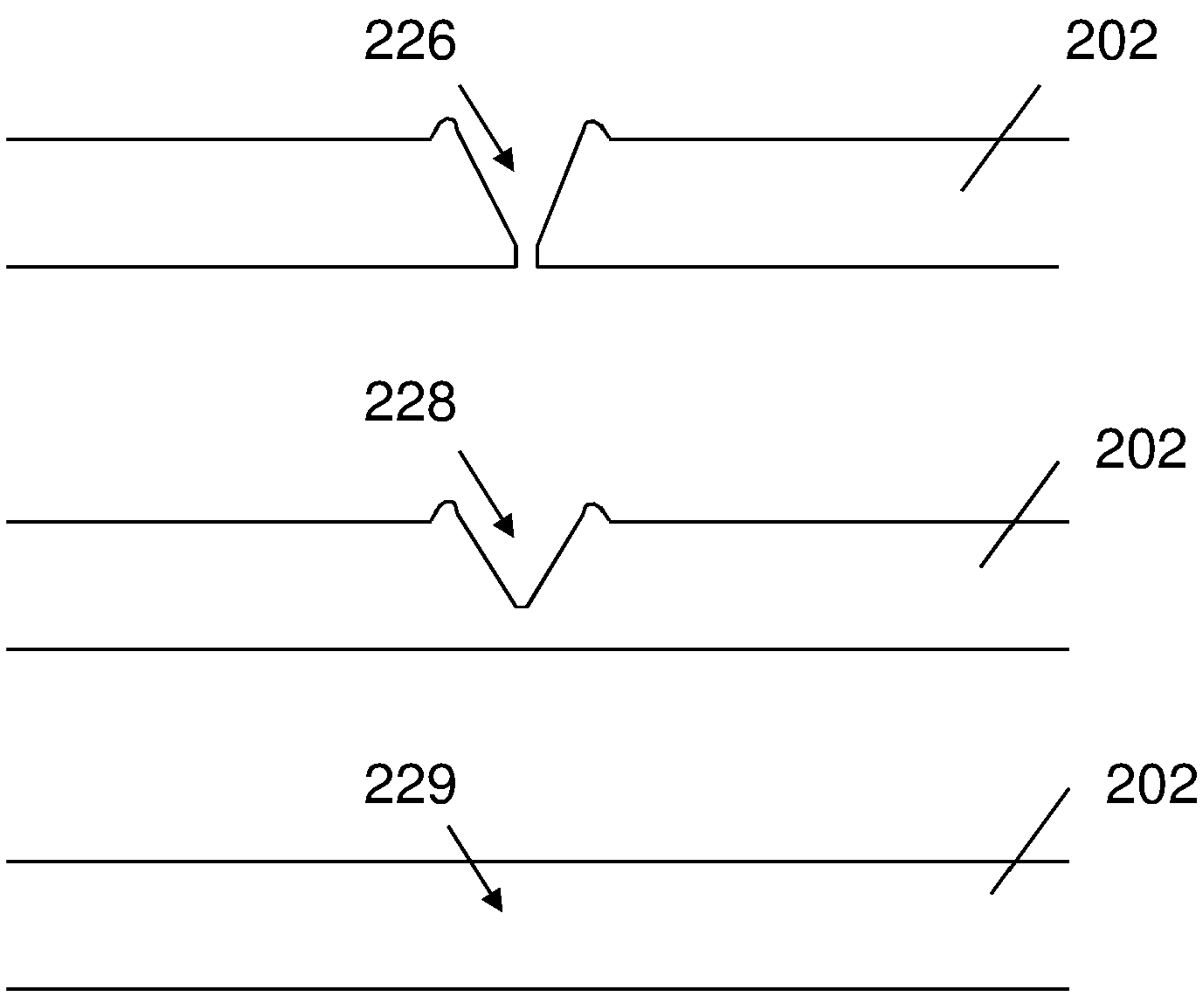

Figure 4

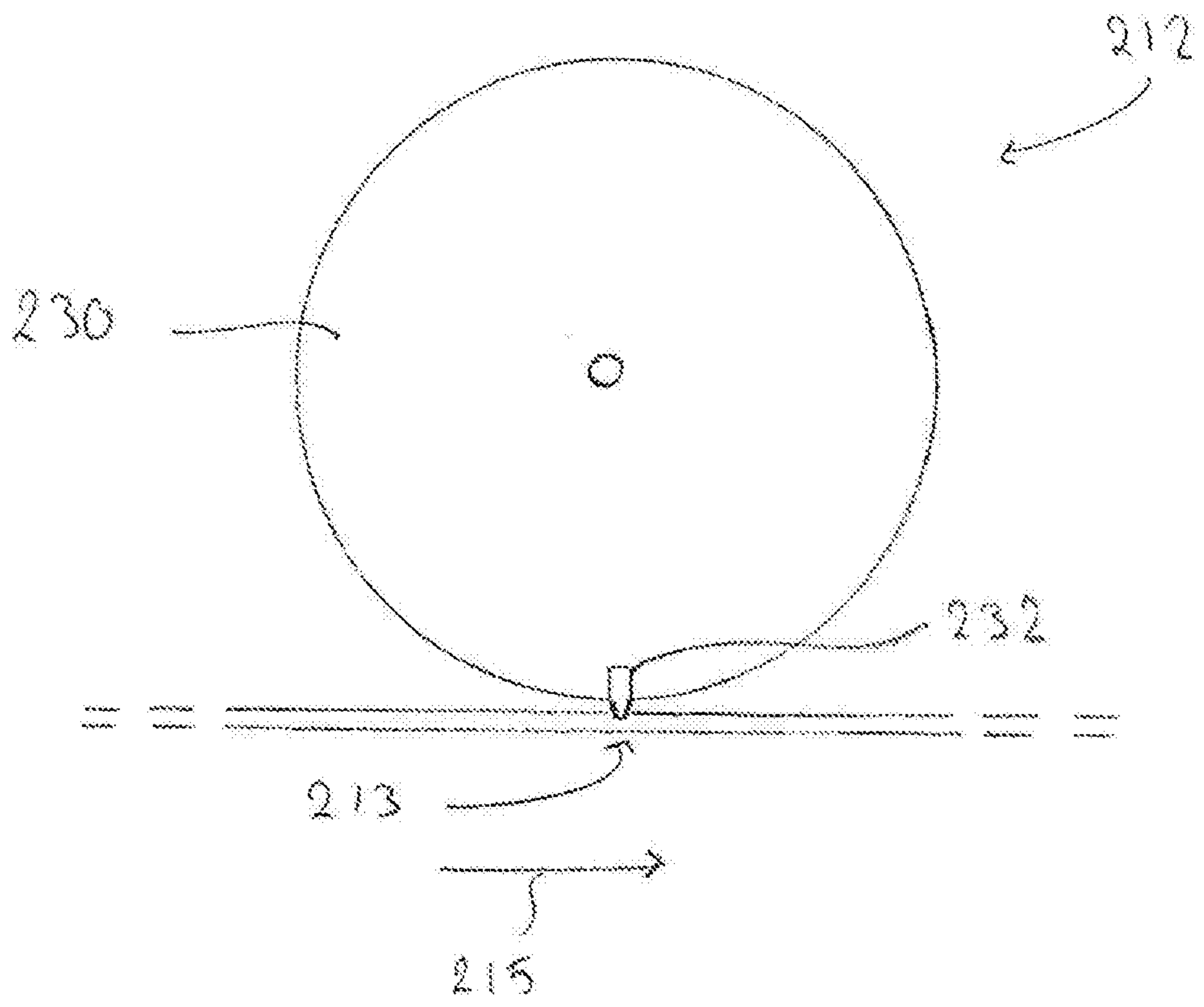

Figure 5

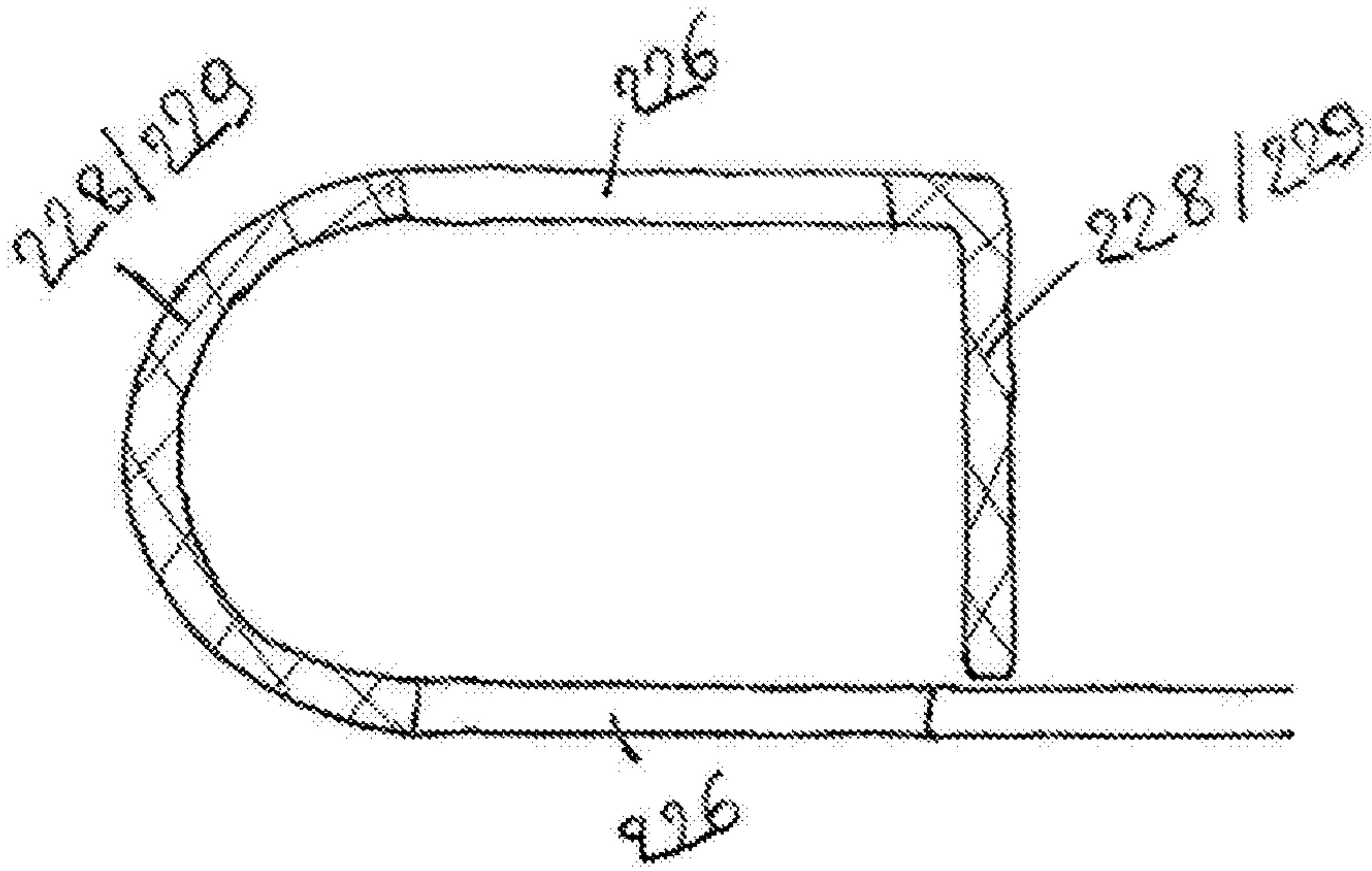

Figure 6a

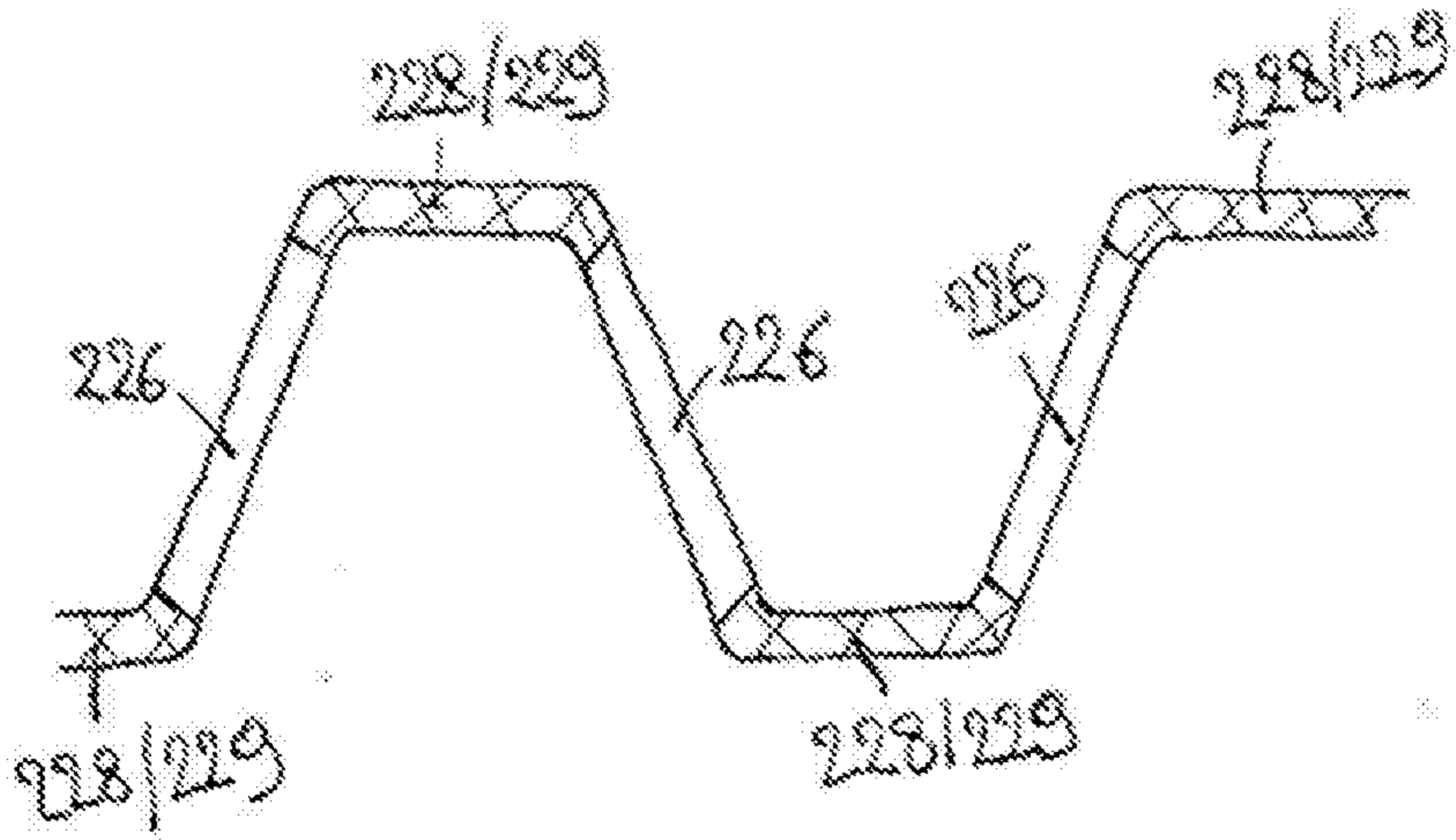

Figure 6b

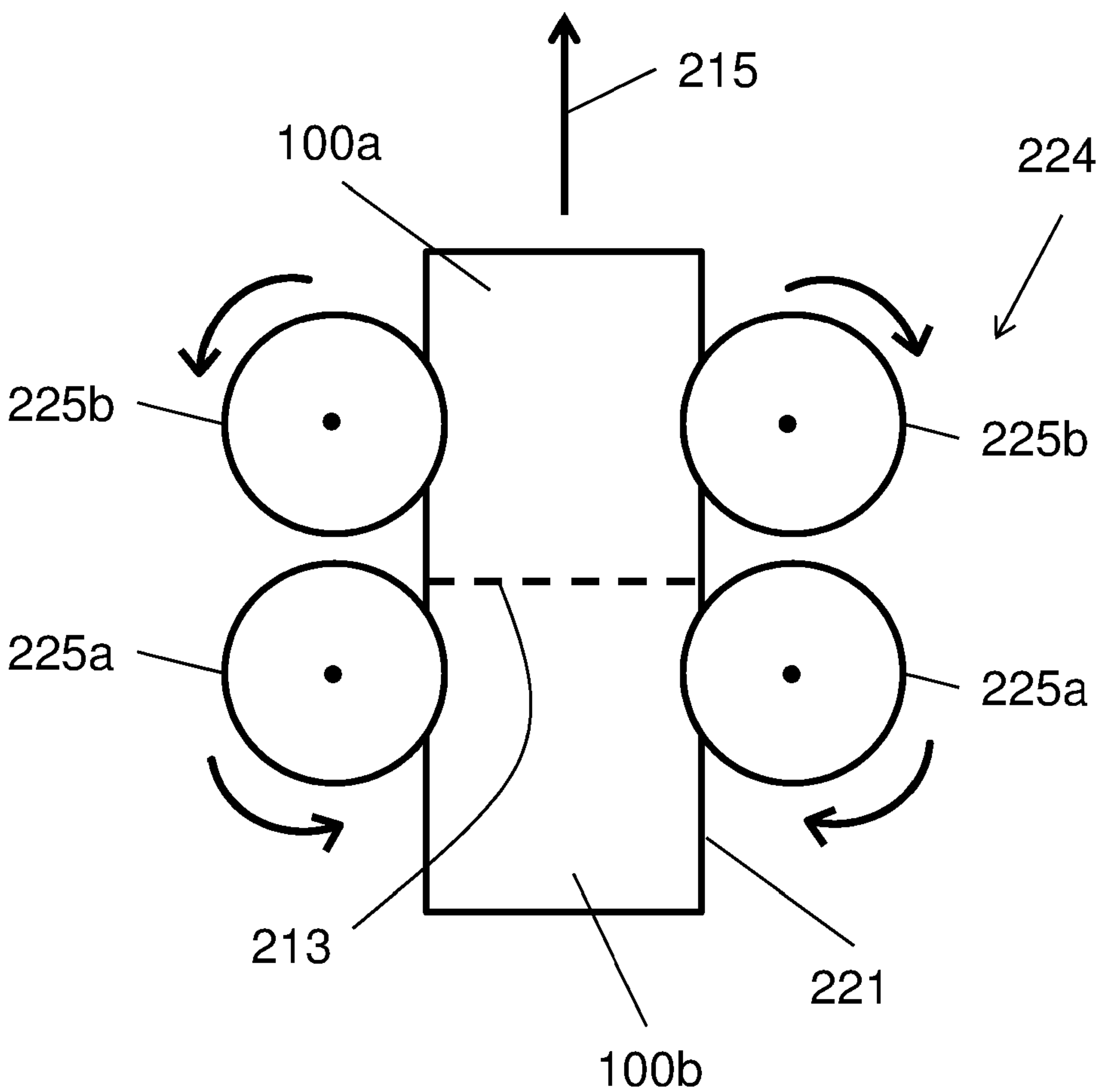

Figure 7

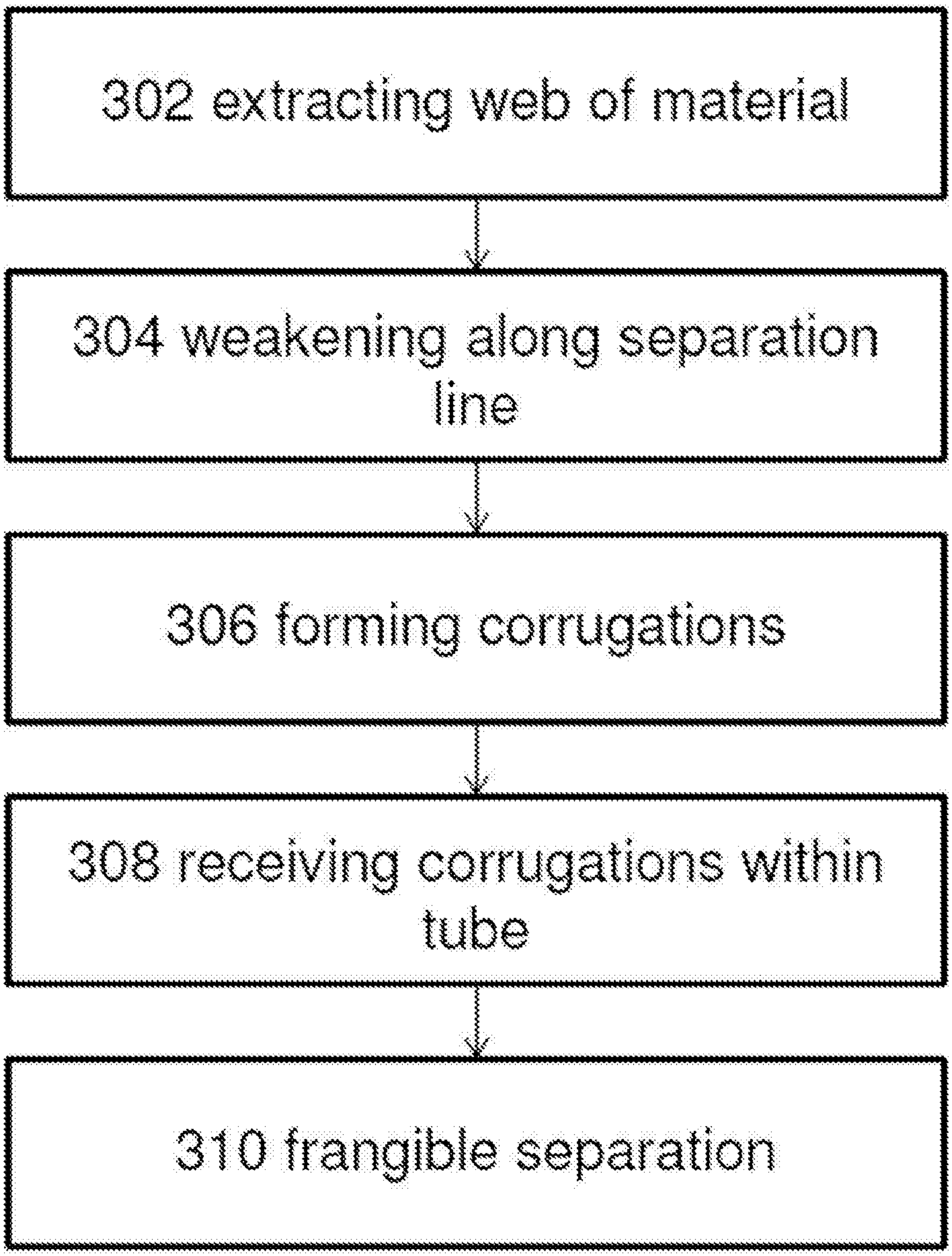
302 extracting web of material
304 weakening along separation line
306 forming corrugations
308 receiving corrugations within tube
310 frangible separation

Figure 8

Frangible Tube Heat Exchanger

FIELD

[0001] The present invention relates to a method of manufacturing a tube for a heat exchanger, and an apparatus for carrying out the method. Specifically, the improved method relates to forming and separating tubes manufactured from a web of material.

BACKGROUND

[0002] In order to regulate temperature in a vehicle, such as a car, one or more heat exchangers may be located in the interior of the vehicle. Heat exchangers can be used to regulate temperature in an environment surrounding the heat exchanger, for example the temperature of an internal combustion engine of the vehicle and/or the interior of the vehicle. Heat exchangers may for example be radiators or condensers. Heat exchangers for vehicles typically comprise a plurality of heat exchange tubes, which may have a flat, narrow shape. The tubes may have an outer body surrounding a hollow interior configured to receive a heat exchange fluid. Heat exchanger tubes often also contain an insert positioned inside the tube that is shaped to form one or more fins. The fins increase the area of material available for heat exchange. The fins are bonded to the sides of the tube and thereby provide additional mechanical strength. The additional strength stops the tube deforming and raises the burst pressure of the tube (the pressure of fluid flowing through the tube that will cause the tube materials to fail). The fins also create an internal structure forming passageways that control the flow of heat exchange fluid through the tube.

[0003] One of the challenges in improving tubes for heat exchangers for vehicles is to increase the lifetime of the tubes. The lifetime of the tubes may be affected by the type of material used to form the tube and the thickness of the tube material. Thicker materials are more resistant to corrosion and therefore it has become common to manufacture tubes with relatively thick outer walls and thinner fins. Fins made from a thin material also allow more internal passageways/chambers to be formed inside the a given tube, compared to fins made from a thicker material. However, thicker materials are more difficult to shape and tend to deform when they are cut. This can lead to problems when the heat exchanger tube is cut to size, as the thicker outer material deforms and partially crushes the thinner fins.

[0004] It is an object of the invention to obviate or mitigate disadvantages of known methods for manufacturing heat exchanger tubes, whether identified herein or elsewhere. It is a further object of the invention to provide an alternative method of manufacturing a heat exchanger tube.

SUMMARY

[0005] According to a first aspect of the invention, there is provided a method of manufacturing a tube for a heat exchanger, the method comprising: extracting a web of material from a spool, weakening a portion of the web along a separation line, the separation line dividing the web into a first web portion and a second web portion; subsequent to the step of weakening, forming a corrugated portion in the web, receiving the corrugated portion within a tube outer body; and frangibly separating the first web portion from the second web portion along the separation line.

[0006] Because the first web portion is frangibly separated from the second web portion, no cutting blades, machining operations or the like are required to form a length of tube. The geometry of the web is therefore not deformed during the separating process, and hence the web does not require any re-working once formed.

[0007] Typically, it is undesirable for a web undergoing a forming process to include any structural weaknesses as this may prevent the web from being successfully formed into a required shape. In particular, the web may fail at the position where the structural weakness occurs. For web processing operations, it is often the case that the web is at least partially formed into the required shape to give the web rigidity and stiffness before the web is cut to length. However, when the partially or fully formed web is cut to length, the profile of the web is typically deformed to some extent such that the geometry of the web no longer matches the required shape. In such circumstances, it may be necessary to re-form the web using one or more subsequent forming processes to create the required shape in the web.

[0008] In the present invention, because the web has been weakened it is possible to frangibly separate the first and second web portions along the line of weakness, and thus avoid the need for physical cutting of the web which could lead to deformation of the web geometry. Furthermore, because the web is weakened before it is corrugated, although the web material is more difficult to handle, the corrugations need only be formed once. This avoids the need for any subsequent re-corrugating processes and therefore saves time and cost. It has been found that the presence of the structural weakness in the web (i.e. along the separation line) provides the advantage that less stress is transmitted from the first web portion to the second web portion as the first web portion is being corrugated. Effectively, the web is broken into sections in which mechanical stresses are isolated to that section, and therefore the web is in fact easier to process.

[0009] Because the stresses in different sections of the web are isolated from one another, in some instances it is possible to reduce the number of straightening operations that are required to straighten the web after it leaves the spool (or even remove the need for straightening operations entirely). Reducing the number of straightening operations can decrease the size of the machinery required to form the tubes, freeing up factory space for other operations, and may also decrease the amount of energy consumed by the machinery thus leading to cost savings.

[0010] A further advantage of weakening before forming of the corrugated portion is that it simplifies the weakening process due to it being performed on an unshaped web of material. Therefore, the weakening process does not have to take into account the presence of corrugations along the separation line.

[0011] By “weakening” it is encompassed that the web undergoes an action that causes a portion of the web to be more susceptible to breakage. The web may be uncorrugated (e.g. flat) before the step of weakening.

[0012] By “separation line” it is encompassed a line along which the material discontinuity extends. The separation line may have any suitable shape, such as for example linear, curved, sinusoidal etc.

[0013] By “corrugated portion” it is encompassed a portion of the web comprising at least one longitudinally extending groove. The groove may be oriented in substantially any suitable direction, such as for example parallel to a direction of extraction of the web. The corrugated portion may in particular comprise a plurality of longitudinally extending grooves, and the plurality of grooves may be parallel to one another. The longitudinally extending grooves may have substantially the same shape, and may be arranged in a repeating wave-like alternating fashion (for example in the manner of a sine wave or the like).

[0014] By “frangibly separating” it is encompassed that the first tube section and the second tube section are separated by breaking the web along the separation line. Such frangible separation may not require additional penetration of the web material by another object, such as for example a cutting blade.

[0015] By “subsequent to” it is encompassed that the forming of the corrugated portion in the web occurs at some point after the step of weakening has occurred. Intermediate processed between weakening and forming the corrugated portion may occur, however in some embodiments the step of corrugating may occur immediately after the step of weakening.

[0016] The corrugated portion may be received within the tube outer body in any suitable manner. For example, the tube outer body may also be formed by the web. In such cases, receiving the corrugated portion in the tube outer body may comprise, for example, folding a portion of the web into a tube around the corrugated portion.

[0017] Weakening a portion of the web along a separation line may comprise forming a material discontinuity in the web. Such a discontinuity may include, for example, forming a crack, groove, cut, or any suitable sharp-edged edged or small-radius corner on the surface of the web which does not entirely penetrate through the web. The discontinuity may additionally or alternatively comprise perforations, holes, slots or apertures which extend through the entire thickness of the web.

[0018] The web may define a width perpendicular to a longitudinal axis of the web, and wherein the material discontinuity may extend along the entire width of the web. Put another way, the separation line may extend across the entire width of the web and the web may be weakened along the entire separation line. Because the material discontinuity extends across the entire width of the web, the entire width of the web has been weakened. As such, frangible separation of the first web portion from the second web portion can be achieved more easily and reliably. That is to say, because there are no “unweakened” portions along the width of the web, there is no part of the web that it likely to remain attached whilst the remaining parts of the web have frangibly separated. Where portions remain attached, this can require additional pulling to cause the attached portion to plastically deform and fail. This can lead to the undesirable formation of protrusions on the end of the web, which may mean that the web does not properly mate with other components and/or present a safety risk. By “width” it is encompassed a dimension of the web that is generally perpendicular to a direction of extraction of the web. In particular, the “width” is the largest dimension of the web in the plane perpendicular to the direction of extraction (the other dimension being the “thickness” of the web).

[0019] The material discontinuity may be at least partially formed by scoring a portion of the web. By “scoring” it is encompassed compressing, indenting, or cutting into a surface of the web in a manner that does not fully penetrate the web.

[0020] The material discontinuity may be at least partially formed by perforating a portion of the web. By “perforating” it is encompassed forming one or more penetrations that extend through the entire thickness of the web.

[0021] A perforation may be formed along the line of separation at a point that corresponds to an unbent section of the corrugated portion. That is to say, the perforation may be positioned at a point along the separation line so that, once the web is corrugated, the perforation is positioned at a substantially straight portion of the corrugations, that is to say, between apexes of the corrugations. In some embodiments, multiple perforations may be formed at positions corresponding to substantially straight sections of the web once it is formed. An advantage of locating a perforation at a substantially straight section of a web of material is that this portion of the web of material requires less work and deformation. Additionally or alternatively, where the method comprises extracting a second web portion that is folded to form the outer body (discussed below), the method may comprise perforating the second web portion at one or more positions that, when the second web portion is folded, correspond to one or more substantially straight portions of the profile of the second web portion. Alternatively, a perforation may be formed along the line of separation at a point that corresponds to an apex of once of the corrugations of the corrugated portion. That is to say, the perforation may be positioned at a point along the separation line such that, once the web is corrugated, the perforation is positioned at an apex of one of the corrugations. In some embodiments, multiple perforations may be formed at positions which correspond to the apexes of the corrugated portions. Additionally or alternatively, where the method comprises extracting a second web portion that is folded to form the outer body (discussed below), the method may comprise perforating the second web portion at one or more positions that, when the second web portion is folded, correspond to one or more apexes of the profile of the second web portion.

[0022] A score line may be formed along the line of separation at a point that corresponds to an apex of one of the corrugations of the corrugated portion. One or more score lines may be applied to areas of the separation line that, when the web of material is formed, corresponding to positions of an apex of the formed material, for example, an apex of a corrugated portion of the material. Score lines may also be applied in areas that, when formed, have a small radius of curvature. Areas at an apex and/or with a small radius of curvature need to be worked more relative to substantially straight areas. An advantage of locating score lines in the areas to be worked more is that some material remains to perform the work on, while at the same tome to material is weakened in order to be frangibly separated at a later step in the tube productions process.

[0023] Frangibly separating the first web portion from the second web portion may comprise pulling the first web portion and the second web portion apart from one another along a longitudinal axis of the web. By “longitudinal axis” it is encompassed an elongate axis running parallel to the direction of extraction of the first and/or second webs. The first and/or second lines of weakness may be perpendicular to the longitudinal axis, such that the pulling action occurs in a direction normal to the first and/or second lines of weakness. Additionally or alternatively, frangibly separating may comprise twisting or shearing.

[0024] The method may further comprise providing a first carriage for gripping the first web portion and a second carriage for gripping the second web portion, and frangibly separating the first web portion from the second web portion may comprise moving the first carriage and the second carriage apart from one another along the longitudinal axis. The first and/or second carriages may directly or indirectly grip the first and/or second web portions. For example, the carriages may grip the outer body of the tube, and thereby transfer a gripping force from the carriage to the first and/or second web portions.

[0025] The method may further comprise: rotating a pair of first rollers at a first speed, and rotating a pair of second rollers at a second speed, wherein the second speed is greater than the first speed such that when the first and second rollers grip the tube outer body the first web portion frangibly separates from the second web portion. Put another way, the method may comprise providing a pair of first rollers and a pair of second rollers. The second rollers may grip the sides of the first web portion, and the first rollers may grip the sides of the second web portion. The pair of first rollers may rotate at a faster speed than the second rollers, so as to frangibly separate the first and second web portions by moving the first web portion away from the second web portion. The pairs of rollers may have a rotational axis perpendicular to the plane in which the web of material moves. The pairs of rollers may be located along the sides of the web of material, with one roller of a pair on an opposite side of the web of material, so that the side of each roller contacts the web as the rollers rotate and the web of material moves. The contact may be a gripping contact, so that the rotational movement pulls on the contacted web of material.

[0026] Each of the pair of first rollers and the pair of second rollers may comprise a groove along the circumference of the roller for receiving the tube outer body. The rollers may comprise a groove along the circumference of the roller, in which the web portion material may be received. This may increase the contact area between the web portion and the roller, which may improve the pulling force, thereby facilitating the frangible separation. The groove may be substantially U-shaped, or V-shaped. The size of the groove may be sufficient to receive the side of the web portion.

[0027] The method may comprise providing two pairs of first rollers and two pairs of second rollers. Using additional rollers may improve the contact between the rollers and their corresponding web portions, improving the efficiency of frangible separation.

[0028] The web may be a first web and the spool may be a first spool, and the method may further comprise: extracting a second web of material from a second spool; and forming the tube outer body from the second web. The corrugated portion may be received within the tube outer body, for example, by folding the second web around the first web, and in particular folding the second web into a tube around the first web. Because the outer body is also formed from a web, the first and second webs can be used to manufacture tubes in a continuous process.

[0029] The separation line may be a first separation line, and wherein the method may further comprise: weakening a portion of the second web along a second separation line, the second separation line dividing the second web into a first web portion a second web portion; and frangibly separating the first web portion of the second web from the second web portion of the second web along the second separation line. Because both the first and second web portions have been weakened along separation lines, the first and second web portions can be separated to form a single section of tube without requiring any cutting or machining operation. As such, the geometry of the first and second webs is not deformed when the first web portions are separated from the second web portions. Separation of the first and second web portions for both webs of material is therefore mechanically simple and reliable with minimal adverse effects on the tube geometry.

[0030] Subsequent to the step of receiving the corrugated portion within the tube outer body, the method may comprise straightening the first and second webs. Because one or both of the webs has been weakened along the separation line, the stresses transmitted along the webs are reduced (or limited). As such, the amount of work required to straighten the webs is reduced, and therefore simpler and/or smaller machinery may be used to straighten the webs. Furthermore, because the amount of work required to straighten the webs is reduced, thinner materials may be used for the webs.

[0031] Frangible separation of the first web may occur simultaneously with frangible separation of the second web. That is to say, the frangible separation of the first web portion of the first web from the second web portion of the first web and the frangible separation of the first web portion of the second web from the second web portion of the second web may occur simultaneously. Because the two webs are frangibly separated simultaneously, the separating step is simple and fast to carry out.

[0032] The method may further comprise aligning the first and second separation lines with one another. By "aligning" it is encompassed that the first and second separation lines are positioned as close as possible to one another relative to a longitudinal axis of the tube. By aligning the separation lines, the adjacent tube sections are easier to separate from one another. This further minimises the amount of adjustment that may be required once the tube sections have been separated.

[0033] The first and second separation lines may be positioned apart from one another by a distance less than or equal to around 2 mm. Because the separation lines of the first and second webs are positioned apart from one another by a distance less than or equal to around 2 mm, misalignment between the separation lines of the webs is minimised. This may facilitate frangible separation.

[0034] Weakening of the first web and the second web may be performed simultaneously. Because the first and second web portions are weakened simultaneously, this simultaneous weakening may facilitate registration and alignment of the first and second separation lines. Specifically, the first and second webs of material may be processed simultaneously, including two or more of the processing steps of the method of forming a tube. In one example, the first and second webs of material are extracted simultaneously, and have portions weakened along a separation line simultaneously. The simultaneous weakening may be carried out, for example, by a single roller comprising a blade or other weakening device, the roller extending over both webs of material positioned side-by-side.

[0035] The second web may have a greater thickness than the first web. The second web may be used to form the outer body and the first web may be used to form a fin positioned within the outer body. Because the second web is thicker than the first web, the outer body will be sturdier than the fin. Furthermore, the material of the fin may be thinner so that it is easier to corrugate.

[0036] The first and/or second webs may be made from a thermally conductive material, such as for example a metal and in particular aluminium.

[0037] It will be appreciated that any of the optional features set out above in relation to the first web may be applied to the second web or any subsequent web.

[0038] According to a second aspect of the invention, there is provided a system for manufacturing a tube for a heat exchanger, the system comprising: a web of material wound onto a spool, a weakening device for weakening a portion of the web along a separation line, the separation line dividing the web into a first web portion and a second web portion; a corrugation device subsequent to the weakening device, the corrugation device configured to form a corrugated portion in the web, a receiving device for receiving the corrugated portion within an interior of a tube outer body; and

[0039] a separation device for frangibly separating the first web portion from the second web portion along the separation line.

[0040] The system of the second aspect of the invention may be a system for carrying out the method of the first aspect of the invention. The system of the second aspect of the invention therefor exhibits the same advantages as set out above in relation to the first aspect of the invention. Furthermore, it will be appreciated that the system of the second aspect of the invention may comprise devices or apparatus that are capable of carrying out any of the optional features of the first aspect of the invention. Particularly, the corrugation device may receive the web after it has been weakened by the weakening device.

[0041] The web may be a first web and the spool may be a first spool and the separation line may be a first separation line, and the system may further comprise: a second web wound onto a second spool, and a weakening device for weakening a portion of the second web along a second separation line, the second separation line dividing the second web into a first web portion and a second web portion. The weakening device that weakens the second web may be the same weakening device that weakens the first web or a different weakening device.

[0042] The system may further comprise a straightening device for straightening the first and second webs subsequent to the receiving device.

[0043] The system may further comprise an alignment device configured to align the first separation line and the second separation line relative to one another.

[0044] It will be appreciated that the optional features of the method of first aspect of the invention may be combined with the system of the second aspect of the invention. The advantages set out above in relation to the first aspect of the invention apply equally to the corresponding features of the second aspect of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0045] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying figures, in which:

[0046] Figure 1 is a schematic perspective view of a tube for a heat exchanger, the tube comprising an outer body and corrugated portion;

[0047] Figure 2 is a schematic diagram of a system for manufacturing the tube of Figure 1;

[0048] Figure 3 is a schematic perspective view of a portion of a web showing a separation line;

[0049] Figure 4 is a schematic view of different types of mechanical weaknesses applied along a separation line;

[0050] Figure 5 is a schematic side view of a weakening device;

[0051] Figure 6a is a schematic cross-sectional view of a portion of an outer body of a tube taken along a separation line;

[0052] Figure 6b is a schematic cross-sectional view of a portion of a fin of a tube taken along a separation line;

[0053] Figure 7 is a schematic top view of a straightening unit; and

[0054] Figure 8 is a flow diagram of a method for forming a tube for a heat exchanger.

DETAILED DESCRIPTION

[0055] Described herein is a method of manufacturing a tube for a heat exchanger. A tube for a heat exchanger may be formed from a web of material, for example a long sheet of metal, wherein the sheet of metal is rolled onto a spool. The material may be formed by shaping the web of material, for example using a plurality of rollers. Multiple tubes may be formed from the same web of material. Therefore the method of forming the tube also includes a separating step, wherein one or more sections of the web are frangibly separated from the rest of the web of material to form separate sections of tube.

[0056] Figure 1 depicts a portion of a tube 100 for a heat exchanger. The tube 100 is generally elongate and defines a longitudinal axis 102. The tube 100 has a length 104 parallel to the longitudinal axis 102, a width 106 perpendicular to the length 104 and a height 108 perpendicular to the width 106 and the length 104. The tube 100 comprises an outer body 110 which defines a hollow interior 130. The outer body 110 defines edges 124 that extend along the length 104 of the outer body 110. The tube 100 further comprises a fin 120 received within the interior 130. The fin 120 comprises a plurality of corrugations 122. The corrugations 122 are local areas of bending which are arranged so that the profile of the fin 120 changes direction in an undulating manner. The corrugations 122 are exemplary and in alternative embodiments may take any suitable form. The fin 120 extends along the longitudinal axis 104 along substantially the entire length 104 of the tube 100. That is to say, the lengths of the outer body 110 and the length of the fin 120 are approximately equal. The cross-section of the tube 100 perpendicular to the longitudinal axis 102 is substantially constant along the longitudinal axis 102 of the tube 100. The tube 100 has a substantially flat shape, that is to say, the width 106 of the tube 100 is significantly greater than the height 108 of the tube. The corrugations 122 are substantially constant along the longitudinal axis 102 of the tube 100 and run generally parallel to the longitudinal axis 102.

[0057] In some instances, the outer body 110 and the corrugated portion 120 may be formed from the same web of material. However, it may be desirable for the outer body and the corrugated portion to have different material properties. For example, increasing the thickness of the tube outer body 110 may provide increased strength and longevity for the tube 100. However, for the corrugated portion 120 of the tube, it may for example be beneficial to reduce the thickness of the web of material in order to fit more corrugations inside the interior 130 of tube 100. In order to achieve a tube 100 with potentially different properties for both the outer body 110 and corrugated portion 120, the outer body 110 and corrugated portion 120 may be formed from two, or more, separate webs of material. The webs of material may have different or identical material properties.

[0058] Figure 2 shows a schematic view of an exemplary system 200 for manufacturing the tube 100. The system 200 comprises a first web of material 202 wound onto a first spool 204 and a second web of material 206 wound onto a second spool 208. The system 200 further comprises a first web straightening device 210, a first web weakening device 212 and a corrugating device 214 for the first web 202. The system 200 further comprises a second web straightening device 216, a second web weakening device 218, and a forming device 219 for the second web 206. Finally, the system 200 comprises a receiving device 220, an alignment device 222, a tube straightening unit 223, and a tube separating device 224.

[0059] The first web 202 forms the fin 120 of the tube 100 and the second web 206 forms the outer body 110 of the tube 100. The thickness of the first web 202 is approximately 0.05 mm to 0.20 mm (and in particular may be 0.08 mm to 0.20 mm). The thickness of the second web 206 is approximately 0.20 mm to 0.25 mm. The width of the first web 202 is approximately 20 mm to 60 mm and the width of the second web is approximately 20 mm to 80 mm. The material of the first and second webs 202, 206 is preferably a thermally conductive material, such as for example metal. The material may additionally or alternatively be corrosion resistant, for example either naturally or via a protective layer. The material of the first web 202 and the second web 206 is preferably metal and, in particular, aluminium . The aluminium may be plain or clad with a coating. However it will be appreciated the first and second webs 202, 206 may be made from any suitable material. Depending upon the material of the first web 202, the first web 202 may have a generally curved shape when it is extracted from the first spool 204. In order to ensure that the first web 202 is flat before any subsequent forming operations are carried out, once the first web 202 is extracted from the first spool 204 it is fed through a straightening device 210. The straightening device 210 comprises one or more pairs of rollers (not shown) which plastically deform the first web 202 to remove the curved shape. The straightening device 210 is optional and in some embodiments the straightening device 210 may be absent.

[0060] After the straightening device 210, the first web 202 is then fed to a weakening device 212. The weakening device 212 weakens the first web 202 along a separation line 213, as shown in Figure 3. The separation line 213 divides the first web 202 into a first web portion 202a and a second web portion 202b. The first web portion 202a is forward of the separation line 213 and the second web portion 202b is behind the separation line 213 relative to a direction of extraction 215 of the first web 202. Typically, the direction of extraction 215 is parallel to the longitudinal axis 102 of the tube 100.

[0061] The weakening device 212 weakens the first web 202 by forming a line of separation 213 on the first web 202. In particular, the line of separation comprises a mechanical discontinuity formed on the first web 202. The mechanical discontinuity may partially or fully penetrate the first web 202. In embodiment of Figure 3, the mechanical discontinuity may comprise removing a small section of material from the first web 202, and for example may comprise a number of perforations 226 and/or a score line 228. Figure 4 illustrates different types of mechanical discontinuity that may be present along a line of separation. Perforations 226 substantially penetrate the entire thickness of the first web 202 to form one or more holes in the first web 202. By contrast, a score line 228 only partially penetrates the first web 202, for example by forming a groove or depression in one surface of the first web 202. One or more stiches 229 may be present along a separation line 213, in which no mechanical weakening is applied. The stitching may for example be applied in areas between perforations and/or score lines, in order to connect these discontinuities along the separation line. In particular, the score line 228 may penetrate between around 25 % to around 85 % of the thickness of the first web 202. The separation line 213 may comprise substantially any suitable number of perforations 226 and/or score lines 228.

Other forms of mechanical discontinuity may be provided, for example by providing a sharp fold line.

[0062] The line of separation 213 comprising the mechanical discontinuity may be substantially perpendicular to the longitudinal axis 102 or may be inclined at any suitable angle relative to the longitudinal axis 102. The separation line comprises at least one part that is not parallel to the longitudinal axis 102. The separation line 213 may be perpendicular to the longitudinal axis 102. The separation line 213 may be a straight line, or may have another shape, for example a curved shape, or an irregular shape.

[0063] In some embodiments, weakening occurs by perforating the first web 202 and/or scoring the surface of the first web 202 to form a mechanical discontinuity. The mechanical discontinuity extends across the entire width of the first web 202 (such that there is no part along the separation line 213 that is not scored or perforated in some manner). The advantage of providing a mechanical discontinuity that extends across the entire width of a web (e.g. the first web 202) is that all points along the width of the web are weakened and therefore separation of two adjacent web portions is straightforward, reliable, and repeatable. However, it will be appreciated that in some embodiments the mechanical discontinuity may extend across only a portion of the width of the first web 202.

[0064] With reference to Figure 5, in order to form the separation line 213, the weakening device 212 comprises a roller 230 having a blade 232. The blade 232 has a profile that is configured to impart the desired pattern or score lines and perforations forming the mechanical discontinuity. During use, the roller 230 brings the blade into contact with one of the surfaces of the first web 202 and presses against the first web 202 to form the mechanical discontinuity. It will be appreciated that the weakening device 212 is illustrative only, and in alternative embodiments the weakening device 212 may have any suitable configuration that is able to form a mechanical discontinuity on the first web 202. For example, the weakening device 212 may use laser cutting, plasma cutting, water jet cutting, chemical etching or the like to create mechanical discontinuities.

[0065] The weakening device 212 weakens the first web 202 at intervals in the direction of extraction of the first web 202. The distance between each separation line 213 (i.e. the distance between the mechanical discontinuities in the direction of extraction) defines the length of the corrugated portion 120 of the tube 100. The distance between each separation line 213 is preferably regular, so that each corrugated portion 120 is the same length. In particular, to achieve a regular interval between the separation lines 213, the roller 230 may rotate continuously and the circumference of the roller 230 may be equal to the desired length of the tubes 100 being manufactured. However, in alternative embodiments the distance between the separation lines 213 may be irregular. An irregular distance between the separation lines 213 may be achieved by electronically controlling the application of a blade into contact with the first web 202. The distance between the separation lines 213 (i.e. the length of the tube 100) may be any suitable distance, for example 15 cm, 30 cm, 80 cm, 1 m or more, depending upon the requirements of the tube 100.

[0066] With reference to Figure 2, once the first web 202 has been weakened along the separation line 213, the first web 202 is then fed to a corrugating device 214. The corrugating device 214 comprises one or more pairs of rollers (not shown) that are configured to form corrugations 122 in the first web 202 to form the fin 120. Such a process may be referred to as progressive roll-forming. When the first web 202 is corrugated, mechanical stresses are introduced into the first web 202 that cause it to stiffen. These stresses are normally transmitted down the length of the first web 202 and can make the first web 202 difficult to work with. However, it has been found that because the first web 202 has been weakened along the separation line 213 before it is corrugated, lower stresses are transferred between adjacent web portions 202a, 202b across the separation line 213. That is to say, the separation line 213 acts to break the path of stress transmission between the first web portion 202a and the second web portion 202b. By limiting the amount of stress transmission it has been found that the first web 202 is easier to deform into the required shape.

[0067] Figure 6b shows a cross-section of a portion of the first web 202 once it has been corrugated according to one embodiment. The first web 202 comprises perforations 226 separated by stitches 229. The stitches 229 are the parts of the first web 202 which connect the first web portion 202a to the second web portion 202b. In the embodiment shown in Figure 6b, the corrugations 122 are formed in the first web 206 so that the perforations 226 are positioned at substantially straight (or unbent) sections of the corrugations 122 and so that the stitches 229 are positioned at or near the apexes of one or more of the corrugations 122. The apexes of the corrugations 122 undergo more deformation during the corrugating process than the straight sections.

The internal stresses in the apexes are therefore higher than the straight sections. An advantage of positioning the stitches 229 at the apexes is that the higher internal stresses may make the material more brittle at the apexes and therefore encourage frangible separation at the stiches 229. To further encourage frangible separation, in some embodiments, the stitches 229 may comprise additional mechanical discontinuities such as score lines 228.

[0068] In an alternative embodiment to the one shown in Figure 6b, the corrugations 122 formed in the first web 202 may align with the perforations 226 such that the perforations 226 are positioned at the apexes of one or more of the corrugations 122 (i.e. the opposite arrangement to Figure 6b). An advantage of positioning the perforations 226 at the apexes is that this reduces the chance of accidental material failure at the apexes when the first web 202 is corrugated. Again, the stitches 229 (positioned on the straight sections of the corrugations 122) may comprise score lines 228 to assist frangible separation.

[0069] As the first web 202 is being extracted from the first spool 204, the second web 206 is simultaneously extracted from the second spool 208. The second web 206 is fed to a straightening device 216 to straighten the second web 206 in a similar manner as described above for the first web 202. The straightening device 206 is optional, and may be omitted. The speed of extraction of the first and second webs 202, 206 is preferably controlled so they are the same. This helps to ensure registration of the first and second webs 202, 206 when they are subsequently brought together.

[0070] The second web 206 is then fed to a weakening device 218 which weakens the second web 206 along a line of separation. The second web 206 may be weakened in substantially the same manner as the first web 202 with reference to the weakening device 212 used for the first web 202. In particular, the mechanical discontinuity formed on the second web 206 by the weakening device 218 preferably extends across the entire width of the second web 206 (although in some embodiments this may not be the case). However, because the second web 206 is used to form the outer body 110 of the tube 100, the mechanical discontinuity formed by the weakening device 218 for the second web 206 may have a different configuration to the mechanical discontinuity of the first web 202. For example, the mechanical discontinuity of the second web 206 may comprise a different number and/or arrangement of perforations 226, or the score line 228 may extend to a different depth. In a similar manner to the first web 202, the mechanical discontinuities of the second web 206 may be located at points that correspond to one or more apexes of the tube outer body 110 once formed. In particular, second web 206 may be perforated at positions that correspond to the outer edges 124 of the outer body 110 so as to relieve stress at these locations.

[0071] The first and second webs 202, 206 may be weakened simultaneously, such that the weakening device 212 of the first web 202 and the same weakening device 218 of the second web 206 are the same device. In particular, a single roller 230 and single blade 232 as shown in Figure 5 may extend across both the first web 202 and the second web 206 to weaken the first and second webs 202, 206 at the same time.

[0072] After weakening, the second web 206 is fed to a forming device 219. The forming device 219 partially or fully folds the second web 206 into a generally tubular shape so as to create the outer body 110 of the tube 100. In some embodiments, the forming device 219 my fold the second web 206 so that at least one side of the tube outer body 110 is open, such that the corrugated first web 202 can be received within the interior of the tube outer body 110. The tube outer body 110 can subsequently be closed, for example in the receiving device 220. Closing the outer body 100 using folds provides the advantage that it is not necessary to weld the opposite edges of the second web 206 together to create a join.

[0073] Figure 6a depicts a partial cross-section of a tube outer body 110 according to one embodiment. The cross-section is depicted along separation line 213. In the embodiment of Figure 6a, the perforations 226 are formed in the straight portions of the second web 206 (i.e. the sides of the tube outer body 110), and the stitches 229 are formed at the apexes of the folds of the second web 206. The stitches 229 may additionally comprise score lines 228 to encourage frangible separation.

[0074] After the first web 204 has been corrugated and the second web 206 has been weakened, the first web 204 and the second web 206 are brought together in a receiving device 220. The paths taken by the first and second webs 202, 206 in Figure 2 is schematic only, and in practice the amount of bending that the first and second webs 202, 206 will undergo to be brought together is minimal. For example, in practice the first and second webs 202, 206 may be arranged so that they are side by side and therefore need only be bent by a small amount in the direction of their widths to bring them together. However, it will be appreciated that any suitable arrangement of the first and second webs 202, 206 relative to one another may be used.

[0075] In the receiving device 220, the at least partially formed second web 206 is folded or wrapped around the first web 202 to close the outer body 110 of the tube 100. As such, the first web 202, which is corrugated, is received within the outer body 110. The first and second webs 202, 206 thereby form a substantially continuous tube 221 having an outer body 110 and a fin 120. In alternative embodiments, the outer body 110 may be provided as a pre-formed length of tube 100 and the first web 202 may be inserted into the interior of the outer body 110. The first web 206 may additionally be bonded to the second web 206 for example in the alignment device (or another suitable device).

[0076] Following the receiving device 220, the continuous tube 221 is passed to an alignment device 222 in which the separation lines 213 of the first and second webs 202, 206 are aligned with one another. The separation lines 213 can be aligned by controlling the speed of one or both of the first and second webs 202, 206 to ensure that the separation lines 213 are positioned adjacent to one another. Some misalignment between the separation lines 213 may be tolerated. An alignment tolerance of the tube 100 may be defined as the maximum allowable deviation position of the separation lines of the first and second webs 202, 206. That is to say, the alignment tolerance may be the maximum distance by which the separation line 213 of the first web 202 (i.e. the corrugation portion 120) may be spaced apart from the separation line 213 of the second web 206 (i.e. the outer body 110) when the first web 202 is received within the second web 206. The alignment tolerance is preferably within the range of around 1 mm to around 2 mm. That is to say, the separation lines 213 may be misaligned relative to one another by an amount up to around 1 mm or 2 mm. For example, the tube 100 may have an alignment tolerance of around 1.5 mm. In some instances the alignment tolerance may be around 1 %, 0.5 %, or 0.2 % of the length of the tube 100 (i.e. the interval between the separation liens 213 of the first and/or second webs 202, 206).

[0077] Preferably, the interval between the separation lines 213 on the first and second webs 202, 206 are the same, so that, once frangibly separated, the first web portions 202a, 206a have substantially the same length. However, in some embodiments the separation lines 213 of the first web 202 may be spaced by a different amount to the separation lines 213 of the second web 202, so that one of the frangibly separated web portions has a longer length than the frangibly separated web portion of the other web. In particular, the corrugated portion 120 may be produced to be shorter than the outer body 110, such that the space between the separation lines 213 of the first web 202 is shorter than the space between the separation lines 213 of the second web 206. The corrugated portion 120 may for example be designed to be up to around 2 mm shorter than the outer body 110 of the tube 100, or may be around may be around 1 %, 0.5 %, or 0.2 % shorter than the length of the tube outer body 110.

[0078] Following the alignment 222 device, the substantially continuous tube 221 is fed to the tube straightening unit 223. The tube straightening unit 223 comprises one or more pairs of rollers which straighten the continuous tube 221 and thereby reduce the internal stresses of the first and second webs 202, 206. As described above, because the first and second webs 202, 206 have been weakened along their separation lines 213, lower stresses are transferred from the first portions of the first and second webs 202a, 206a to the second portions of the first and second webs 202b, 206b. That is to say, lower stress is transferred from a first tube section 100 (formed by the first web portions 202a, 206a) to an adjacent second tube section 100 (formed by the second web portions 202b, 206b) along the continuous tube 221. Because lower stress is transferred along the continuous tube 221, this significantly reduces the amount of work to be performed by the straightening unit 223. This may enable a simplified or smaller straightening unit 223 to be used in system 200, leading to cost savings. In some instances it may even be possible to dispense with the tube straightening unit 223 completely.

[0079] Previously, a limiting factor in the design of heat exchanger tubes 100 has been that when the fin 120 is too thin it is unable to withstand the straightening process in the tube straightening unit 223. However, because the first web 202 is weakened along the separation lines 213 before it is corrugated and straightened, the overall stress in the first web 202 is lower. As such, this enables a thinner material to be used for the first web 202. In particular the first web 202 may be reduced to a thickness of around 0.05 mm. Because the first web 202 is thinner, more corrugations 122 can be formed in the first web 202. Furthermore, in some embodiments, the corrugations 122 are bonded to the tube outer body 110 in the completed tube 100. Having more corrugations 122 therefore increases the number of mechanical linkages extending across the interior 130 of the tube 100 thus increasing the burst pressure of the tube 100.

[0080] Put another way, when the continuous tube 221 is straightened, the straightening unit 233 reverses or removes residual stresses in the first and second webs 202, 206 that have been caused by the corrugating and forming processes. The webs 202, 206 must be strong enough so that straightening the material removes stress without buckling the material or deforming the formed cross-sectional shape. The grain structure of thinner materials often makes them too weak to resist buckling, and therefore makes stress removal harder. However, because the webs 202, 206 have been weakened before they are corrugated / formed and straightened, less stress can be transmitted along the continuous tube 221 and therefore the residual stresses in the webs 202, 206 are lower. As a result, the straightening unit 223 does not need to exert as much force to straighten the continuous tube 221 and therefore thinner web materials may be used.

[0081] Following the alignment device 222, the shaped webs 202, 206 are passed to a separating device 224. The separating device 224 exerts a force on the first web portions 202a, 206a of the first and second webs 202, 206 which causes the first web portions 202a, 206a to break from the second web portions, 202b, 206b so as to form an individual tube 100. That is to say, when the shaped webs 202, 206 arrive at the separating device 224, they are shaped into an outer body 110 and a corrugated portion 120 that are still attached to the remainder of the webs 202, 206. The separation device 224 detaches the forwardmost parts of the webs 202, 206 from the remainder of the webs 202, 206 thus resulting in a detached length of tube 100. Put another way, the first web portions 202a, 206a may be located at the end of the length of the webs 202, 206. When the first web portions 202a, 206a are frangibly separated along the separation lines 213, the first web portions 202a, 206a form a separate tube section 100, and the second web portions 202b, 206b are now positioned at the end of the webs 202, 206. Because the second web portions 202b, 206b are now positioned at the end of the webs 202, 206, the second web portions can be said to be first web portions 202a, 206a. The process is then repeated.

[0082] The mechanical discontinuities defining the separation lines facilitate frangible separation. In particular, the more of the web that the mechanical discontinuities extend across, the smaller the force required to frangibly separate the first web portions 202a, 206a from the second web portions 202b, 206b. Furthermore, because the tubes 100 are separated from the webs 202, 206 frangibly, no cutting machinery is required to slice through the tubes 100 once they have been formed. This means that the cross-sectional geometry of the tubes 100 perpendicular to the longitudinal axis 102 is not deformed when the tubes 100 are separated. Furthermore, in the present invention the geometry of the webs 202, 206 is continuously formed and therefore problems such as flaring of the geometry at the ends of the web portions is avoided (this is common where the webs are cut to length / separated before they are formed into their desired cross-sectional shapes).

[0083] Frangible separation of the tubes 100 may comprise pulling the first web portions 202a, 206a apart from the second web portions 202b, 206b. In some embodiments, this may comprise gripping the first web portions 202a, 202b and gripping the second web portions 202b, 206b, using two separate gripping apparatus. Pulling the first tube section may comprise moving the gripping apparatus gripping the first web portions 202a, 206a away from the gripping apparatus gripping the second web portions 202b, 206b. The two separate gripping apparatuses may be located on separate carriages moving along with the webs 202, 206. As part of the frangible separation, the carriage of the gripping apparatus gripping the first web portions 202a, 206a moves relative to the carriage of the apparatus gripping the second web portions 202b 206b to create a pulling action. In some embodiments the frangible separation may additionally or alternatively comprise torsional (i.e. twisting or shearing) movement of the first web portions 202a, 206a relative to the second web portions 202b 206b. In general, it will be appreciated that any suitable separation action may be used.

[0084] Figure 7 depicts an embodiment of a separating device 224, in which a pair of first rollers 225a and a pair of second rollers 225b are located along the sides of the continuous tube 221, with one roller of each pair located on either side of the continuous tube 221 to grip the sides of the continuous tube 221. Each of the rollers 225a, 225b is supported for rotation around an axis perpendicular to the direction of extraction 215 and is driven by a drive system (not shown). The drive system may for example comprise one or more motor and/or transmissions to impart rotational motion on the rollers 225a, 225b. The first rollers 225a are driven to rotate at a first speed, and the pair of second rollers 225b are driven to rotate at a second speed, wherein the second speed is higher than the first speed.

[0085] As shown in Figure 7, the continuous tube 221 comprises a first tube section 100a, (formed by the first web portions 202a, 206a) and a second tube section 100b (formed by the second web portions 202b, 206b) which are joined at a separation line 213. The continuous tube 221 may comprise any number of tube sections joined together in a sequential manner, however, for clarity, only two such tube sections are shown. During use, the continuous tube 221 enters the separating device 224 and is pulled along in the direction of travel 215 by the first rollers 225a at the first speed. When the first tube section 100a has sufficiently advanced, it is gripped by the second pair of rollers 225b. As a result of the faster speed of the first rollers 225a gripping the first tube section 100a, the first tube section 100a is pulled away from the second tube section 100b, thereby causing the first tube section 100a to frangibly separate from the second tube section 100a along the separation line 213. As a result, the first tube section 100a forms a detached tube 100.

[0086] The rollers 225a, 225b of separating device 224 may comprise circumferential grooves for receiving the continuous tube 221. The grooves increase the contact area and gripping force of the rollers 225a, 225b, by partially wrapping around the top and bottom sides of the tube outer body 110. This improves the pulling force and efficiency of the rollers 225a, 225b. The grooves can also have a guiding effect, keeping the substantially continuous tube 221 in position. The grooves may be U-shaped. In some embodiments, a separating device has two or more pairs of first rollers and/or two or more pairs of second rollers. The first rollers 225a all rotate at a first speed, which is less than a second speed at which the second rollers 225b rotate. Using two pairs increases the gripping strength and separating strength of the separating device 224. It will be appreciated that the separating device may comprise any suitable number of rollers, and that the rollers may rotate at incrementally increasing speeds so as to cause the first tube section 100a to separate from the second tube section 100b.

[0087] A tube 100 is formed when the first web portions 202a, 206a have been frangibly separated from the second web potions 202b, 206b. Following frangible separation of the tube 100 from the webs 202, 206, the corrugated portion 120 and the outer body 110 may still be misaligned by a small distance. The system 200 may comprise an additional device for pressing the corrugated portion 120 into the outer body 110 so that the corrugated portion 120 does not protrude from the outer body 110.

[0088] Figure 8 is an illustrative flow chart of a method of forming a tube for a heat exchanger as described above. The method may comprise 302 extracting a web of material from a spool. After extracting the web from the spool, the method may comprise 304 weakening a portion of the web of material along a separation line, wherein the separation line divides the web into a web portion and a second web portion. Subsequent to the step of weakening a portion of the web, the method may include 306 forming a plurality of corrugations in a portion of the web. In step 308, the corrugations may be received within a tube outer body. The tube outer body may be formed in at least another portion of a web of material. The method further comprises 310 frangibly separating the first web portion from the second web portion along the separation line. The web of material from which the outer body 110 is formed may be the same web of material from which the corrugations are formed. Alternatively, the outer body 110 may be formed from a different web of material than the web of material from which the corrugations are formed. The step 304 of weakening the web along a separation line may be repeated at another position of the web. The interval (i.e. the distance) between the separation lines will determine the length of an individual web portion.

[0089] Although the system 200 described above produces a tube 100 using two separate webs of material (namely, the first web 202 and the second web 206), it will be appreciated that in alternative embodiments a different number of webs may be used. For example, the web of material from which the outer body 110 is formed may be the same web of material from which the corrugated portion is formed such that only a single web is used. Alternatively, more than two webs may be used, for example three or more webs. However, it will be appreciated that at least one of the webs is corrugated after it has been weakened along a line of separation. The term "corrugated" is to be understood to encompass shaping a web into a geometry with a repeating pattern of generally U-shaped or V-shaped longitudinally extending channels.

[0090] The system 200 described above may comprise additional tube forming steps and/or devices. For example, dimples may be added to the first web 202 (i.e. corrugated portion 120) and/or the second web 206 (i.e. tube outer body 110). The dimples may improve heat exchanging properties of the finally formed tube 100. The dimples may be applied to the web at any suitable point. Additionally or alternatively, the system 200 may comprise a de-burring or edging device for removing any sharp edges from the frangibly separated ends of the tube 100.

[0091] It will be appreciated that the method steps outline above may be completed in any suitable order, provided that the step of weakening a web occurs before the subsequent shaping of that web into a constituent part of the tube outer body 110 or the corrugated portion 120. For example, the step of aligning the webs relative to one another using the alignment device 222 may occur before the step of receiving the first (corrugated) web 202 in the second web 206 using the receiving device 220.

[0092] Although the straightening devices 210, 216, weakening devices 212, 218, corrugating device 214, receiving device 220, alignment device 222 and separating device 224 are described as separate devices, it will be appreciated that in some embodiments one or more of these devices may be combined into a single device. For example, the system 200 may comprise a device that is capable of both receiving the first web 202 within the outer body formed by the second web 206 at the same time as aligning the separation lines 213 of the first and second webs 202, 206.

CLAIMS:

1. A method of manufacturing a tube for a heat exchanger, the method comprising:

extracting a web of material from a spool,

weakening a portion of the web along a separation line, the separation line dividing the web into a first web portion and a second web portion;

subsequent to the step of weakening, forming a corrugated portion in the web,

receiving the corrugated portion within a tube outer body; and

frangibly separating the first web portion from the second web portion along the separation line.

2. A method according to claim 1, wherein weakening a portion of the web along a separation line comprises forming a material discontinuity in the web.

3. A method according to claim 2, wherein the web defines a width perpendicular to a longitudinal axis of the web, and wherein the material discontinuity extends along the entire width of the web.

4. A method according to claim 2 or 3, wherein the material discontinuity is at least partially formed by scoring a portion of the web.

5. A method according to any of claims 2 to 4, wherein the material discontinuity is at least partially formed by perforating a portion of the web.

6. A method according to any of claims 2 to 5, wherein a perforation is formed along the line of separation at a point that corresponds to an unbent section of the corrugated portion.

7. A method according to any of claims 2 to 6, wherein a score line is formed along the line of separation at a point that corresponds to an apex of one of the corrugations of the corrugated portion.

8. A method according to any of the preceding claims, wherein frangibly separating the first web portion from the second web portion comprises pulling the first web portion and the second web portion apart from one another along a longitudinal axis of the web.

9. A method according to claim 8, wherein the method comprises providing a first carriage for gripping the first web portion and a second carriage for gripping the second web portion, and wherein frangibly separating the first web portion from the second web portion comprises moving the first carriage and the second carriage apart from one another along the longitudinal axis.

10. A method according to claim 8, wherein the method comprises:

rotating a pair of first rollers at a first speed, and

rotating a pair of second rollers at a second speed,

wherein the second speed is greater than the first speed such that when the first and second rollers grip the tube outer body the first web portion frangibly separates from the second web portion.

11. A method according to claim 10, wherein each of the pair of first rollers and the pair of second rollers comprise a groove along the circumference of the roller for receiving the tube outer body.

12. A method according any of claim 10 or claim 11, wherein the method comprises providing two pairs of first rollers and two pairs of second rollers.

13. A method according to any preceding claim, wherein the web is a first web and the spool is a first spool, wherein the method further comprises:

extracting a second web of material from a second spool; and

forming the tube outer body from the second web.

14. A method according to claim 13, wherein the separation line is a first separation line, and wherein the method further comprises:

weakening a portion of the second web along a second separation line, the second separation line dividing the second web into a first web portion a second web portion; and

frangibly separating the first web portion of the second web from the second web portion of the second web along the second separation line.

15. A method according to claim 14, wherein the method comprises, subsequent to the step of receiving the corrugated portion within the tube outer body, straightening the first and second webs.

16. A method according to claim 14 or 15, wherein the frangible separation of the first web occurs simultaneously with the frangible separation of the second web.

17. A method according to any of claims 13 to 16, further comprising aligning the first and second separation lines with one another.

18. A method according to claim 17, wherein the first and second separation lines are positioned apart from one another by a distance less than or equal to around 2 mm.

19. A method according to any of claims 13 to 18, wherein the weakening of the first web and the second web is performed simultaneously.

20. A method according to any of claims 13 to 19, wherein the second web has a greater thickness than the first web.

21. A tube manufactured using the method of any preceding claim.

22. A system for manufacturing a tube for a heat exchanger, the system comprising:

a web of material wound onto a spool,

a weakening device for weakening a portion of the web along a separation line, the separation line dividing the web into a first web portion and a second web portion;

a corrugation device subsequent to the weakening device, the corrugation device configured to form a corrugated portion in the web,

a receiving device for receiving the corrugated portion within an interior of a tube outer body; and

a separation device for frangibly separating the first web portion from the second web portion along the separation line.

23. A system according to claim 22, wherein the web is a first web and the spool is a first spool and the separation line is a first separation line, the system further comprising:

a second web wound onto a second spool, and

a weakening device for weakening a portion of the second web along a second separation line, the second separation line dividing the second web into a first web portion and a second web portion.

24. A system according to claim 23, wherein the system further comprises a straightening device for straightening the first and second webs subsequent to the receiving device.

25. A system according to claim 23 or 24, further comprising an alignment device configured to align the first separation line and the second separation line relative to one another.

Intellectual Property Office

Application No:	GB1905148.1	**Examiner:**	Tim James
Claims searched:	1-25	**Date of search:**	23 September 2019

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-8, 13-18 and 20-25	US2010/024508 A1 (OPFERKUCH et al) see figure 21, particularly perforation station P1 corrugating station U1 for the centre strip, and paragraphs 0039 and 0040
A	-	US2012/031602 A1 (EISELE) see paragraph 0023 and claims 1 and 7

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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International Classification:

Subclass	Subgroup	Valid From
B21D	0043/28	01/01/2006
B21D	0053/04	01/01/2006