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

(11) EP 2 425 193 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
19.07.2017 Bulletin 2017/29

(21) Application number: **10726891.4**

(22) Date of filing: **30.04.2010**

(51) Int Cl.:
F28D 7/10 *(2006.01)* ***F28F 1/06*** *(2006.01)*
F28F 1/08 *(2006.01)* ***B21D 53/06*** *(2006.01)*

(86) International application number:
PCT/EP2010/002656

(87) International publication number:
WO 2010/124871 (04.11.2010 Gazette 2010/44)

(54) HEAT EXCHANGER

WÄRMETAUSCHER

ECHANGEUR DE CHALEUR

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR

(30) Priority: **30.04.2009 EP 09159260**
29.05.2009 GB 0909221

(43) Date of publication of application:
07.03.2012 Bulletin 2012/10

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(56) References cited:
EP-A1- 1 840 495
EP-A1- 1 895 256
JP-A- 2002 318 015
JP-A- 2004 278 854
JP-A- 2006 162 241
US-A- 4 194 560
US-A1- 2006 096 314

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Description

TECHNICAL FIELD

[0001] The invention relates generally to the technical field of heat exchangers and particularly, but not exclusively, to internal heat exchangers and more particularly those used for use air-conditioning systems for automotive applications.

BACKGROUND

[0002] Air-conditioning systems of motor vehicles, for example, are frequently equipped with a so-called internal heat exchanger. Such heat exchangers may be used to increase the operating efficiency of the system by preheating the refrigerant supplied to the suction side of a compressor of the air-conditioning system and at the same time cooling the refrigerant (liquid side) being conveyed to an expansion device. One example of an inner heat exchanger is disclosed in DE10 2006 017 816 B4. This document discloses a single piece extruded aluminium heat exchanger element. In this one extruded profile channels are formed for conveying both liquid side and suction side refrigerant. Whilst, extruded heat exchanger elements of this type offer high levels of heat exchange between the suction and the liquid sides, they suffer from certain drawbacks: they require machining and/or cleaning before they can be used; welding or brazing must be used in order to connect the suction line to the profile; and, the geometry of the heat exchanger is fixed by the extrusion tool, meaning that new tools must be developed for a new applications requiring different extrusion profiles.

[0003] In order to achieve a desired heat transfer between the suction side and the liquid side the heat exchanger must have a given heat exchange area. Sometimes, space is at a premium, for example in automotive applications. In such cases it is desirable to be able to use heat exchangers of reduced outer dimensions. This often means that it is required to form or bend the heat exchanger as a U-shaped pipe or into other shapes so that it may be installed in a given space. This in turn requires that the heat exchanger pipe be designed in a sufficiently bendable manner so that it may be deformed without collapsing its fluid conveyance channels. Moreover, it may also mean that the outer diameter of the heat exchanger is limited or constrained.

[0004] In view of such design requirement it would therefore be desirable to provide a heat exchanger that overcomes at least some of the above mentioned problems.

[0005] A heat exchanger and a method in accordance with the preamble of claims 1 and 9 are known from US 4,194,560. Dent portions are alternately formed on the outside face of the inner tube. The inner tube is then fitted within the outer tube to form a space between outer tube and inner tube wherein oil flows in zigzag fashion to assure heat transfer. Due to the dents formed in the inner tube, the cross-sectional area of the inner tube is reduced in relation to the original tube. This results in undesirable higher pressure drop in the inner tube. Moreover will the described increased contact area also increase the refrigerant pressure drop between the outer and inner tube.

SUMMARY

[0006] According to the present invention there is provided a heat exchanger and a method of manufacturing of a heat exchanger as defined in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The above and other aspects, features and advantages of the invention will be apparent from the following detailed description of illustrative embodiments which is to be read in connection with the accompanying drawings, in which:

Fig. 1 is a schematic diagram of an air conditioning system for an automotive application comprising an internal heat exchanger;
Fig. 2 shows a schematic illustration of the internal heat exchanger shown in Fig. 1 in a U-shaped configuration;
Fig. 3a shows a perspective view of an internal heat exchanger according to a first embodiment of the invention in its assembled state but prior to being bent into a U-shaped configuration;
Fig. 3b shows a photograph of the exterior of an internal heat exchanger according to the first embodiment;
Fig. 3c shows a photograph of the exterior of a section of the deformed portion of the inner tube of the internal heat exchanger according to the first embodiment;
Fig. 3d shows a schematic illustration of the exterior of a section of the deformed portion of the inner tube of the internal heat exchanger according to the first embodiment, more clearly showing its helical structure;
Fig. 4 is an image schematically illustrating part of the inner tube of the internal heat exchanger according to a first embodiment, which illustrates one exemplary method of creating a helical structure in a portion of the inner tube;
Fig. 5a to Fig. 5c show cross sectional views of the internal heat exchanger according to the first embodiment, illustrating exemplary alternative profiles for the internal heat exchanger inner tube;
Fig. 6 is a schematic illustration of the flow of refrigerant in the internal heat exchanger of the first embodiment;
Fig. 7 shows part of an image of Fig. 4, showing how parameters of the inner tube may be varied to achieve different performance characteristics of the

internal heat exchanger of the first embodiment;

DETAILED DESCRIPTION

[0008] Referring now to the drawings, several embodiments of the present invention are shown in detail. The drawings are not necessarily to scale and certain features may be exaggerated to better illustrate and explain the present invention. Further, the embodiments set forth herein are not intended to be exhaustive or otherwise limit or restrict the invention to the precise configurations shown in the drawings and disclosed in the following detailed description.

[0009] Referring to FIG. 1 an air conditioning system **1** suitable for use in a motor vehicle is schematically illustrated. The air conditioning system **1** includes a compressor **2,** which may be driven, for example, by the engine of the vehicle or by a separate electric motor or the like. The compressor **2** has an inlet **4,** connected to a low pressure line **21,** via which where the compressor **2** takes in refrigerant, or coolant, at low pressure. The compressor **2** also has an outlet **3,** via which pressurized refrigerant is output, into a high pressure line **5.** The high pressure line **5** leads to a cooling device **6** where the compressed and thus heated refrigerant is cooled and condensed. Therefore, the cooling device **6** is also referred to as a condenser. In this example, the refrigerant used is R-134a that works at low pressure.

[0010] At an outlet **7** of the cooling device, the refrigerant is discharged to another high pressure line **8** that leads to a high-pressure inlet **9** of an internal heat exchanger **11.** The internal heat exchanger **11** has a high-pressure outlet **12** that is in turn connected to an expansion valve **15** via a high pressure line **14.** The expansion valve **15** relaxes the refrigerant that is introduced into an evaporator **16.** The refrigerant evaporates in the evaporator **16** and, as a result, absorbs thermal energy from the environment; in this example, cooling the air supplied to the interior of the motor vehicle. The resultant refrigerant vapor is then transported from the evaporator **16,** via a low-pressure line **17,** to the low-pressure inlet **18** of the internal heat exchanger **11.** This refrigerant vapor flows through the internal heat exchanger **11** in a countercurrent direction to the refrigerant that is being fed through the high-pressure inlet **9.** In so doing, the refrigerant vapor cools the pressurized refrigerant, thus itself becoming heated. The refrigerant vapor is discharged, having been heated, at the low-pressure outlet **19** of the internal heat exchanger **11.** It is then conducted, via a low-pressure line **21,** to the inlet **4** of the compressor **2.**

[0011] The internal heat exchanger **11** allows the temperature of the refrigerant flowing to the compressor **2** to be increased, which in turn increases the temperature of the refrigerant at the outlet **3** of the compressor. Therefore, the cooling device **6** releases a greater amount of thermal energy. At the same time, the internal heat exchanger **11** lowers the temperature of the refrigerant fed to the evaporator **16,** thus providing an improved heat transfer between the evaporator **16** and ambient air. In this manner, the internal heat exchanger **11** may be used to increase the efficiency of the air conditioning system.

[0012] Fig. 2 shows a further schematic illustration of the internal heat exchanger **11.** In this example, it is shown as a U-shaped bent pipe **22.** It will be appreciated that the exact shape of the heat exchanger will depend upon its application. However, in certain applications, but not all, bending of the heat exchanger **11** is required. Where it is required, the coaxial tube should be able to be bent sufficiently without causing the fluid flow channels or conduits to collapse or break. The bent pipe **22** has two legs **23, 24,** that are bent away from each other at their upper ends.

[0013] The high-pressure inlet **9** and the high-pressure outlet **12** are in fluid connection with the remainder of the system 1 at position **26a.** The low-pressure inlet **18** and the low-pressure outlet **19** of the internal heat exchanger **11** are in fluid connection with the remainder of the system 1 at position **26b.** As can be seen from the figure, positions **26a** and **26b** are located at or relatively close to the terminations of at the upper ends of the bent pipe 22.

[0014] Referring now to Figs. 3a-3d, the structure of the internal heat exchanger **11** will be described in more detail. Fig. 3a shows a perspective view of the internal heat exchanger **11** of a first embodiment in its assembled state but prior to being bent into its final U-shaped configuration. As can be seen from the figure, the internal heat exchanger **11** includes an outer tube **30,** and inner tube **32,** of which end portions **32a** and **32b** are visible from this figure Both the outer tube **30** and inner tube **32** being designed as refrigerant conduits. The inner tube **32** is located inside and runs the entire length of the outer tube **30.** The internal and external diameters of the outer tube **30** are 18mm and 20mm, respectively. The internal and external diameters of the parts of the inner tube **32** that extend beyond the outer tube **30** and can be seen in the figure are 12mm and 15mm, respectively. It will be understood that the dimensions of the outer tube **30** and inner tube **32** are selected for a given application and will therefore change in dependence upon application. The inner diameter of the outer tube **30** may from range 9-19mm for automotive or car applications, 20-39mm for bus applications and, 23-50mm for train applications. In one example having R-134a as the refrigerant, the outer tube is 24mm outer diameter with a 20mm inner diameter. The starting material, or base tube, for the inner tube is 18mm outer diameter with an inner diameter of 15mm.

[0015] Also shown in the figure are the high-pressure inlet **9** and the high-pressure outlet **12** of the internal heat exchanger **11.** Each of these is connected to a suitable orifice in the outer tube **30** using a conventional process such as welding or brazing. The weld points are referenced **34** in the figure. In this manner, a fluid connection is formed between the high-pressure inlet **9** and the high-pressure outlet **12** via the outer tube **30.** The connection orifices may be machined, or otherwise manufactured using any convenient process. In this manner, the outer tube **30** may be used as a connection sleeve which allows the system costs to be reduced. The extreme end points **36** of the outer tube **30** are joined to inner tube **32** to ensure that the joint is effectively sealed against leakage of the refrigerant. Again a conventional process may be used; for example o-rings, crimping and or welding or brazing. Fig. 3b shows a photograph of an example of an internal heat exchanger **11** similar to that shown in Fig. 3a

[0016] In the figure the inner tube **32** has end portions **32a** and **32b** that are circular. These respectively form the low-pressure inlet **18** and the low-pressure outlet **19** of the internal heat exchanger **11.** In this example, the end portions **32a** and **32b** are unmodified base tube material. Therefore end portions **32a** and **32b** may be configured to be the required lengths to provide the function of low pressure tubes **21** and **17,** shown in Fig. 1. This in turn means that no suction side connection tubes are needed; thus obviating the need for costly connection processes, such as welding and eliminating the risk of refrigerant leakage at such connection points.

[0017] Between the end portions **32a** and **32b** of the inner tube **32** is a central portion **32c** that has been deformed into a helical shape along its longitudinal axis. A photograph of the exterior of a section of the deformed portion **32c** of the inner tube of the internal heat exchanger **11** according to the first embodiment is shown in Fig. 3c. The central portion **32c** may be deformed using any convenient deforming procedure. In the present example it is deformed through a repeated clamping process. However, other deforming processes or apparatus, such as a press or hammer, may be used. In this example, the clamping process is implemented using shaped opposing clamping surfaces to achieve the desired exterior profile of the portion **38b.** The marks **38a** left in the outer surface of the deformed portion **32c** by the action of the clamping process may be seen in Fig. 3c. Furthermore, it can be seen from Fig. 3c that the deformed portion **32c** has a helical profile. This helical profile can be more clearly seen from the schematic illustration of a section of portion **32c** illustrated in Fig. 3d.

[0018] Referring to Fig. 4 the method of manufacturing elliptical helix of central portion **32c,** according to this example, will now be described. Fig. 4 shows an image schematically illustrating a part of the inner tube **32,** including part of central portion **32c,** arranged about its longitudinal axis **42.** As can be seen from the figure, the left hand end **32a** of the inner tube **32** is not deformed and is circular is cross section. Adjacent the left hand end **32a** end of the inner tube **32** is portion **44a** that has been deformed to an approximate elliptical shape of predetermined dimensions. These dimensions may be controlled using the parameters of the deforming process; for example the linear extent of the clamping operation and the shape, dimensions and material properties of the clamping surfaces.

[0019] In the figure, the major axis **46a** of the elliptical portion **44a** is shown orientated vertically. When the clamp is removed from portion **44a** of the inner tube **32,** the inner tube **32** is advanced a fixed predetermined distance along its longitudinal axis **42** to bring the portion **44b** of the tube adjacent the clamping surfaces and the inner tube **32** is rotated by a fixed angle in a given direction about its longitudinal axis; in this example 45 degrees. The clamping operation is then repeated. This process is then repeated along the desired length of central portion **32c** of the inner tube **32,** as is illustrated by deformed portions 44b - **44f.** In this manner an approximate helical structure of approximately fixed helical pitch and approximately constant elliptical cross section may be formed. With the exception of its helical form, the central portion **32c** of the inner tube **32** is free or substantially free of projections and is relatively smooth in both its circumferential direction and its longitudinal direction. The inventors have found that this process of manufacture may be largely automated by using a bending machine set to zero bend radius. Thus, the creation of the helical structure of the central portion **32c** of the inner tube **32** may be a relatively rapid and inexpensive process.

[0020] Once the inner tube **32** is formed, it is assembled with the outer tube **30,** by inserting the inner tube **32** inside the outer tube **30.** The fit between the inner tube **32** and the outer tube **30** may be any convenient fit, such as a loose fit or a slight interference fit. Thus, inner tube **32** and the outer tube **30** may be assembled by hand or be automated. The welding or braising, including crimping if this is required, of the extreme end points **36** of the outer tube **30** to inner tube **32** may then be carried out. This may be done in the region where the non-deformed end sections **32a** and **32b** of the inner tube **32** transition into the adjacent deformed portion **32c.**

[0021] Fig. 5c shows a cross sectional view, in the direction of arrows A-A shown in Fig. 3a, of the internal heat exchanger **11,** and illustrates the inner tube **32** and the outer tube **30** once assembled. As can be seen from the figure, the inner tube **32** forms an approximate ellipse, the major axis of which is approximately equal to the internal diameter of the outer tube **30;** i.e. 18mm. It will be understood that the cross sectional profile of the inner tube **32** could be varied either to meet heat exchange requirements or in order to meet manufacturing requirements. For example as an ellipse, as is illustrated in Fig. 5a could be used. Other examples could include a triangular or quadrilateral shape, such as an approximate square as is illustrated in Fig. 5b could also be used. Indeed, other cross sectional profiles may be contemplated, which have increased numbers of sides.

[0022] In this example shown in Fig. 5c, the inner tube **32** contacts the inner surface of outer tube **30** at points **56a** and **56b,** thus forming two substantially line contacts between the outer surface of the inner tube **32** and the inner surface of outer tube **30** which run the entire length of the helical structure of the central portion **32c** of the inner tube **32.** In this manner, two refrigerant fluid flow channels **52a** and **52b** are formed between the outer surface of the inner tube 32 and the inner surface of outer tube **30.** The fluid flow channels **52a** and **52b** carry liquid side refrigerant. In some embodiments a certain degree of fluid connection between the fluid flow channels **52a** and **52b** may be permitted. The extent of this permitted fluid connection may be dependent upon the application. A third refrigerant fluid flow channel **50** lies on the inside of the inner tube **32.** The third refrigerant fluid flow channel **50** carries refrigerant supplied to the suction side of the compressor. The three refrigerant fluid flow channels run substantially the entire length of the helical structure of the central portion **32c** of the inner tube **32.**

[0023] The third refrigerant fluid flow channel **50** has a cross sectional area which is substantially equal to, or is only marginally reduced relative to the cross sectional area of the base circular tube from which it is formed, and from which the remainder of the suction side, low pressure lines of the air conditioning system **1,** are made. This means that the pressure drop caused per unit length of the fluid flow channel **50** is substantially the same as, or not significantly increased relative to, that of the base circular tube from which it is formed, such as low pressure line **21.** By avoiding significant pressure loss on the suction side of the internal heat exchanger **11,** a considerable loss in the efficiency of the air conditioning system 1 may be avoided, especially in systems operating at lower pressures.

[0024] In addition, the inventors have surprisingly discovered that the creation of the helical structure of the central portion **32c** of the inner tube **32** does not cause a significant or measurable drop in pressure in the fluid flow channel **50** relative to a correspondingly profiled tube with no helical structure. The surprising lack of pressure drop in the suction side of the internal heat exchanger **11** of the present embodiment may strongly contribute to the efficiency of the air conditioning system **1.**

[0025] Whilst in applications for which the internal heat exchanger **11** of the present embodiment is designed benefit from no significant drop per unit length in pressure in the fluid flow channel **50** relative to a correspondingly profiled tube with no helical structure, it will be appreciated that in other applications of the invention a greater pressure drop may be permitted. This may be for example, 2%, 5% or 7% increase relative to a correspondingly profiled tube with no helical structure. However, in some embodiments for certain applications, the suction side pressure drop per unit length of the internal heat exchanger **11** may be up to 30% higher than that of the normal suction side line. In other embodiments this figure may be 10% or 20%.

[0026] It will be appreciated that in certain known heat exchangers, in which the design causes such a pressure drop, it may not be easy to remedy. One reason for this is that the technical characteristics of the low pressure fluid flow channel of the heat exchanger may not be easily changed to overcome this problem. For example, it may not be possible to change the cross sectional area of the channel due to space constraints or bending constraints. Additionally, this may not be possible due to the fact that manufacturing costs may be unduly increased due to increased operations being required. Furthermore, it may not be possible to change the internal geometry or flow characteristics of the low pressure fluid flow channel since this may adversely affect the heat exchanging characteristics of the device.

[0027] As can be see from Fig. 5c, the area across which heat may be exchanged between fluid flow channel 50 and each of fluid flow channels **52a** and **52b** is large, being approximately equivalent to half of the external area of the inner tube **32.** Moreover, due to the cross sectional shape of the refrigerant fluid flow channels **52a** and **52b** the efficiency of heat exchange between the flow channel **50** and each of fluid flow channels **52a** and **52b** is increased. The fluid flow channels **52a** and **52b** are approximately crescent shaped, having a relatively small height or thickness in the radial direction and a relatively high length of contact with the external circumference of the inner tube **32.** This length of contact is illustrated, in the case of fluid flow channels **52a** by line **58** in the figure. It will be appreciated that this line of contact provides a convex heat transfer surface (the external surface of the inner tube **32)** against which the fluid in fluid flow channels **52a** and **52b** flows; and thereby a large and efficient heat exchange surface over the length of the fluid flow channels **52a** and **52b.**

[0028] Fig. 6 illustrates the flow of refrigerant in the internal heat exchanger **11** according to the present embodiment. The refrigerant flowing in refrigerant fluid flow channel **50** is referenced **60** and the refrigerant flowing in refrigerant fluid flow channels **52a** and **52b** is referenced **62a** and **62b,** respectively. As can be seen from the figure, in this example the refrigerant flowing in refrigerant fluid flow channels **52a** and **52b** follows a helical path along the internal heat exchanger **11** and completes three complete cycles around the fluid in fluid flow channel **50.**

[0029] It will be understood that the heat exchange characteristics required for a different applications will vary. Accordingly, the heat transfer surface of the present embodiment may be varied. Clearly, the exterior dimensions, such as length and diameter, of the internal heat exchanger may be varied where space permits. Where this is not possible or not desired, parameters of the inner tube **32** may be varied as is illustrated in Fig. 7. Fig. 7 illustrates part of the image of Fig. 4 illustrating several deformed portions **44** of the inner tube **32;** where:

"a" = width of base form, determined by the height of the base form if the cross sectional area is equal to the base, or starting, material tube;

"b" = height of base form:

"c" = depth of the of base form along the longitudinal axis of the inner tube 32

"**d**" = distance between two deformations

"e" = angle between symmetry axis of two deformations

"f" = length of straight portion of the base form, which depends upon **"a"** and **"b"** and is zero if the form is elliptical.

[0030] The heat transfer surface, the flow velocity and therefore the heat transfer may be adjusted by modifying the geometry of the inner tube **32.** The parameters **"a", "b"** and **"f"** determine the cross section of the liquid flow channels **52a** and **52b** and therefore the flow velocity and the heat transfer coefficient. The parameters **"c"** and **"e"** determine heat exchange, or contact length and therefore the liquid side heat transfer surface. In general:

(i) the efficiency of the internal heat exchanger **11** may be increased by decreasing **"c"** and **"e";** i.e. by increasing the number of deformations per unit length of the inner tube **32** and decreasing the slope of the helix; this may be in the range of 20 to 45 degrees for example;

(ii) the efficiency of the internal heat exchanger **11** may be decreased by increasing **"c"** and **"e";** i.e. by decreasing the number of deformations per unit length of the inner tube **32** and increasing the slope of the helix; this may be in the range of 45 to 90 degrees for example.

[0031] It will be appreciated that if the internal heat exchanger **11** is to be formed as U-shaped pipe or other shape, the internal heat exchanger **11** should have sufficient bending stability. The bending stability of the internal heat exchanger **11** may be increased by decreasing the value of parameter "**f**".

[0032] It will be understood that the above described embodiments give rise to certain advantages. The contours of the inner tube **32** can be placed anywhere along, or even along only a part of, the length of the inner tube **32.** Moreover, heat transfer may be adjusted by changing the geometry of the interface between the inner tube **32** and the outer tube **30,** and this may be done without significantly changing the forming tool, such as a clamp, or process used. This provides considerable flexibility in terms or manufacturing. Heat exchanger applications with different performance criteria may be achieved without having to significantly modify the manufacturing process or tooling. As the inner tube may be made from standard tubing material, it is low cost. No expensive extrusions are required and no suction side connection tubes are needed, which may help to ensure that manufacturing is simplified and reliability of the system is increased. Bending flexibility may be adjusted by altering the geometry of the deformed tube. The outer tube **30** may be used as a connection sleeve which further allows the system costs to be reduced. Despite the fact that that low-pressure channel may be particularly large, reducing the tendency for suction side pressure drop, a relatively small outside diameter may be achieved.

[0033] It will also be understood that various changes may be made to the above described embodiments. For example, whilst the internal heat exchangers of the embodiments have been described such that the high and low pressure fluid flows through the heat opposite directions, or "counter current", these embodiments could also be implemented using a "same direction" implementation. Furthermore, whilst the refrigerant used in the above described embodiments is R-134a, other refrigerants could equally be used. For example, other low pressure refrigerants or refrigerants that work at high pressures, such as carbon dioxide. Moreover, although the above described embodiments have been described in relation to automotive applications, it will be appreciated that the invention may be applied to a wide range of other applications. These may include for example, busses, lorries, trains and non-mobile applications. Additionally, whilst the above described embodiments have been described as utilizing base tube material that is circular in cross section, other cross sections could be used, such as elliptical cross sections.

[0034] The preceding description has been presented only to illustrate and describe exemplary embodiments of the methods and systems of the present invention. It is not intended to be exhaustive or to limit the invention to any precise form disclosed. It will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the claims. The invention may be practiced otherwise than is specifically explained and illustrated without departing from its spirit or scope. The scope of the invention is limited solely by the following claims.

Claims

1. A heat exchanger comprising an outer conduit and an inner conduit, arranged inside of and along the longitudinal axis of the outer conduit, the inner conduit and the outer conduit being arranged to form a fluid flow channel between the inner surface of the outer conduit and the outer surface of the inner conduit, the fluid flow channel having a cross sectional form, in a plane substantially perpendicular to the longitudinal axis of the outer conduit, that is elongate being substantially greater in the circumferential direction of the outer conduit than in the radial direction of the outer conduit, **characterized in that** the inner conduit has a plurality of zones distributed along its axial length at which the inner conduit is locally de-

formed, each zone comprising (i) a region of decreased outer dimension of the inner conduit located at a first angular position in a plane substantially perpendicular its axial length, and (ii) a corresponding region of increased outer dimension of the inner conduit at a second angular position in a plane substantially perpendicular its axial length, the region of decreased outer dimension corresponding to the fluid flow channel and the region of increased outer dimension corresponding to a point of contact between the inner and the outer conduits, and that the fluid flow channel is arranged in a helical shape along the longitudinal axis of the outer conduit..

2. A heat exchanger according to claim 1, wherein the inner conduit is deformed such that it has a cross sectional form, in a plane substantially perpendicular to the longitudinal axis of the outer conduit, that is substantially oval (non-circular ellipse), triangular or quadrilateral, providing respectively two, three or four fluid flow channels separated respectively by two, three or four points of contact between the outer conduit and the inner conduit.

3. A heat exchanger according to claim 1 or 2, wherein the cross sectional form of the fluid flow channel is substantially crescent-shaped.

4. A heat exchanger according any of claims 1 to 3, wherein the part of the outer surface of the inner conduit defining the fluid flow channel presents a substantially convex surface to the interior of the fluid flow channel.

5. A heat exchanger according to any of claims 1 to 4, wherein the deformations are discrete deformations.

6. A heat exchanger according any of claims 1 to 5, wherein the deformations are nonoverlapping.

7. A heat exchanger according to any one of claims 1 to 5, wherein the deformations are continuous along the longitudinal axis of the inner conduit.

8. A heat exchanger according to any of claims 1-7, wherein the inner refrigerant conduit, along the length of the outer refrigerant conduit, comprises a cross sectional area which is substantially equal to, or is only marginally reduced relative to an equivalent non-deformed conduit so that the pressure drop caused per unit length of the inner refrigerant conduit is substantially the same as, or not significantly increased relative to the pressure drop of the equivalent non-deformed conduit.

9. A method of manufacturing a heat exchanger comprising an outer conduit and an inner conduit arranged inside of and along the longitudinal axis of the outer conduit, the method comprising:

locally deforming the inner conduit at a plurality of positions distributed along its axial length, such that at each position the outer dimension of the inner conduit is reduced;
assembling the deformed inner conduit with the outer conduit such that the inner conduit substantially forms at least two line contacts with the outer conduit and at least two substantially separate fluid flow channels between the inner surface of the outer conduit and the outer surface of the inner conduit, **characterized by** applying a deformation operation at the inner conduit such that at each position the outer dimension of the inner conduit is reduced at a first angular position in a plane substantially perpendicular its axial length, and the outer dimension of the inner conduit is increased at a second angular position in a plane substantially perpendicular its axial length, and progressively rotating the inner tube relative to the deforming operation as the inner conduit is deformed at the plurality of positions along its axial length, such that the fluid flow channel in the assembled heat exchanger follows a helical path along the longitudinal axis of the outer conduit..

10. A method according to claim 9, wherein the deforming operation at each of the plurality of positions is a discrete operation, such as a clamping or an impact operation.

11. A method according to claim 9, wherein the deforming operation at each of the plurality of positions is a continuous deforming process such as rolling.

12. A method according to any one of claims 9 to 11, wherein the base conduit material is a tube of substantially circular cross section.

13. A method according to any one of claims 9 to 12, wherein the deforming operation utilises one or more profiled deforming elements to provide the inner conduit with an oval, triangular or quadrilateral cross sectional profile.

14. Method according to any of claims 9 to 13, wherein the helix shape of the inner refrigerant conduit is manufactured by fixing a tube with a given cross-sectional shape, preferably a circular shape, at a fixed angle in a given direction of the longitudinal axis of the tube; forming, preferably clamping or sledging, the fixed tube in order to create a local deformation of the tube, rotating the tube to another a fixed angle in a given direction of its longitudinal axis, preferably rotating the tube by steps of 45°, deforming the tube at a new position along the longitudinal

axis with the new fixed angle, and repeating this step until the desired helix or spiral shape is created.

15. Method according to any of claims 9 to 14, wherein the forming is automated by using a bending machine set to zero bend radius.

Patentansprüche

1. Wärmetauscher umfassend eine äußere Leitung und eine innere Leitung, die innerhalb und entlang der Längsachse der äußeren Leitung angeordnet ist, wobei die innere Leitung und die äußere Leitung angeordnet sind, um einen Fluidströmungskanal zwischen der inneren Fläche der äußeren Leitung und der äußeren Fläche der inneren Leitung zu bilden, wobei der Fluidströmungskanal eine Querschnittsform in einer zur Längsachse der äußeren Leitung im Wesentlichen senkrechten Ebene aufweist, die länglich ist, die in der Umfangsrichtung der äußeren Leitung im Wesentlichen größer als in der radialen Richtung der äußeren Leitung ist, **dadurch gekennzeichnet, dass** die innere Leitung mehrere Zonen aufweist, die entlang ihrer axialen Länge verteilt sind, an welchen die innere Leitung lokal verformt ist, wobei jede Zone (i) einen Bereich mit verringerter äußerer Abmessung der inneren Leitung, der in einer ersten Winkelstellung in einer zu ihrer axialen Länge im Wesentlichen senkrechten Ebene liegt, und (ii) einen entsprechenden Bereich mit vergrößerter äußerer Abmessung der inneren Leitung in einer zweiten Winkelstellung in einer zu ihrer axialen Länge im Wesentlichen senkrechten Ebene umfasst, wobei der Bereich mit verringerter äußerer Abmessung dem Fluidströmungskanal entspricht und der Bereich mit vergrößerter äußerer Abmessung einer Kontaktstelle zwischen der inneren und äußeren Leitung entspricht, und dass der Fluidströmungskanal in einer Spiralform entlang der Längsachse der äußeren Leitung angeordnet ist.

2. Wärmetauscher nach Anspruch 1, wobei die innere Leitung derart verformt ist, dass sie eine Querschnittsform in einer zur Längsachse der äußeren Leitung im Wesentlichen senkrechten Ebene aufweist, die im Wesentlichen oval (nicht-kreisförmige Ellipse), dreieckig oder viereckig ist, vorausgesetzt, jeweils zwei, drei oder vier Fluidströmungskanäle sind jeweils durch zwei, drei oder vier Kontaktstellen zwischen der äußeren Leitung und der inneren Leitung getrennt.

3. Wärmetauscher nach Anspruch 1 oder 2, wobei die Querschnittsform des Fluidströmungskanals im Wesentlichen sichelförmig ist.

4. Wärmetauscher nach einem der Ansprüche 1 bis 3, wobei der Teil der äußeren Fläche der inneren Leitung, der den Fluidströmungskanal definiert, eine im Wesentlichen konvexe Fläche zum Inneren des Fluidströmungskanals aufweist.

5. Wärmetauscher nach einem der Ansprüche 1 bis 4, wobei die Verformungen separate Verformungen sind.

6. Wärmetauscher nach einem der Ansprüche 1 bis 5, wobei die Verformungen sich nicht überlagern.

7. Wärmetauscher nach einem der Ansprüche 1 bis 5, wobei die Verformungen entlang der Längsachse der inneren Leitung durchgehend sind.

8. Wärmetauscher nach einem der Ansprüche 1 - 7, wobei die innere Kältemittelleitung entlang der Länge der äußeren Kältemittelleitung einen Querschnittsbereich umfasst, welcher bezüglich einer entsprechenden nicht verformten Leitung im Wesentlichen gleich oder nur geringfügig verkleinert ist, so dass der Druckabfall, der pro Längeneinheit der inneren Kältemittelleitung verursacht wird, im Wesentlichen derselbe ist wie der Druckabfall der entsprechenden nicht verformten Leitung oder bezüglich diesem nicht deutlich vergrößert ist.

9. Verfahren zum Herstellen eines Wärmetauschers umfassend eine äußere Leitung und eine innere Leitung, die innerhalb und entlang der Längsachse der äußeren Leitung angeordnet ist, wobei das Verfahren Folgendes umfasst:

lokales Verformen der inneren Leitung in mehreren Positionen, die entlang ihrer axialen Länge verteilt sind, so dass in jeder Position die äußere Abmessung der inneren Leitung verringert ist;
Zusammenbauen der verformten inneren Leitung mit der äußeren Leitung, so dass die innere Leitung im Wesentlichen mindestens zwei Linienberührungen mit der äußeren Leitung und mindestens zwei im Wesentlichen getrennte Fluidströmungskanäle zwischen der inneren Fläche der äußeren Leitung und der äußeren Fläche der inneren Leitung bildet, **gekennzeichnet durch** das Anwenden eines Verformungsvorgangs an der inneren Leitung, so dass in jeder Position die äußere Abmessung der inneren Leitung in einer ersten Winkelstellung in einer zu ihrer axialen Länge im Wesentlichen senkrechten Ebene verringert wird, und die äußere Abmessung der inneren Leitung in einer zweiten Winkelstellung in einer zu ihrer axialen Länge im Wesentlichen senkrechten Ebene vergrößert wird, und progressives Drehen des inneren Rohrs bezüglich des Verformungsvor-

gangs, wenn sich die innere Leitung in den mehreren Positionen entlang ihrer axialen Länge verformt, so dass der Fluidströmungskanal in dem zusammengebauten Wärmetauscher einem schraubenförmigen Weg entlang der Längsachse der äußeren Leitung folgt.

10. Verfahren nach Anspruch 9, wobei der Verformungsvorgang in jeder der mehreren Positionen ein separater Vorgang, wie zum Beispiel ein Klemm- oder ein Einschlagvorgang, ist.

11. Verfahren nach Anspruch 9, wobei der Verformungsvorgang in jeder der mehreren Positionen ein durchgehender Verformungsprozess, wie zum Beispiel Walzen, ist.

12. Verfahren nach einem der Ansprüche 9 bis 11, wobei das Grundleitungsmaterial ein Rohr mit im Wesentlichen kreisförmigem Querschnitt ist.

13. Verfahren nach einem der Ansprüche 9 bis 12, wobei der Verformungsvorgang ein oder mehrere profilierte Verformungselemente verwendet, um die innere Leitung mit einem ovalen, dreieckigen oder viereckigen Querschnittsprofil zu versehen.

14. Verfahren nach einem der Ansprüche 9 bis 13, wobei die Schraubenform der inneren Kältemittelleitung durch Fixieren eines Rohrs mit einer gegebenen Querschnittsform, vorzugsweise einer kreisförmigen Form, in einem fixierten Winkel in einer gegebenen Richtung der Längsachse des Rohrs; Bilden, vorzugsweise Klemmen oder Hämmern, des fixierten Rohrs, um eine lokale Verformung des Rohrs zu schaffen, Drehen des Rohrs in einen anderen fixierten Winkel in einer gegebenen Richtung seiner Längsachse, vorzugsweise Drehen des Rohrs in 45°-Schritten, Verformen des Rohrs in einer neuen Position entlang der Längsachse mit dem neuen fixierten Winkel und Wiederholen dieses Schritts, bis die gewünschte Schrauben- oder Spiralform geschaffen wird, hergestellt wird.

15. Verfahren nach einem der Ansprüche 9 bis 14, wobei das Bilden durch Verwenden einer Biegemaschine, die auf einen Biegeradius von Null eingestellt ist, automatisiert wird.

Revendications

1. Echangeur de chaleur comprenant une conduite extérieure et une conduite intérieure, agencée à l'intérieur et le long de l'axe longitudinal de la conduite extérieure, la conduite intérieure et la conduite extérieure étant agencées pour former un canal d'écoulement fluidique entre la surface intérieure de la conduite extérieure et la surface extérieure de la conduite intérieure, le canal d'écoulement fluidique ayant une forme en coupe transversale, dans un plan sensiblement perpendiculaire à l'axe longitudinal de la conduite extérieure, qui est allongée sensiblement plus grande dans la direction circonférentielle de la conduite extérieure que dans la direction radiale de la conduite extérieure, **caractérisée en ce que** la conduite intérieure a une pluralité de zones réparties le long de sa longueur axiale au niveau desquelles la conduite intérieure est déformée localement, chaque zone comprenant (i) une région de dimension extérieure diminuée de la conduite intérieure située à une première position angulaire dans un plan sensiblement perpendiculaire à sa longueur axiale, et (ii) une région correspondante de dimension extérieure augmentée de la conduite intérieure à une seconde position angulaire dans un plan sensiblement perpendiculaire à sa longueur axiale, la région de dimension extérieure diminuée correspondant au canal d'écoulement fluidique et la région de dimension extérieure augmentée correspondant à un point de contact entre les conduites intérieure et extérieure, et **en ce que** le canal d'écoulement fluidique est agencé selon une forme hélicoïdale le long de l'axe longitudinal de la conduite extérieure.

2. Echangeur de chaleur selon la revendication 1, dans lequel la conduite intérieure est déformée de façon à avoir une forme en coupe transversale, dans un plan sensiblement perpendiculaire à l'axe longitudinal de la conduite extérieure, qui est sensiblement ovale (ellipse non circulaire), triangulaire ou quadrilatérale, fournissant respectivement deux, trois ou quatre canaux d'écoulement fluidique séparés respectivement par deux, trois ou quatre points de contact entre la conduite extérieure et la conduite intérieure.

3. Echangeur de chaleur selon la revendication 1 ou 2, dans lequel la forme en coupe transversale du canal d'écoulement fluidique est sensiblement en croissant.

4. Echangeur de chaleur selon l'une quelconque des revendications 1 à 3, dans lequel la partie de la surface extérieure de la conduite intérieure définissant le canal d'écoulement fluidique présente une surface sensiblement convexe vers l'intérieur du canal d'écoulement fluidique.

5. Echangeur de chaleur selon l'une quelconque des revendications 1 à 4, dans lequel les déformations sont des déformations discrètes.

6. Echangeur de chaleur selon l'une quelconque des revendications 1 à 5, dans lequel les déformations sont non chevauchantes.

7. Echangeur de chaleur selon l'une quelconque des revendications 1 à 5, dans lequel les déformations sont continues le long de l'axe longitudinal de la conduite intérieure.

8. Echangeur de chaleur selon l'une quelconque des revendications 1 à 7, dans lequel la conduite intérieure de fluide frigorigène, le long de la longueur de la conduite extérieure de fluide frigorigène, comprend une aire en coupe transversale qui est sensiblement égale à, ou n'est que légèrement réduite par rapport à une conduite non déformée équivalente de sorte que la chute de pression provoquée par unité de longueur de la conduite intérieure de fluide frigorigène soit sensiblement la même que, ou non augmentée de façon significative par rapport à la chute de pression de la conduite non déformée équivalente.

9. Procédé de fabrication d'un échangeur de chaleur comprenant une conduite extérieure et une conduite intérieure agencée à l'intérieur et le long de l'axe longitudinal de la conduite extérieure, le procédé comprenant :

la déformation locale de la conduite intérieure à une pluralité de positions réparties le long de sa longueur axiale, de sorte qu'à chaque position la dimension extérieure de la conduite intérieure soit réduite ;
l'assemblage de la conduite intérieure déformée avec la conduite extérieure de sorte que la conduite intérieure forme sensiblement au moins deux contacts linéaires avec la conduite extérieure et au moins deux canaux d'écoulement fluidique sensiblement séparés entre la surface intérieure de la conduite extérieure et la surface extérieure de la conduite intérieure, **caractérisé par** l'application d'une opération de déformation au niveau de la conduite intérieure de sorte qu'à chaque position, la dimension extérieure de la conduite intérieure soit réduite à une première position angulaire dans un plan sensiblement perpendiculaire à sa longueur axiale, et la dimension extérieure de la conduite intérieure soit augmentée à une seconde position angulaire dans un plan sensiblement perpendiculaire à sa longueur axiale, et la rotation progressive du tube intérieur par rapport à l'opération de déformation à mesure que la conduite intérieure est déformée à la pluralité de positions le long de sa longueur axiale, de sorte que le canal d'écoulement fluidique dans l'échangeur de chaleur assemblé suive un chemin hélicoïdal le long de l'axe longitudinal de la conduite extérieure.

10. Procédé selon la revendication 9, dans lequel l'opération de déformation à chacune de la pluralité de positions est une opération discrète, telle qu'une opération de serrage ou de frappe.

11. Procédé selon la revendication 9, dans lequel l'opération de déformation à chacune de la pluralité de positions est un processus de déformation continu tel que le laminage.

12. Procédé selon l'une quelconque des revendications 9 à 11, dans lequel le matériau de conduite de base est un tube de coupe transversale sensiblement circulaire.

13. Procédé selon l'une quelconque des revendications 9 à 12, dans lequel l'opération de déformation utilise un ou plusieurs éléments de déformation profilés pour doter la conduite intérieure d'un profil en coupe transversale ovale, triangulaire ou quadrilatérale.

14. Procédé selon l'une quelconque des revendications 9 à 13, dans lequel la forme hélicoïdale de la conduite intérieure de fluide frigorigène est fabriquée par la fixation d'un tube avec une forme en coupe transversale donnée, de préférence une forme circulaire, à un angle fixe dans une direction donnée de l'axe longitudinal du tube ; le formage, de préférence le serrage ou le calage, du tube fixe afin de créer une déformation locale du tube, la rotation du tube à un autre angle fixe dans une direction donnée de son axe longitudinal, de préférence la rotation du tube par étapes de 45°, la déformation du tube à une nouvelle position le long de l'axe longitudinal avec le nouvel angle fixe, et la répétition de cette étape jusqu'à ce que la forme hélicoïdale ou en spirale souhaitée soit créée.

15. Procédé selon l'une quelconque des revendications 9 à 14, dans lequel le formage est automatisé par l'utilisation d'une machine à cintrer réglée à un rayon de courbure nul.

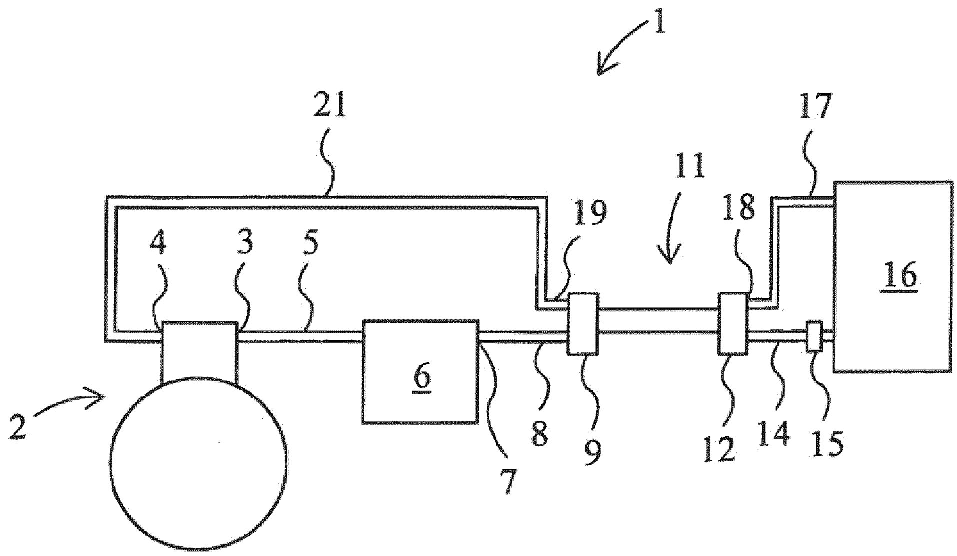

Fig. 1

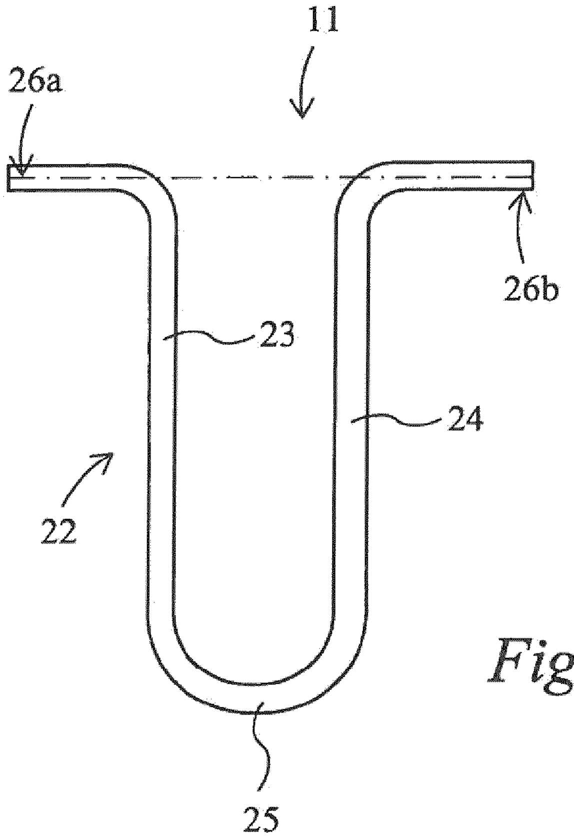

Fig. 2

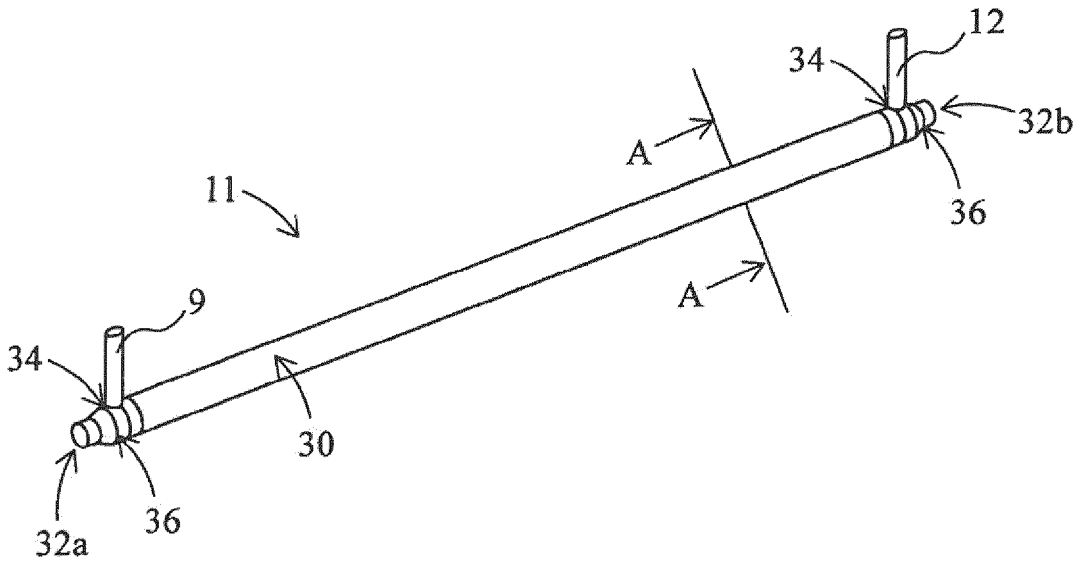

Fig. 3a

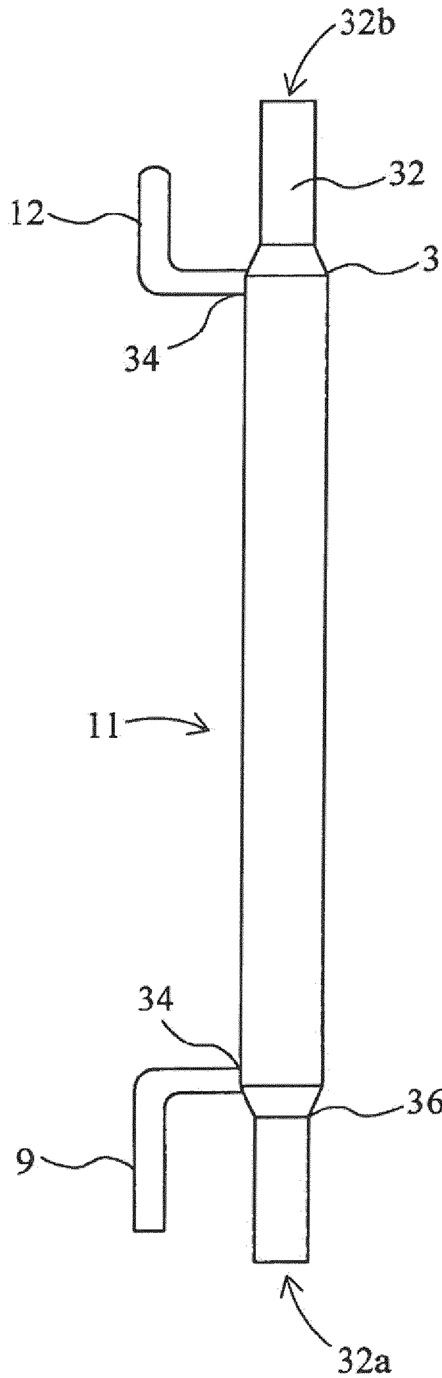

Fig. 3b

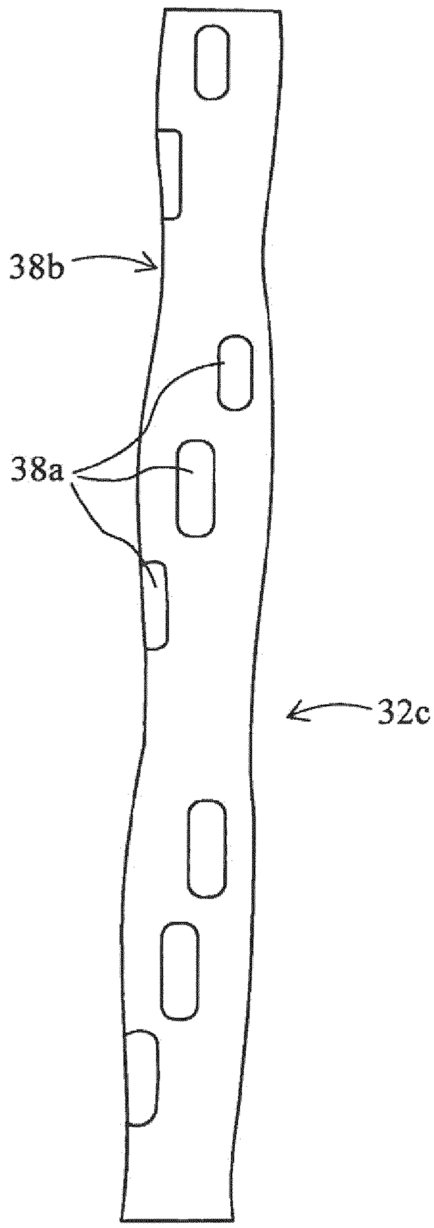

Fig. 3c

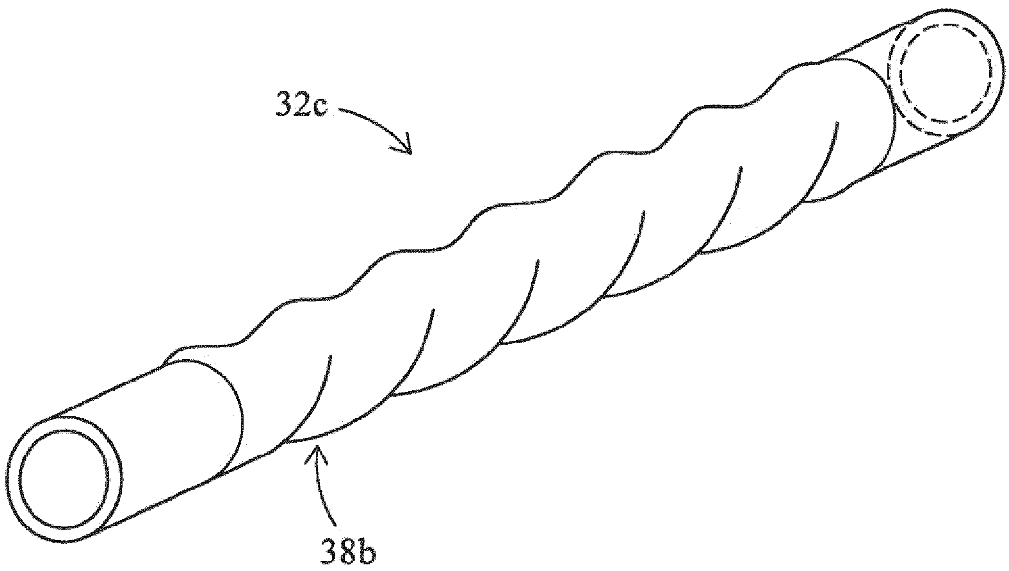

Fig. 3d

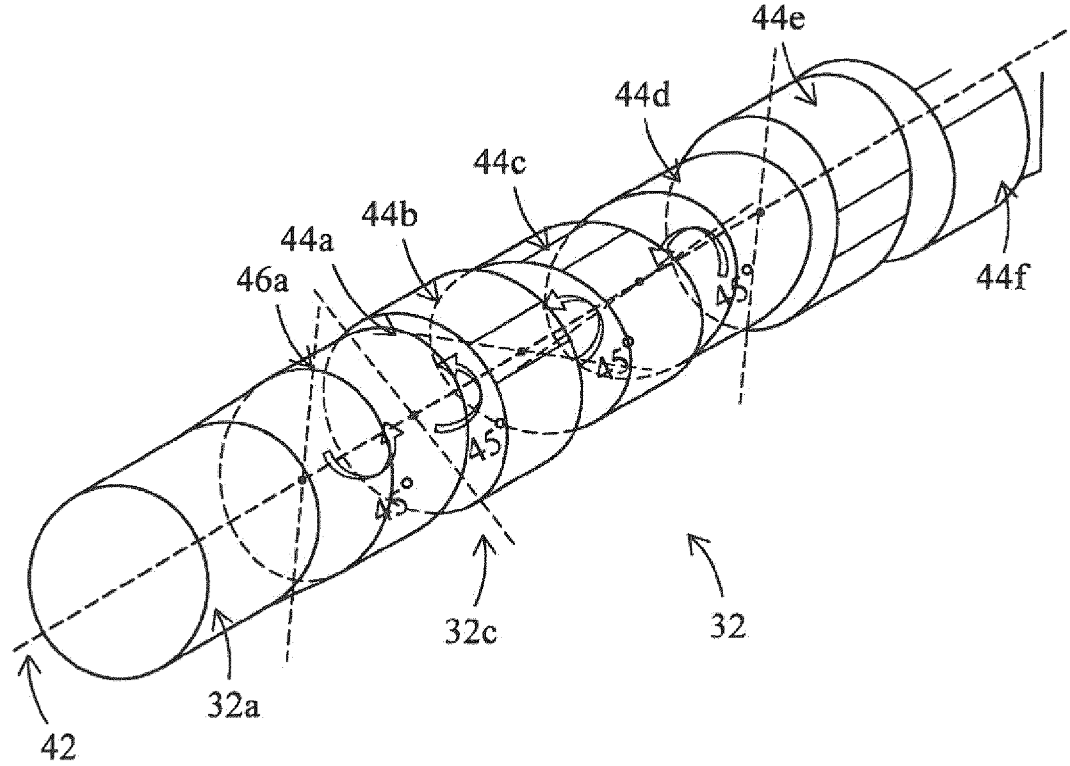

Fig. 4

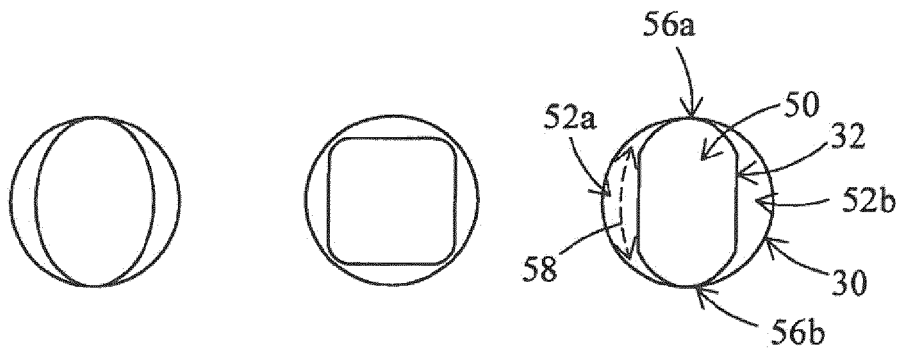

Fig. 5a *Fig. 5b* *Fig. 5c*

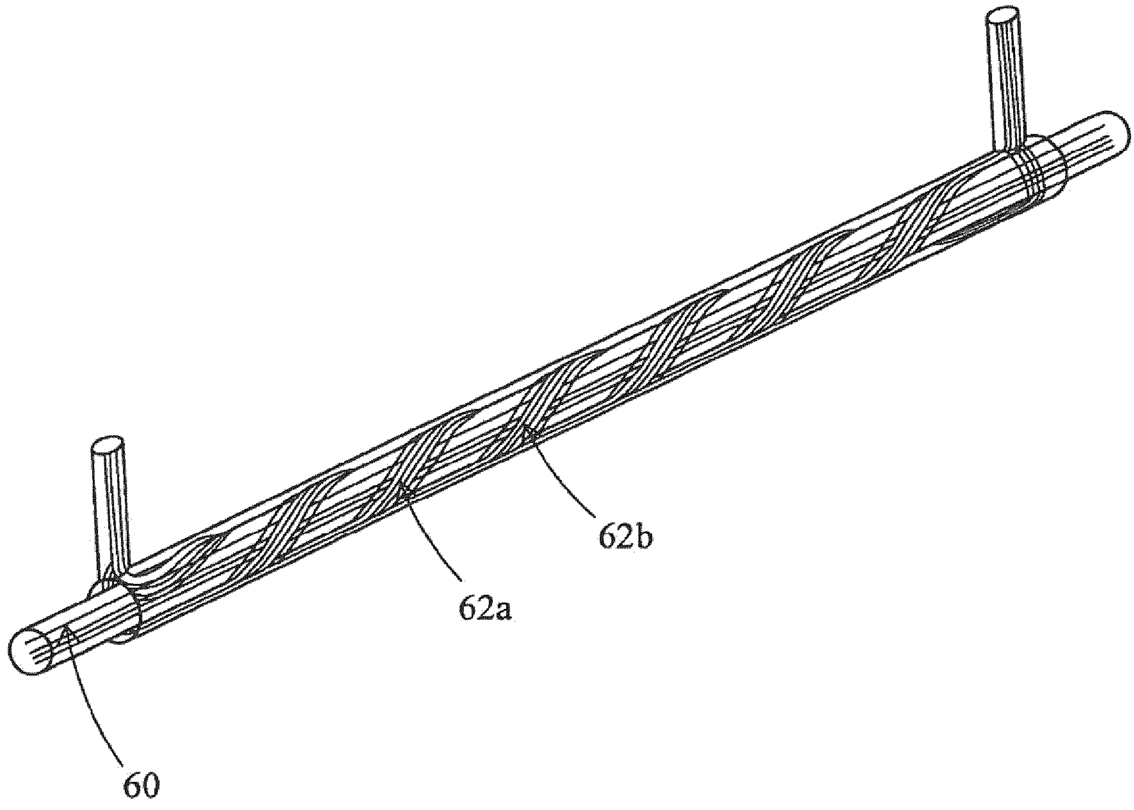

Fig. 6

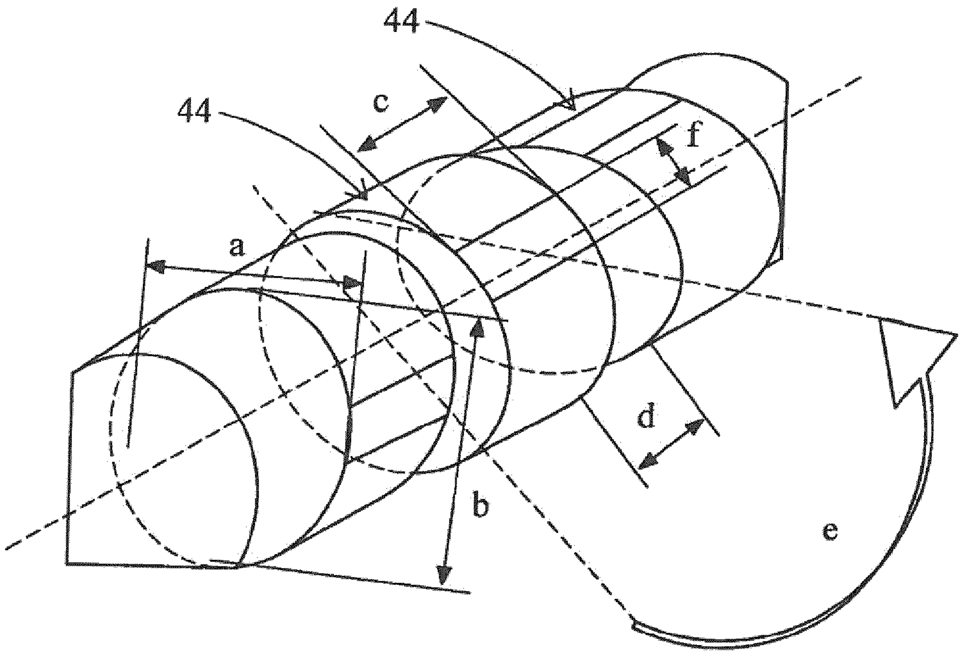

Fig. 7

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- DE 102006017816 B4 **[0002]**
- US 4194560 A **[0005]**