(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 March 2001 (15.03.2001)

PCT

(10) International Publication Number
WO 01/18406 A1

(51) International Patent Classification[7]: F15D 1/02

(21) International Application Number: PCT/US00/23121

(22) International Filing Date: 23 August 2000 (23.08.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/382,184 9 September 1999 (09.09.1999) US

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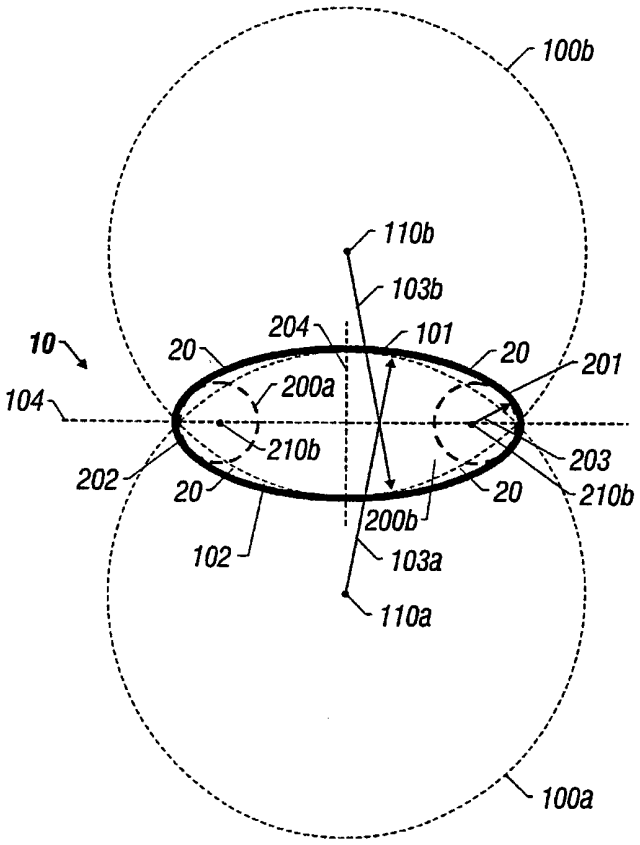
(81) Designated States *(national)*: AU, BR, CA, JP.

(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

**Published:**
— *With international search report.*
— *Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.*

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(54) Title: IMPROVED TUBE FOR HEAT EXCHANGERS




(57) Abstract: The present invention relates to tubes useful for heat exchangers. The present invention's improved dual radius cross-sectional profile is formed from two sets of circles (100a,b and 200a,b), each set of circles having the same radius but the two sets having different radii. The present invention's dual radius tube non-elliptical profile is therefore defined by two sets of opposing, intersecting arcs (101, 102 and 201, 202) that form a dual radius tubular with two unequal sets of radii of predetermined values. Because each radius within a set of radii is equal, each of the opposing sides within a set of sides is substantially symmetrical, but because each set of sides are arcs of circles the sides are not flattened. The improved tube's overall dual radius cross-sectional profile is therefore neither elliptical, round, rectangular, nor obround. The dual radius profile aids in creating turbulence in a fluid within the tube, enhancing heat transmissivity. The tube may also be twisted into a predetermined number of twists, creating further turbulence in a fluid within and without the tube and further enhancing heat transmissivity.

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# IMPROVED TUBE FOR HEAT EXCHANGERS

## TECHNICAL FIELD

The present invention relates to tubes useful for heat transfer where the improved tube of the present invention has a non-elliptical, dual radius cross-sectional profile.

## BACKGROUND ART

Tubing, both twisted and non-twisted, has application in heat exchangers where a first carrier medium, normally a liquid, passes through the inside of the tubing while simultaneously a second carrier medium, normally air or a gas, flows transversely to and in contact with the exterior of the tubing so that heat is transferred from one carrier medium to the other.

In the current art, tubes for use in heat exchangers have shapes that vary from round to oval to obround, but no dual radius configuration is taught in the prior art. For example, the prior art includes United States Patent No. 9,481, issued to Månsson, teaches a flattened, obround tube profile in a twisted configuration where the flattened non-round tubes have two or more ridges extending helically around the tube's center line. United States Patent No. 4,466,479, issued to MacLean, teaches an upright diamond shaped tube. United States Patent No. 5,031,694, issued to Lloyd, teaches a flattened tube section having leading and trailing edges with a plurality of fins. United States Patent No. 5,538,079, issued to Pawlick, teaches an oblong shaped tube having substantially flat sides and shorter rounded sides. United States Patent No. 4,206,806, issued to Togashi, teaches oval pipes that are flattened to form joining faces.

As is well known to those skilled in the heat transfer arts, round tubes can contain fluids at greater pressures than other shaped tubes, *i.e.,* obround and rectangular tubes have limited pressure containment properties when compared to round or elliptical tubes. However, round tubes are not as efficient as twisted or non-round shaped tubes with respect to heat transfer characteristics.

Elliptical tubes are preferable to round tubing inasmuch as a greater contact area for heat transfer is obtained within a given flow cross section for the carrier medium, but true elliptical tubes are difficult to manufacture.

Obround tubes are relatively easy to manufacture but tend to deform and stress under pressure.

It is therefore an object of the present invention to provide an improved tube profile for tubes used in heat exchangers to provide increased induced fluid medium turbulence, thus improving heat transmission characteristics.

It is a further objective to provide an improved twisted tube having increased heat transmission characteristics capable of containing higher pressures than twisted obround or twisted rectangular tubes.

Accordingly, an improved tube profile for a tube used in heat exchangers is described.

## BRIEF DESCRIPTION OF DRAWINGS

For a further understanding of the nature and objects of the present invention, reference should be had to the following detailed description, taken in conjunction with the accompanying drawings, in which like elements are given the same or analogous reference numbers and wherein:

**Fig. 1a** is a cross-sectional view of an exemplar of current twisted tube profiles having a set of rounded and a set of substantially flat sides.

**Fig. 1b** is a cross-sectional view of an exemplar of true elliptical profiles.

**Fig. 2** is a cross-sectional view of an exemplary relief of the improved tube profile of the present invention.

**Fig. 3** is a graphical representation indicating representative overlaps of circles and an ellipse.

**Fig. 4** is a perspective view, partially in cross section, of the present invention's improved profile in a twisted configuration.

## GENERAL DESCRIPTION AND PREFERRED MODE FOR CARRYING OUT THE INVENTION

The present invention relates generally to improvements in tubes such as those used in heat exchangers, specifically to a dual radius cross-sectional profile for such tubes.

In heat exchangers, one fluid, which can be either a gas or liquid, flows through the interior of at least one heat exchange tube while another fluid, which can also be either a gas or a liquid, flows about the exterior of the heat exchange tube. It is well known in the art of heat transfer that turbulence in the liquids improves heat transmission effectiveness.

Referring now to **Fig. 1a**, an exemplar of current twisted tube profiles, most processes in the current art that produce twisted tubes suitable for use in heat exchangers create a tube having an obround cross-sectional profile 50, *i.e.,* one having an opposing set of rounded sides 51 and a set of opposing substantially flattened sides 52. As is well known to those skilled in the heat transfer arts, tubes 50 having an obround geometry are limited in pressure containment as compared to profiles which are not obround.

Referring now to **Fig. 1b**, a profile of an elliptical tube, as is also well known to those skilled in the heat transfer arts, the smaller the radius of curvature, the higher a pressure containment capability of the tube. Accordingly, a true elliptical profile 60 is a preferred profile, where a set of foci 66 and 67 exist such the tube describes an ellipse or oval. However, production of tubes 10 with true elliptical profiles 60 is difficult in the current art because it is extremely difficult to maintain a consistent cross-sectional profile having a constant, uniformly varying radius. This is especially true for twisted tubes.

Accordingly, in the current art twisted tubes are typically made with obround profiles, as shown in **Fig. 1a**, because such profiles are the easiest to manufacture although they do not maximize inside flow area and pressure containment capabilities.

Referring now to **Fig. 2**, a cross-section of the improved profile of the present invention, the present invention's dual radius cross-sectional tube 10 is more readily manufactured than elliptical profiles tubes. Tube 10 has two sets of curved, symmetrically opposing sides. Sides 101 and 102 are arcs of two circles 100a and 100b, indicated by dashed lines and jointly referred to herein as circle 100, that have equal but opposed, non-collocated radii 103a and 103b, generally referred to as radius 103. Radii 103 are of an equal, predetermined length. Centers 110a and 110b of circles 100a and 100b are diametrically disposed outside tube 10 along minor axis 204, defined

by a straight line terminating at the widest points of cross-sectional sides 101 and 102 with respect to each other. If extended beyond tube 10, minor axis 204 would pass through center 110a and center 110b.

Sides 201 and 202 are arcs of two other circles 200, indicated by dashed lines and shown as circle 200a and circle 200b, that have equal radii 203a and 203b, generally referred to as radius 203. Centers 210a and 210b of circles 200a and 200b are located on major axis 104, defined by a line disposed within tube 10 which passes through centers 210a and 210b to the widest points of the cross-sectional profile with respect to sides 201 and 202.

Major axis 104 is substantially perpendicular to minor axis 204. However, the magnitude of major axis 104 is not equal to the magnitude of minor axis 204, and the ratio of the magnitude of major axis 104 to the magnitude of minor axis 204 is greater than zero. In the preferred embodiment, this ratio is greater than zero, with the preferred range being 1.1 to 4.0, or

$$[(1.1) < (\text{major axis } 104/\text{minor axis } 204) < 4.0]$$

Moreover, side 101 and side 102 are opposing but not parallel as each is not flattened but rather each is a curved arc of different circles, *i.e.,* circles 100a and 100b, whose centers are not collocated. These characteristics are also true for sides 201 and 202.

Referring now to **Fig. 3**, a graphical representation of flow areas within one quadrant of tube 10, line 150 describes the perimeter of a theoretical tube 10 having a true elliptical profile in one quadrant. Line 151 describes the perimeter of circle 200b having radius 203b. Line 152 describes the perimeter of circle 100a having radius 103a. Line 153 describes the perimeter of tube 10 having the present invention's dual radius cross-section profile.

As noted herein above, radius 103 is not equal in magnitude to radius 203. Further, as radius 103 traverses the arc defined by side 101, radius 103 intersects radius 203 at center 210a of radius 203 along major axis 104, *i.e.,* the center of circle 200a of which side 201 is an arc. At the point of intersection 20 of side 101 and 201 on the perimeter of tube 10, radius 103 transitions into radius 203. Accordingly, the points of intersection between side 101 and side 201, side 101 and side 202, side 102 and side 201, and side 102 and side 202 are defined by the intersection of radii 103 and radii 203 such that the outer and inner perimeters of tube 10 form neither an oval, circular, nor rectangular shape but instead form the present invention's unique dual radius profile.

As is well known in the art of heat transfer, flow rate at the inner wall of a tube is less than the flow rate at the center of the tube. Additionally, for any given tube placed inside another, such

as is the case with many heat exchangers, an increase in the cross-sectional profile of the tube leads to a decrease in the flow area outside the tube within the heat exchangers, leading to positive results with respect to the flow rate of a second medium used for heat transfer which is flowing outside the tube. As can be seen from **Fig. 3**, one benefit of the present invention's dual radius cross-sectional profile is that the total cross-sectional flow area within the present invention's profile is increased by additional flow area 154 as compared to the total cross-sectional flow area 160 of a true ellipse. Further, the flow area outside tube 10 is decreased.

Referring now to **Fig. 4**, a side perspective view of the profile of tube 10 in a twisted configuration, in another preferred embodiment tube 10, whose cross-sectional profile is shown in **Fig. 2**, is twisted to further improve turbulence in and around tube 10. Generally, a helical shape is obtained by introducing one or more twists 105 along longitudinal axis 120 of tube 10 such that the number of complete twists 105 per a given length of longitudinal axis 120 of tube 10 is defined by the ratio of complete twists 105 to a predetermined length of longitudinal axis 120 of tube 10 equal in magnitude to the length of major axis 104. In this alternative preferred embodiment, the ratio of complete twists 105 to the given length along longitudinal axis 120 is greater than zero, with a preferred range being between 2.0 and 100.0, or

$$[2.0 < (\text{number of twists } 105/\text{length of longitudinal axis } 120) < 100.0]$$

**In the operation of the preferred embodiment**, tubes 10 are placed into a forming apparatus of the type well known to those skilled in the tube fabrication arts and processed into the present invention's improved dual radius cross-sectional profile as shown in **Fig. 2**. In an alternative embodiment, tubes 10 are also twisted into the helical shape of **Fig. 4** while being formed into the present invention's improved profile.

After being formed into the profile of the present invention, one or more tubes 10 are placed within a heat exchanger to form a heat exchange bundle as that term is well known in the art of heat exchange. Fluid is passed within and without tubes 10. As fluid travels within tube 10, generally under pressure, turbulence is enhanced by the interior discontinuities created by the set of opposing sides 101 and 102 and the set of opposing sides 201 and 202. As is well known to those skilled in the art, greater turbulence leads to greater heat transferability.

As noted herein above, in a twisted embodiment tube 10 is twisted into a substantially helical shape having a predetermined number of twists 105 in accordance with the teachings of the present invention prior to insertion within a heat exchanger. Turbulence of fluids within and

without tube 10 is enhanced by the twists as well as by interior and exterior discontinuities. Increased turbulence increases the heat transmissivity of the fluids and the heat exchanger as a whole.

It may be seen from the preceding description that an improved tube for heat exchange is provided.

It is noted that the embodiment of the improved tube for heat exchange described herein in detail for exemplary purposes is of course subject to many different variations in structure, design, application and methodology. Because many varying and different embodiments may be made within the scope of the inventive concept(s) herein taught, and because many modifications may be made in the embodiment herein detailed in accordance with the descriptive requirements of the law, it is to be understood that the details herein are to be interpreted as illustrative and not in a limiting sense.

## CLAIMS

What is claimed is:

**1.** An improved tube suitable for use in heat exchangers, said tube having an improved cross-sectional profile comprising:

a first curved side which is an arc of a first imaginary circle having a first radius of a predetermined magnitude, said first circle having an imaginary first center disposed outside said tube;

a second curved side which is an arc of a second imaginary circle having a second radius of a predetermined magnitude equal in magnitude to said first radius, said second circle having an imaginary second center disposed outside said tube on a side of said tube opposite to said first curved side;

a third curved side which is an arc of a third imaginary circle having a third radius of a predetermined magnitude, said third radius being smaller than said first radius and said third circle having an imaginary third center disposed within said tube; and

a fourth curved side which is an arc of a fourth imaginary circle having a fourth radius of a predetermined magnitude equal in magnitude to said third radius, said fourth circle having an imaginary fourth center disposed within said tube distally located from said third center;

wherein said first curved side intersects said third and fourth curved sides and said second curved side intersects said third and fourth curved sides.

**2.** The improved tube of **Claim 1**, wherein

a minor axis within said tube is defined by an imaginary straight line between a first point on said first curved side directly opposite a second point on said second curved side at a widest distance between said first curved side and said second curved side;

a major axis is defined by an imaginary straight line between a third point on said

third curved side directly opposite a fourth point on said fourth curved side at a widest distance between said third curved side and said fourth curved side, said major axis being substantially perpendicular to said minor axis;

said first center and said second center align along said minor axis such that a straight line intersecting said first center and said second center is colinear with said minor axis;

said major axis intersects said third center and said fourth center;

said first radius transitions into said third radius at a point where said first radius intersects said third center;

said third radius transitions into said second radius at a point where said second radius intersects said third center;

said second radius transitions into said fourth radius at a point where said second radius intersects said fourth center;

said fourth radius transitions into said first radius at a point where said first radius intersects said fourth center; and

at least one set of foci exist within said tube such that said tube is not an ellipse.

**3.** The improved tube of **Claim 1**, wherein said tube is twisted into a substantially helical shape.

**4.** The improved tube of **Claim 3**, wherein said twisted tube has a predetermined number of twists per unit length of a longitudinal axis of said tube.

**5.** The improved tube of **Claim 2**, wherein a ratio of a length of said major axis to a length of said minor axis is greater than zero.

**6.** The improved tube of **Claim 2**, wherein a ratio of a length of said major axis to a length of said minor axis is greater than 1.1.

**7.** The improved tube of **Claim 2**, wherein a ratio of a length of said major axis to a length of said minor axis is less than 4.0.

**8.** The improved tube of **Claim 2**, wherein said tube is twisted into a substantially helical shape about a longitudinal axis of said tube.

**9.** The improved tube of **Claim 8**, wherein said twisted tube has a predetermined number of complete twists per unit length of said tube along said longitudinal axis, wherein said unit length of said tube is equal in magnitude to a length of said major axis.

**10.** The improved tube of **Claim 9**, wherein a ratio of said complete twists to said unit length is greater than zero.

**11.** The improved tube of **Claim 10**, wherein a ratio of said complete twists to said unit length is greater than 2.0.

**12.** The improved tube of **Claim 11**, wherein a ratio of said complete twists to said unit length is less than 100.0.

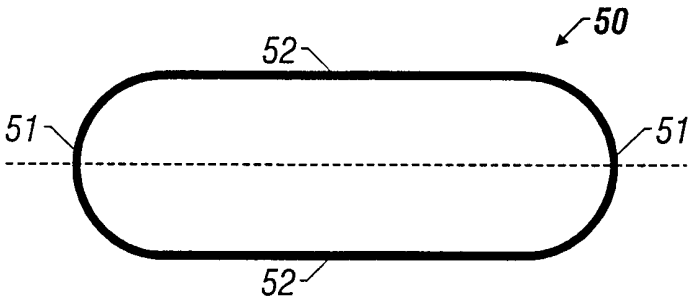



FIG. 1A

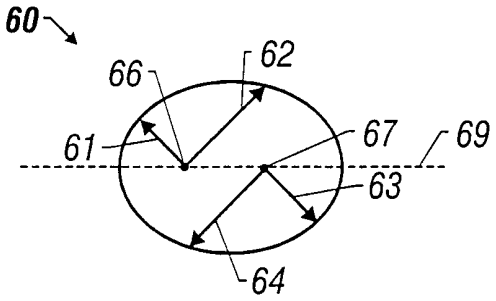
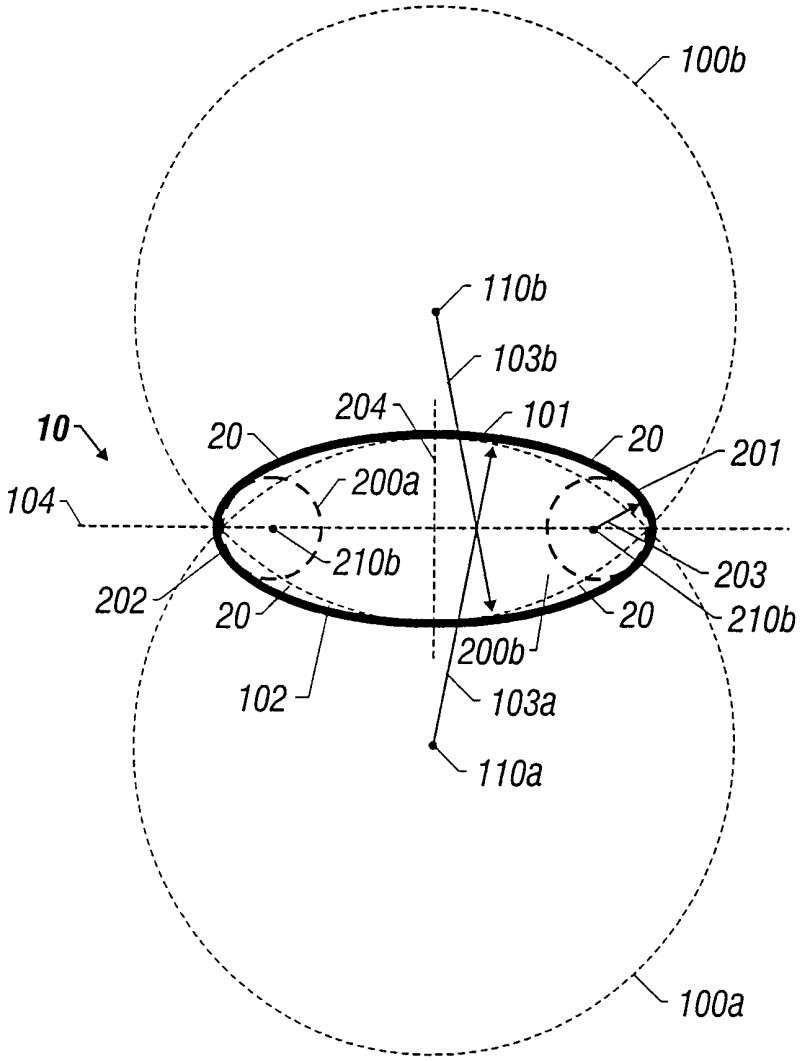



FIG. 1B


100b
110b
103b
204
101
10
20
20
201
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104
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202
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20
210b
200b
102
103a
110a
100a

FIG. 2

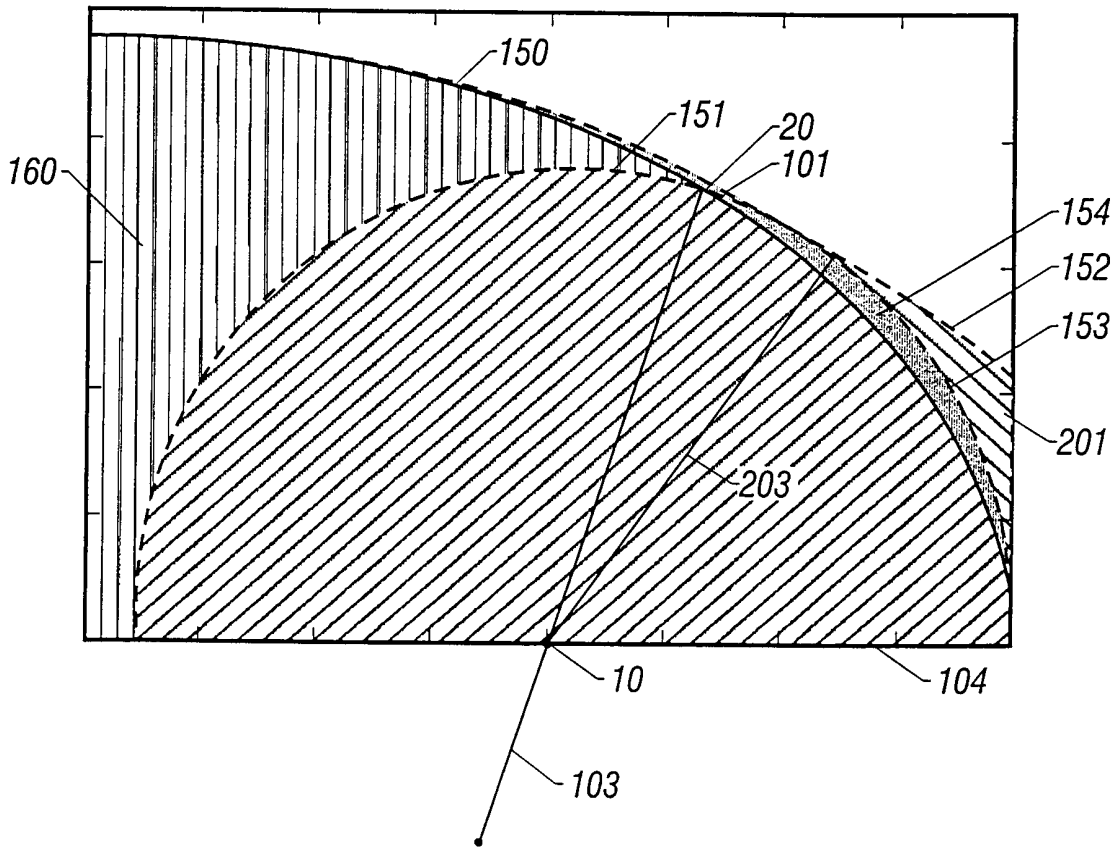


FIG. 3

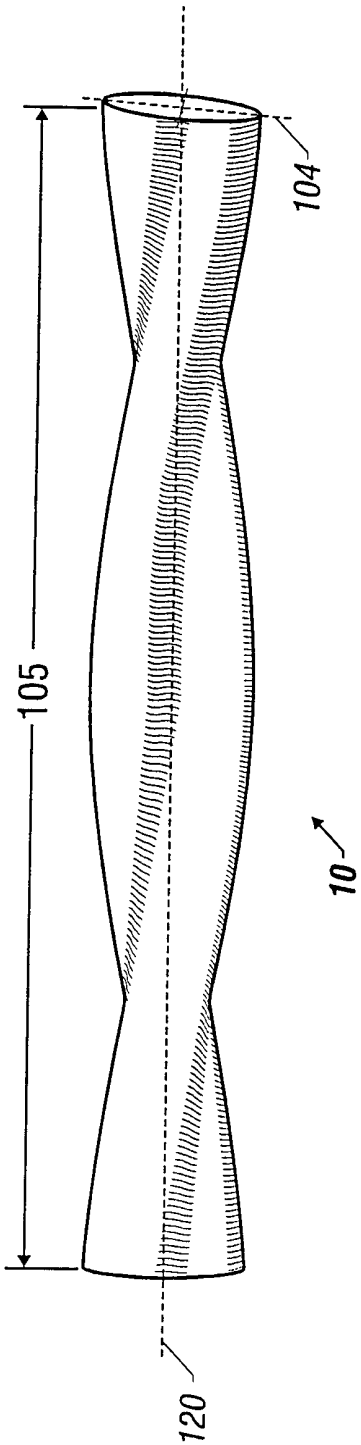


FIG. 4

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/23121

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :F15D 1/02
US CL : 138/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 138/38, 177, 178, dig 11

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | US 1,150,407 A (WELLS) 17 August 1915, see entire document. | 1, 2, 5 |
| Y | | 3,4, 6-12 |
| X | US 1,780,319 A (SONNEBORN) 04 November 1930, see entire document. | 1, 2, 5 |
| Y | | 3, 4, 6-12 |
| X | US 1,839,919 A (HALL) 05 January 1932, see entire document. | 1, 2, 5 |
| Y | | 3, 4, 6-12 |
| X | US 4,044,797 A (FUJIE et al) 30 August 1977, see entire document. | 1, 2, 5 |
| Y | | 3, 4, 6-12 |
| Y | US 4,995,450 A (GEPPELT et al) 26 February 1991, see entire | 3, 4, 8-12 |

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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| * | Special categories of cited documents | "T" | later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention |
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| "E" | earlier document published on or after the international filing date | "Y" | document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art |
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| Date of the actual completion of the international search<br>05 DECEMBER 2000 | Date of mailing of the international search report<br>03 JAN 2001 |
| Name and mailing address of the ISA/US<br>Commissioner of Patents and Trademarks<br>Box PCT<br>Washington, D.C. 20231<br>Facsimile No. (703) 305-3230 | Authorized officer<br>JAMES F. HOOK<br>Telephone No. (703) 308-0870 |

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/23121

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | US 5,004,374 A (GREY) 02 April 1991, see entire document. | 1-12 |