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(54) **SPIRAL HEAT EXCHANGER**

(57) A spiral heat exchanger (1) including a spiral body (2) formed by at least one spiral sheet (10a, 10b) wound to form the spiral body (2) forming at least a spiral-shaped first flow channel (14a) for a first medium and a spiral-shaped second flow channel (14b) for a second medium. Distance members (12) are provided to separate the windings of the spiral body (2). Each distance member (12) defines a first longitudinal direction (L) extending between two adjacent windings (10a, 10b) of said at least one spiral sheet (10a, 10b)- Each distance member (12) also defines a transversal direction (T) extending perpendicular to the longitudinal direction (L). At least some of the distance members (12) are provided with a protective sleeve (20) at least partly covering the external surface of the distance member (12). A method of making a spiral body (2) for such a spiral heat exchanger (1).

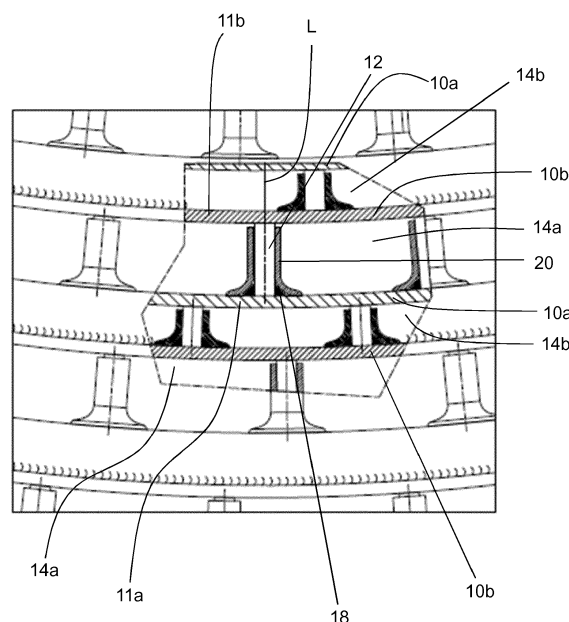


Fig.4

## Description

### Technical Field

**[0001]** The present invention generally relates to spiral heat exchangers and in particular to spiral heat exchangers with distance members, also called studs, separating the windings of spiral heat exchangers.

### Background

**[0002]** Conventionally, spiral heat exchangers are manufactured by means of a winding operation. Typically, two sheets are welded together at a respective end, wherein the welded joint will be comprised in a center portion of the sheets, or to a cylindrical center piece. The two sheets are wound around one another by use of a retractable mandrel or the like to form the spiral element of the sheets so as to delimit two separate passages or flow channels. Distance members, having a height corresponding to the width of the flow channels, may be attached to the sheets to separate the windings and allow the spiral heat exchanger to withstand higher pressures. Alternatively, one single sheet is used for the manufacturing of the heat exchanger.

**[0003]** After retraction of the mandrel, two inlet/outlet channels are formed in the center of the spiral element. A shell is formed by the outer turn of the spiral element. Alternatively, a separate shell is provided. The side ends of the spiral element are processed, wherein the spiral flow channels may be laterally closed at the two side ends in various ways. Typically, a cover is attached to each of the ends. Two connection pipes extending into the center and communicating with a respective one of the two flow channels are arranged on the covers. At the radial outer ends of the spiral flow channels a respective header is welded to the shell or the spiral element to form an outlet/inlet member to the respective flow channel.

**[0004]** US 2013/0248157 A1 discloses a spiral heat exchanger comprising heat transfer elements in the form of two spiral shaped sheet metal pieces, which are welded together. A first passage for a first heat transfer fluid and a second passage for a second heat transfer fluid are provided between the spiral shaped sheet metal pieces. Each sheet metal piece has a first surface facing the first passage and a second surface facing the second passage. Studs extend in the first passage between the first and second spiral shaped sheet metal pieces. The first surface is provided with a nickel plating, which has been applied to the first surface after the heat exchanger has been assembled by circulating a solution containing nickel ions through the first passage.

### Summary

**[0005]** It is an objective of the invention to improve the prior art. It is also an objective to provide an alternative to the prior art.

**[0006]** Another objective is to prolong the lifetime of a spiral heat exchanger.

**[0007]** Yet another objective is to prevent wear of and/or around studs of a spiral heat exchanger.

**[0008]** A further objective is to simplify the production of a spiral heat exchanger.

**[0009]** One or more of these objectives, as well as further objectives that may appear from the description below, are at least partly achieved by a spiral heat exchanger including a spiral body and a method of making a spiral body of a spiral heat exchanger according to the independent claims, embodiments thereof being defined by the dependent claims.

**[0010]** In particular, the above and further objectives are achieved by a spiral heat exchanger including a spiral body formed by at least one spiral sheet wound to form the spiral body forming at least a spiral-shaped first flow channel for a first medium and a spiral-shaped second flow channel for a second medium. The spiral body is enclosed by a substantially cylindrical shell being provided with first connecting elements communicating with the first flow channel and second connecting elements communicating with the second flow channel. Distance members are provided to separate the windings of the spiral body, wherein each distance member defines a first longitudinal direction extending between two adjacent windings of said at least one spiral sheet, wherein each distance member also defines a transversal direction extending perpendicular to the longitudinal direction. At least some of the distance members are provided with a protective sleeve at least partly covering the external surface of the distance member.

**[0011]** The protective sleeve prevents erosion of the distance members. The protective sleeve also prevents erosion of the area of the spiral sheet around the distance members. The protective sleeve reduces the wear of the distance members. The protective sleeve also reduces the wear of the area of the spiral sheet around the distance members. The lifetime of a spiral heat exchanger is thereby prolonged. The protective sleeve also increases the ability of the spiral heat exchanger to withstand abrasive media and conditions. The protective sleeve also enables that the distance members are produced in a less costly material such that the material cost and thus the cost for the spiral heat exchanger is reduced.

**[0012]** The above and further objectives are also achieved by a method of making a spiral body for a spiral heat exchanger. The method comprises providing distance members on a surface of at least one spiral sheet, providing at least some of the distance members with a protective sleeve at least partly covering the external surface of the distance member, and forming a spiral body by winding said at least one spiral sheet and optionally a further spiral sheet forming at least a spiral-shaped first flow channel for a first medium and a spiral-shaped second flow channel for a second medium, whereby the distance members separate the wind-

ings of the spiral body.

**[0013]** Still other objectives, features, aspects and advantages of the invention will appear from the following detailed description, from the attached claims as well as from the drawings.

### Drawings

**[0014]** Embodiments of the invention will now be described in more detail, by way of example, with reference to the accompanying schematic drawings, in which

Fig. 1 is a perspective view of a spiral heat exchanger according to the present invention,

Fig. 2 is a schematic view of the spiral heat exchanger shown in Fig. 1,

Fig. 3 is a perspective view of a section of the spiral body of the spiral heat exchanger shown in Fig. 1,

Fig. 4 is a side view of a section of the spiral body of the spiral heat exchanger shown in Fig. 1 with a partial cross sectional cut out,

Fig. 5 is a cross sectional side view of two adjacent windings and a distance member with a protective sleeve of the spiral body shown in Figs. 3 and 4,

Fig. 6 is a perspective view of the distance member and protective sleeve shown in Fig. 5 with a partial cut out of the protective sleeve,

Fig. 7a is a cross sectional side view of the protective sleeve shown in Figs. 3-6,

Fig. 7b is a top view of the protective sleeve shown in Fig. 7a.

### Detailed Description

**[0015]** A spiral heat exchanger normally includes at least two spiral sheets extending along a respective spiral-shaped path around a common center axis and forming at least two spiral-shaped flow channels, which are substantially parallel to each other, wherein each flow channel includes a radially outer orifice, which enables communication between the respective flow channel and a respective outlet/inlet conduit and which is located at a radially outer part of the respective flow channel with respect to the center axis, and a radially inner orifice, which enables communication between the respective flow channel and a respective inlet/outlet chamber, so that each flow channel permits a heat exchange fluid to flow in a substantially tangential direction with respect to the center axis, wherein the center axis extends through the inlet/outlet chambers at the radially inner orifice. Distance members, having a height corresponding to the width of the flow channels, may be attached to the sheets to separate the sheets, obtain a desired distance between the sheets and give rigidity to the spiral heat exchanger, in particular to the spiral body of the heat exchanger. The distance members also enable the spiral heat exchanger to operate with different pressures in the flow channels and at a high pressure of at least one of

the working fluids.

**[0016]** In figure 1 is shown a perspective view of such a spiral heat exchanger 1 according to the present invention. The spiral heat exchanger 1 is also schematically shown in figure 2. The spiral heat exchanger 1 includes a spiral body 2. The spiral body 2 is formed by at least one spiral sheet wound to form the spiral body 2. The spiral body 2 forms at least a spiral-shaped first flow channel 14a for a first medium and a spiral-shaped second flow channel 14b for a second medium. The spiral body 2 shown in figure 1 is formed by two spiral sheets wound to form the spiral-shaped first flow channel 14a and the spiral-shaped second flow channel 14b. Alternatively, the spiral body may be formed from a single sheet of metal providing two sheet portions extending from the center of the spiral body and wound to form the spiral body. The spiral body may also be formed by more than two spiral sheets, such as four spiral sheets. The spiral body may also comprise more than two spiral-shaped flow channels, such as four spiral-shaped flow channels. The spiral body 2 may be formed in a conventional way by winding two sheets of metal around a retractable mandrel, but it can also be formed in other ways. In figure 1 the spiral body 2 only has been schematically shown with a number of windings, but it is obvious that it may include further windings and that the windings are formed from the center of the spiral body 2 all the way out to the periphery of the spiral body 2. When the at least one spiral sheet is wound windings are formed, more precisely, a plurality of windings are formed.

**[0017]** The flow channels 14a, 14b may extend substantially in parallel to each other. Each flow channel 14a, 14b may be adapted to permit the respective medium to flow in a substantially tangential direction with respect to the center axis A.

**[0018]** The spiral body 2 is enclosed by a substantially cylindrical shell 4. The cylindrical shell 4 is provided with first connecting elements 8a, 9a communicating with the first flow channel 14a and second connecting elements 8b, 9b communicating with the second flow channel 14b.

**[0019]** The spiral body 2 may be enclosed by a separate shell 4, or alternatively the sheets forming the spiral body 2 may also constitute the shell by the outer winding of the sheet. The center 3 of the spiral heat exchanger 1 may be covered by a center cover 15 (schematically shown in figure 2), which may be welded onto the spiral body 2. The flow channels 14a, 14b may be covered by lids or end covers 7a, 7b, which are removably attached to the spiral heat exchanger by bolts 6 or similar.

**[0020]** Each of the end covers 7a, 7b may include a primary connecting element 8a, 8b, extending into the center and communicating with a respective one of the two flow channels, as shown in figures 1 and 2, or one of the end covers 7a, 7b may include two primary connecting elements extending into the center and communicating with a respective one of the two flow channels. At the radial outer ends of the spiral-shaped flow channels 14a, 14b, respectively a header 5 may be welded

to the shell 4 or the spiral element forming an outlet/inlet member to the respective flow channel 14a, 14b.

**[0021]** The spiral heat exchanger 1 may further be provided with gaskets, where each gasket being arranged between the end portions of the spiral body 2 and the inner surface of the end covers 7a, 7b to seal off the flow channels 14a, 14b from external leakage and to prevent bypass between the different windings or turns of the same flow channel. The gasket may be formed as a spiral similar to the spiral of the spiral body 2, which may be squeezed onto each winding of the spiral body 2. Alternatively, the gaskets may be squeezed between the spiral body 2 and the inner surface of the end covers 7a, 7b. The gaskets can also be configured in other ways as long as the sealing effect is achieved.

**[0022]** The spiral body 2 may be provided with shell studs that supports against the inner surface of the shell to resist the pressure of the working fluids of the spiral heat exchanger 1. In certain applications there is no need for shell studs.

**[0023]** As mentioned above the center of spiral body 2 may be formed by winding two sheets 10a, 10b of metal around a retractable mandrel, typically by means of a winding machine.

**[0024]** The spiral center 3 of the spiral body may be formed by a cylindrical piece on which an end of each spiral sheet is welded. Alternatively, the spiral center of the spiral body may be formed by inserting an end of each of the two sheets of metal into opposite slits of the retractable mandrel as described in WO2010/130580A1, which is incorporated herein by reference. As a further alternative, the starting material for the spiral body may be a single sheet, where a central portion of the single sheet is inserted in a mandrel and two sheet portions extending from the central portion are wound to form the spiral body as well as the spiral center. The winding machine winds the sheets to form the spiral body 2. After the winding machine has completed the winding of the sheets of metal the spiral body 2 is removed from the winding machine and the retractable mandrel is removed. The spiral body 2 is then moved to a welding station for manually or by a welding machine seal or close up the two flow channels 14a, 14b from each other and to seal the spiral center 3 from the flow channels 14a, 14b, by welding together the sheets 10a, 10b to each other. The lids or center covers 15 (schematically shown in figure 2) are welded onto each end opening of the spiral center 3 to achieve a resistant and sealed spiral center 3.

**[0025]** The spiral center 3 and the first winding of the flow channels 14a, 14b may in each end be retracted compared with the remaining windings of the flow channels 14a, 14b to enable fluids to enter/exit the spiral heat exchanger since the spiral center 3 is sealed by lids/center covers 15. The measure of the spiral center retraction may be depending on the required fluid flow, and in a preferred embodiment the retraction amounts to about 90 mm, but obviously other measures are also possible.

**[0026]** To close the two flow channels 14a, 14b from

each other and to prevent mixing of the fluid of the respective flow channels the outermost edges of the spiral body 2 may be folded so that every second winding opening is closed and the fold may be welded to secure the closure. This may be done alternately on the two ends of the spiral body 2 so that e.g. in the end of spiral body 2 later covered by the first end cover 7a the second flow channel 14b is closed and in the end of spiral body 2 later covered by the second end cover 7b the first flow channel 14a is closed. As mentioned above gaskets may be arranged between the end portions of the spiral body 2 and the inner surface of the end covers 7a, 7b to seal off and to guide the fluid through the flow channels.

**[0027]** The functionality of the spiral heat exchanger 1 may be as follows: A first medium enters the spiral heat exchanger 1 through the primary first connecting element 8a arranged in the center of the first end cover 7a of the spiral heat exchanger 1 and formed as an inlet and where the primary first connecting element 8a is connected to a piping arrangement. The primary first connecting element 8a communicates with a first flow channel 14a of the spiral body 2, which "starts" at the first open winding outside the spiral center 3 and the first medium is transported through the first flow channel 14a to the secondary first connecting element 9a, which is arranged at the periphery of the spiral body 2 and on the shell 4, formed as an outlet, where the first medium leaves the spiral heat exchanger 1. The secondary first communication element 9a is connected to a piping arrangement for further transportation of the first medium.

**[0028]** A second medium enters the spiral heat exchanger 1 through the secondary second connecting element 9b, which is arranged at the outer periphery of the spiral body 2 and on the shell 4, formed as an inlet, the secondary second connecting element 9b being connected to a piping arrangement. The secondary second connecting element 9b communicates with a second flow channel 14b of the spiral body 2 and the second medium is transported through the second flow channel 14b to the primary second connecting element 8b formed as an outlet, where the second medium leaves the spiral heat exchanger 1. The primary second connecting element 8b, which is arranged in the center of the second end cover 7b of the spiral heat exchanger 1, is further connected to a piping arrangement for further transportation of the second medium.

**[0029]** Inside the spiral body 2 a heat exchange will occur between the first and second medium, so that one medium is heated and the other medium is cooled. Depending on the specific use of the spiral heat exchanger 1 the selection of the two mediums will vary. In the above it has been described as the two mediums circulate in opposite directions through the spiral heat exchanger 1, but it is apparent that they may also circulate in parallel directions. To obtain circulation in parallel directions, the flow direction of one of the media may be reversed, such that the first medium enters through the secondary first connecting element 9a and exits through the primary first

connecting element 8a or the second medium enters through the primary second connecting element 8b and exits through the secondary second connecting element 9b. The flow directions for both media may be reversed such that the first medium enters through the secondary first connecting element 9a and exits through the primary first connecting element 8a and the second medium enters through the primary second connecting element 8b and exits through the secondary second connecting element 9b, in which case a circulation in opposite directions is obtained.

**[0030]** In the above description the term connecting element has been used as an element connected to the spiral heat exchanger and more specifically to the flow or fluid channels 14a, 14b of the spiral heat exchanger 1, but it should be understood that the connecting element is a connecting flange or pipe or similar that typically is welded onto the spiral heat exchanger and may include means for connecting further piping arrangements to the connecting element.

**[0031]** The spiral heat exchanger can be set up differently depending on the specific application of the spiral heat exchanger 1. For example, the spiral heat exchanger can be horizontally or vertically mounted, i.e. the spiral heat exchanger may be arranged with the center axis A horizontally or vertically.

**[0032]** Distance members 12 are provided to separate the windings of the spiral body 2, i.e. the windings of said at least one spiral sheet 10a, 10b of the spiral body 2, as shown in figure 4. Each distance member 12 defines a first longitudinal direction L extending between two adjacent windings 11a, 11b of said at least one spiral sheet 10a, 10b, as seen in figure 4 and 5. For each distance member 12, the longitudinal direction L of the distance member 12 coincides with a radial direction of the spiral heat exchanger 1, i.e. with the radial direction of the spiral body 2 of the spiral heat exchanger 1. The longitudinal direction L can be seen to extend in the direction of the shortest distance between two adjacent windings 11a, 11b. Each distance member 12 also defines a transversal direction T extending perpendicular to the longitudinal direction L. The transversal direction T is perpendicular to the longitudinal direction L. For each distance member 12, the transversal direction T of the distance member 12 coincides with a tangential direction of the spiral heat exchanger 1, i.e. with the tangential direction of the spiral body 2 of the spiral heat exchanger. More precisely, the transversal direction T of each distance member 12 coincides with the tangential direction of the winding 11a of the spiral sheet 10a, 10b at the location where the distance member 12 is located on the spiral sheet 10a, 10b. The transversal direction T of each distance member 12 thus also coincides with the tangential direction of the winding 11a of the spiral sheet 10a, 10b on which the distance member 12 is located in the point where the longitudinal direction L of the distance member 12 intersects said winding 11a of the spiral sheet 10a, 10b. The spiral body 2 comprises a plurality of distance members

12.

**[0033]** Each distance member 12 is located between two adjacent windings 11a, 11b of the at least one spiral sheet 10a, 10b. The distance member 12 is located between an outer winding 11a and an inner winding 11b of the at least one spiral sheet 10a, 10b. The inner winding 11b of two adjacent windings 11a, 11b is located closer to the center of the heat exchanger 1, i.e. the center of the spiral body 2 of the heat exchanger 1, more precisely as seen in the radial direction of the spiral heat exchanger 1, than the outer winding 11a. The inner winding 11b is located closer to the center axis A than the outer winding 11a. Consequently, the outer winding 11a of two adjacent windings 11a, 11b is located more distant from the center of the heat exchanger 1, i.e. the center of the spiral body 2 of the heat exchanger 1, more precisely as seen in the radial direction of the spiral heat exchanger 1, than the inner winding 11b. The outer winding 11a is located more distant from the center axis A than the inner winding 11b.

**[0034]** The spiral sheets 10a, 10b may be provided with the distance members 12. The distance members 12 may be attached to the spiral sheets 10a, 10b. The distance members serve to form the flow channels between the sheets and typically have a height corresponding to the width of the flow channels.

**[0035]** Each distance member 12 may be attached to an outer winding 11a of two adjacent windings 11a, 11b as seen in a direction from the center of the spiral body 1, i.e. as seen from the center axis A, more precisely as seen in a radial direction from the center axis A. Each distance member 12 may be attached to an outer winding 11a of two adjacent windings 11a, 11b of the at least one spiral sheet 10a, 10b.

**[0036]** At least some of the distance members 12 are provided with a protective sleeve 20 at least partly covering the surface of the distance member 12, more precisely the external surface of the distance member, as seen in e.g. figures 3 and 4.

**[0037]** Preferably, a majority of the distance members 12 are provided with a protective sleeve 20. More preferred, substantially all, such as all, distance members 12 are provided with a protective sleeve 20.

**[0038]** The protective sleeve 20 may cover the external surface of the distance member 12. The protective sleeve 20 may cover the complete external surface of the distance member 12. However, it is in some applications sufficient that a base section 13 of the distance member 12 is covered by the protective sleeve 20, since it has been experienced that the wear is most pronounced at the base of the distance member, e.g. in the area where the distance member is attached to the outer adjacent winding of the spiral sheet. Thus, the protective sleeve 20 may cover at least the surface of a base section 13 of the distance member 12, more precisely at least the external surface of the base section 13 of the distance member 12. Preferably, the protective sleeve 12 covers a majority of the external surface of the distance member 12. Preferably, the protective sleeve 12 covers at least

75 % of the external surface of the distance member. More preferred, the protective sleeve 12 covers at least 80 %, such as at least 85 %, such as at least 90 %, such as at least 95%, of the external surface of the distance member. It may be advantageous to leave a gap between the end of the protective sleeve 20 facing the inner winding 11b and the inner winding 11b such that it is secured that the distance member abuts the inner winding 11b. This inner winding 11b can also be seen as the winding of the two adjacent windings 11a, 11b that the distance member not is attached to. Thereby, the protective sleeve may cover 80-95 % of the external surface of the distance member, such as 90-95 % of the distance member. The external surface of the distance member is to be understood as the outer surface of the distance member and more precisely the outer surface of the distance member that without the protective sleeve is subject to fluid flow. In other words, the external surface of the distance member is to be understood as the outer surface of the distance member not being in contact with any of the sheets.

**[0039]** The protective sleeve 20 may be made of a first material and the distance member 12 may be made of a second material. The first material may have a higher hardness than the second material. Thereby, the protective sleeve is made of a material having a higher hardness than the distance member, i.e. a higher hardness than the material of the distance member. By making the protective sleeve of a hard material, the ability to withstand wear increases. The first material may have a higher elongation than the second material. Thereby, the protective sleeve is made of a material having a higher elongation than the distance member, i.e. a higher elongation than the material of the distance member. By making the protective sleeve of a material having a high elongation, crack formation and rupture is avoided. With a low elongation, the protective sleeve may be too brittle and risk rupture. The hardness and elongation should preferably be balanced, such that the protective sleeve is sufficiently hard to withstand wear and has a sufficient elongation to not be too brittle in order to avoid crack formation and rupture.

**[0040]** The protective sleeve 20 may be made of a material having a Vickers hardness of 230-330 HV. Preferably, the protective sleeve is made of a material having a Vickers hardness of 250-330 HV. More preferred, the protective sleeve is made of a material having a Vickers hardness of 270-320 HV. Even more preferred, the protective sleeve is made of a material having a Vickers hardness of 280-310 HV. Even more preferred, the protective sleeve is made of a material having a Vickers hardness of 290-300 HV. Most preferred, the protective sleeve is made of a material having a Vickers hardness of about 295 HV. The maximum value of the Vickers hardness of the material of the protective sleeve may be 330 HV, such as 320 HV, such as 310 HV, such as 300 HV. The minimum value of the Vickers hardness of the material of the protective sleeve may be 230 HV, such as 250 HV, such as 270 HV such as 280 HV, such as 290

HV. These hardnesses of the protective sleeve are in particular suitable when the rest of the spiral heat exchanger, in particular the spiral sheet(s) and/or the distance members, is made of stainless steel. The Vickers hardness may be established according to the standard NF EN ISO 6507-1 (March 2006).

**[0041]** The protective sleeve 20 may be made of a material having an elongation of 30-70%. Preferably, the protective sleeve is made of a material having an elongation of 40-65%. More preferred, the protective sleeve is made of a material having an elongation of 50-60%. The maximum value of the elongation of the material of the protective sleeve may be 70%, such as 65%, such as 60%. The minimum value of the elongation of the material of the protective sleeve may be 30%, such as 40%, such as 50%. These elongations of the protective sleeve are in particular suitable when the rest of the spiral heat exchanger, in particular the spiral sheet(s) and/or the distance members, is made of stainless steel, in particular duplex stainless steel. Alternatively, the elongation may be established according to the standard NF EN ISO 6892-1 (November 2016).

**[0042]** The protective sleeve 20 is preferably made of a metallic material. The protective sleeve 20 may be made of an Inconel alloy, such as Inconel 625.

**[0043]** The distance member 12 is preferably made of a metallic material. The distance member 12 may be made of stainless steel, such as stainless steel 316, such as 316L, or duplex stainless steel, such as duplex stainless steel 2205, such as S31803 or S32205. Stainless steel 316 typically has a Vickers hardness of 228 HV and an elongation of 40 %. Duplex stainless steel 2205 typically has a Vickers hardness of maximum 309 HV and an elongation of 25%. The spiral sheets 10a, 10b are preferably made of a metallic material, which usually is but need not be the same material as the distance members 12.

**[0044]** In case the distance member 12 is made of a regular stainless steel, such as stainless steel 316, the first material, i.e. the material of the protective sleeve 20, may have a higher hardness than the second material, i.e. than the material of the distance member 12. In case the distance member 12 is made of a duplex stainless steel, such as duplex stainless steel 2205, the first material, i.e. the material of the protective sleeve 20, may have a higher elongation than the second material, i.e. than the material of the distance member 12.

**[0045]** Each distance member 12 may comprise a base section 13 attached to one of said at least one spiral sheets 10a, 10b. The base section 13 is in figure 5 schematically distinguished from the rest of the distance member by a dashed line. The protective sleeve 20 may cover at least the base section 13 of the distance member 12. Thereby the base section of the distance member is protected. Also the attachment of the distance member to the spiral sheet is protected. This secures the attachment of the distance member to the spiral sheet. Thereby, the rigidity of the spiral body is improved and deformation of

the spiral body prevented.

**[0046]** The erosion of the distance member 12 is most pronounced at the outer winding 11a of the two adjacent windings 11a, 11b that the distance member 12 is located between, i.e. at the end of the distance member 12 facing the outer winding 11a of the two adjacent windings 11a, 11b. Also the erosion of the spiral sheet 10a, 10b around the distance member 12 is most pronounced at the outer winding 11a of the two adjacent windings 11a, 11b that the distance member 12 is located between. This is caused by the fluid dynamic flow pattern in the spiral shaped flow channels.

**[0047]** By covering at least the base section 13 of the distance member 12 with the protective sleeve 20 when the distance member 12 is attached to the outer winding 11a of two adjacent windings 11a, 11b, the section of the distance member subjected to greatest erosion and wear is protected. Also erosion and wear of the portion of the spiral sheet subjected to extensive erosion may thereby be prevented. The base section 13 of the distance member 12 may be attached to the outer winding 11a of said at least one spiral sheets 10a, 10b.

**[0048]** The protective sleeve 20 may comprise a main portion 21 and a base portion 22, as shown in figure 5. The main portion 21 and the base portion 22 are in figure 5 schematically distinguished by a dashed line. The base portion 22 may have a larger transversal extension than the main portion 21, i.e. the base portion 22 may have a larger extension in the transversal direction T than the main portion 21. Thereby, the base portion 22 is enlarged compared to the main portion 21. The base portion 22 covers, and thereby protects, an area of the spiral sheet around the distance member 12, more precisely an area of the winding 11a of the spiral sheet 10a, 10b to which the distance member 12 is attached. The base portion 22 also covers the attachment of the distance member 12 to the spiral sheet 10a, 10b, such as a weld 18.

**[0049]** The base portion 22 of the protective sleeve 20 may be located at the base section 13 of the distance member 12.

**[0050]** The base portion 22 may comprise a first end 24 facing the main portion 21 and a second end 25 facing away from the main portion 21. The second end 25 may face the outer winding 11a of said two adjacent windings 11a, 11b. The base portion 22 may have an increasing transversal extension from the first end 24 towards the second end 25, i.e. the extension of the base portion 22 in the transversal direction T may increase from the first end 24 towards the second end 25. The transversal extension of the base portion 22 may increase stepwise and/or continuously from the first end 24 towards the second end 25. Preferably, the transversal extension of the base portion 22 is continuously increasing from the first end 24 towards the second end 25. The second end 25 of the base portion 22 may face the winding 11a of the spiral sheets 10a, 10b to which the distance member 12 is attached. As seen from the first end 24 to the second end 25 of the base portion 22, the transversal extension

may increase outward from a center line C of the distance member 12, as seen in figures 5 and 6.

**[0051]** An increasing transversal extension of the base portion 22 creates an advantageous flow pattern around the protective sleeve 12 such that not only erosion of the portion of the spiral sheet around the distance member that is covered by the protective sleeve is protected but also erosion of the area of the spiral sheet around the protective sleeve is prevented. Thereby, erosion of the area of the spiral sheet subjected to most intensive erosion, i.e. the area next to the distance member and the area around the distance member/protective sleeve, is prevented. The eroding effect acting on the protective sleeve is also decreased.

**[0052]** The increasing transversal extension may comprise a concave curvature 26. A concave curvature 26 obtains a flow pattern that efficiently prevents erosion of the spiral sheet around the protective sleeve as well as the protective sleeve.

**[0053]** The concave curvature 26 may be seen to be located at, or more precisely starting at, the first end 24 of the base portion 22. The concave curvature 26 may extend in the longitudinal direction L, i.e. be arranged along the longitudinal direction L. The base portion 22 may thereby be tapered towards the first end 24. More precisely, the base portion 22 may be tapered towards the first end 24 by the concave curvature 26. Preferably, the base portion 22 is tapered towards the first end 24 such that the base portion 22 at the first end 24 has substantially the same transversal extension, e.g. the same radius, as the main portion 21, in particular as the main portion 21 has at the end of the main portion 21 facing the base portion 22. The concave curvature 26 may comprise a concave radius R1. The concave radius R1 gives a flow pattern that efficiently prevents erosion of the spiral sheet around the protective sleeve as well as the protective sleeve.

**[0054]** The base portion 22 may comprise a convex curvature 27 at the second end 25. A convex curvature 27 implies a smooth transition from the protective sleeve 20 to the spiral sheet 10a, 10b and contributes to an advantageous flow pattern. The convex curvature 27 may extend in the longitudinal direction L, i.e. may be arranged along the longitudinal direction L. The convex curvature 27 may comprise a convex radius R2. The convex radius may be smaller than the concave radius.

**[0055]** The base portion 22 may have a first diameter D1 at the first end 24, as seen in figures 5 and 7a. The base portion 22 may have a second diameter D2 at the second end 25. The base portion 22 may have a third diameter D3 at a central section 28 of the base portion 22 of the protective sleeve 20. The central section 28 is located between the first end 24 and the second end 25. The concave curvature 26 connects the first end 24 and the central section 28. The convex curvature 27 connects the central section 28 and the second end 25. The concave curvature 26 overbridges the first diameter D1 and the third diameter D3. In other words, the concave cur-

vature 26 transforms the first diameter D1 to the third diameter D1. The convex curvature 27 overbridges the third diameter D3 and the second diameter D2. In other words, the convex curvature 27 transforms the third diameter D3 to the second diameter D2.

**[0056]** The main portion 21 of the protective sleeve may have a substantially cylindrical shape. The main portion 21 may have a diameter being equal to the first diameter D1 of the base portion 22.

**[0057]** The distance member 12 may have a substantially cylindrical shape. The distance member 12 are typically cylindrical and usually cut from a cylindrical rod.

**[0058]** The protective sleeve 20 may comprise a substantially cylindrical hole 29, as seen in figures 7a and 7b. The substantially cylindrical hole 29 of the protective sleeve 20 may accommodate the distance member 12. Thereby, the protective sleeve may substantially enclose the distance member. The substantially cylindrical hole 29 is preferably a through hole, in which case the distance member 12 preferably extends all through the protective sleeve 20. However, the cylindrical hole may also be a blind hole, in which case the distance member typically extends through a portion of the protective sleeve. The cylindrical hole 29 may be open at the base portion 22 and in case of a through hole also at the top of the protective sleeve 20. In case of a blind hole, the top of the protective sleeve is covered and abuts the inner winding 11b of the two adjacent windings 11a, 11b.

**[0059]** The protective sleeve 20 may be circular symmetric. Thereby, the protective sleeve 20 is symmetric and identical along all radial directions extending from the center line C and laying in a plane perpendicular to the center line C. This implies a shape that is independent on the circumferential orientation such that the protective sleeve not need any specific rotational orientation, which simplifies the assembly of the protective sleeve on the distance member. The center line C is coinciding with the longitudinal direction L of the distance member 12

**[0060]** Each distance member 12 may be attached to one of said at least one spiral sheets 10a, 10b by means of a weld 18. Each distance member 12 may be attached by means of the weld 18 to the spiral sheet 10a, 10b to which the distance member 12 is attached. Each distance member 12 may be welded to the spiral sheet 10a, 10b to which the distance member 12 is attached. More precisely, it is the base section 13 of the distance member 12 that may be attached to the spiral sheet 10a, 10b by means of a weld 18. As described above, each distance member 12 is usually attached to the outer winding 11a of the two adjacent windings 11a, 11b that the distance member 12 is arranged between. Thus, each distance member 12 may be attached to the outer winding 11a of the spiral sheets 10a, 10b by means of a weld 18. The base portion 22 may cover the weld 18. By covering the weld 18, the attachment of the distance member 12 to the spiral sheet 10a, 10b is secured. By covering the weld with the protective sleeve, the wear of the weld is decreased. This prevents that the distance member 12 is

introduced into the fluid, which may cause contamination of the fluid, clogging of the heat exchanger or other equipment located downstream as well as damage to downstream equipment.

**[0061]** The distance members 12 may be provided on a surface of at least one of said at least one spiral sheet 10a, 10b. The distance members 12 are preferably provided on a surface of each of said at least one spiral sheet 10a, 10b. In case of at least two spiral sheets 10a, 10b, the distance members 12 are preferably provided on a surface of at least two of the spiral sheets 10a, 10b. In case of two spiral sheets 10a, 10b, the distance members 12 are preferably provided on a surface of each of the two spiral sheets 10a, 10b. The distance members 12 may be provided on one surface of at least one of said at least one spiral sheet 10a, 10b. Preferably, the distance members 12 may be provided on one surface of each of said at least one spiral sheet 10a, 10b.

**[0062]** The distance members 12 may be distributed over a majority of the surface of at least one of said at least one spiral sheets 10a, 10b. The distance members 12 are preferably distributed over a majority of the surface of said at least one spiral sheet 10a, 10b. In case of two spiral sheets 10a, 10b, the distance members may thus be distributed over a majority of the surface of each of the spiral sheets 10a, 10b. The distance members 12 are preferably arranged in both the spiral-shaped first flow channel 14a and the spiral-shaped second flow channel 14b. Preferably, both the spiral-shaped first flow channel 14a and the spiral-shaped second flow channel 14b comprise a plurality of distance members 12. Preferably, the distance members 12 are distributed over at least 75 % of the surface of at least one of said at least one spiral sheets 10a, 10b. More preferred, the distance members 12 are distributed over at least 80 %, such as at least 85 %, such as at least 90 %, of the surface of at least one of said at least one spiral sheets 10a, 10b. The distance members 12 may be distributed over a majority of the surface to which the distance members are attached in each of the first flow channel 14a and the second flow channel 14b. Preferably, the distance members 12 are distributed over at least 75 %, such as at least 80 %, such as at least 85 %, such as at least 90 %, of the surface to which the distance members are attached in each of the first flow channel 14a and the second flow channel 14b. That distance members are distributed over a majority or a certain percentage (X %) of a surface implies that distance members are spread out over a majority or a certain percentage (X %) of the surface, while possibly leaving some regions, i.e. a minority or complementary percentage (100-X %), free from distance members. It does not imply that a majority or certain percentage of the surface area is covered with distance members.

**[0063]** The protective sleeve 20 may cover at least an external surface of the distance member 12 next to the outer winding 11a of said two adjacent windings 11a, 11b.

**[0064]** The protective sleeve 20 may rest at the spiral sheet 10a, 10b to which the distance member 12 is at-

tached, e.g. welded. More precisely, the base portion 22 of the protective sleeve 20 may rest at the spiral sheet 10a, 10b to which the distance member 12 is attached. The protective sleeve 20, or more precisely the base portion 22, may abut the spiral sheet 10a, 10b to which the distance member 12 is attached.

**[0065]** The distance member may have a diameter of 2-20 mm, such as 3-20 mm, such as 4-15 mm. The diameter of the distance member is typically about 5 mm or about 6 mm or about 8 mm or about 12 mm, depending on the required strength of the distance member.

**[0066]** The inner diameter of the protective sleeve, i.e. the inner diameter of the cylindrical hole 29, may be about the same as the (outer) diameter of the distance member or somewhat larger. The inner diameter of the protective sleeve may typically be about 3 % larger than the (outer) diameter of the distance member.

**[0067]** The thickness of the protective sleeve, in particular the thickness of the main portion, may be 10-100 % of the diameter of the distance member, such as 20-60 %, such as about 30 %, of the diameter of the distance member. In case of a distance member having a diameter of about 5 mm, the thickness of the protective sleeve, in particular the thickness of the main portion, may be about 1.5 mm, whereby an outer diameter of the main portion (in the embodiment shown in the figures corresponding to the first diameter D1) is about 8 mm.

**[0068]** The maximum diameter of the protective sleeve, i.e. the diameter of the protective sleeve where it has its largest diameter, in particular the maximum diameter of the base portion, may be 200-1000 % of the diameter of the distance member, such as about 300-600 %, such as 350-400 %, such as about 380-400 %, such as about 380 %, of the diameter of the distance member. In case of a distance member having a diameter of about 5 mm, the maximum diameter of the protective sleeve (in the embodiment shown in the figures corresponding to the second diameter D2), in particular the maximum diameter of the base portion, may be about 19-20 mm, such as about 19 mm. The maximum diameter of the protective sleeve, as well as the maximum diameter of the base portion, may be next to the outer winding of said two adjacent windings.

**[0069]** The concave radius R1 may typically be 3-4 mm, such as about 3.5 mm, which in particular is suitable for a protective sleeve having an outer diameter of the main portion (in the embodiment shown in the figures corresponding to the first diameter D1) being about 8 mm and a maximum diameter of the base portion being about 19-20 mm, such as about 19 mm. The convex radius R2 may typically be about 1 mm, which in particular is suitable for a protective sleeve having an outer diameter of the main portion (in the embodiment shown in the figures corresponding to the first diameter D1) being about 8 mm and a maximum diameter of the base portion being about 19-20 mm, such as about 19 mm.

**[0070]** The protective sleeve may comprise a top portion. The top portion may be devised as the base portion.

Consequently, the top portion may have a larger transversal extension than the main portion, i.e. the top portion may have a larger extension in the transversal direction than the main portion. Thereby, the top portion is enlarged compared to the main portion. The top portion covers, and thereby protects, an area of the spiral sheet around the distance member, more precisely an area of the winding of the spiral sheet to which the distance member not is attached. The top portion of the protective sleeve is located at a top section of the distance member.

**[0071]** The top portion may comprise a first end facing the main portion and a second end facing away from the main portion. The second end of the top portion may face the inner winding of said two adjacent windings. The top portion may have an increasing transversal extension from the first end of the top portion towards the second end of the top portion. The second end of the top portion may face the winding of the spiral sheet to which the distance member not is attached. As seen from the first end of the top portion to the second end of the top portion, the transversal extension increases outward from the center line of the distance member.

**[0072]** The increasing transversal extension of the top portion may comprise a concave curvature. The concave curvature of the top portion can be seen to be located at, or more precisely starting at, the first end of the top portion. The concave curvature of the top portion may extend in the longitudinal direction, i.e. be arranged along the longitudinal direction. The top portion may be tapered towards the first end. More precisely, the top portion may be tapered towards the first end of the top portion by the concave curvature of the top portion. Preferably, the top portion is tapered towards the first end of the top portion such that the top portion at the first end of the top portion has substantially the same transversal extension, e.g. the same radius, as the main portion, in particular as the main portion has at the end of the main portion facing the top portion. The concave curvature of the top portion may comprise a concave radius.

**[0073]** The top portion may comprise a convex curvature at the second end of the top portion. The convex curvature of the top portion may extend in the longitudinal direction, i.e. be arranged along the longitudinal direction. The convex curvature of the top portion may comprise a convex radius.

**[0074]** However, a protective sleeve without top portion is preferred, i.e. a protective sleeve with a main portion extending from the base portion all the way to the top of the protective sleeve.

**[0075]** The protective sleeve may be composed of at least two pieces, such as two or three pieces. The main portion of the protective sleeve may compose a first, main piece. The base portion of the protective sleeve may compose a second, base piece. The top portion of the protective sleeve may compose a third, top piece. Preferably, the protective sleeve is composed of a single piece. The single piece preferably includes the main portion and the base portion. The single piece may further include

the top portion, even though it is not preferred.

**[0076]** The above described spiral body 2 of the spiral heat exchanger 1 may be manufactured by means of a method of making a spiral body. In particular, a method of making a spiral body 2 for a spiral heat exchanger 1 may comprise

providing distance members 12 on a surface of at least one spiral sheet 10a,

providing at least some of the distance members 12 with a protective sleeve 20 at least partly covering the surface of the distance member 12, more precisely the external surface of the distance member 12,

forming a spiral body 2 by winding said at least one spiral sheet 10a and optionally a further spiral sheet 10b forming at least a spiral-shaped first flow channel 14a for a first medium and a spiral-shaped second flow channel 14b for a second medium, whereby the distance members 12 separate the windings of the spiral body 2.

**[0077]** The further spiral sheet need not be provided with any distance members. Preferably, the forming of a spiral body 2 is performed by winding said at least one spiral sheet and a further spiral sheet, i.e. at least two spiral sheets 10a, 10b. Preferably providing distance members involves providing distance members 12 on a surface of said at least one spiral sheet 10a and a surface of the further spiral sheet 10b, i.e. on a surface of at least two spiral sheets 10a, 10b. The method of making a spiral body 2 for a spiral heat exchanger 1 may be formulated as a method of making a spiral heat exchanger 1.

**[0078]** The method may further involve the above mentioned features, versions and advantages, in particular those mentioned in conjunction with the spiral body, distance members and protective sleeve. For example, the spiral body in the method may be a spiral body as specified above. The distance member in the method may be a distance member as specified above. The protective sleeve in the method may be a protective sleeve as specified above. The method may be a method of making a spiral body as specified above, e.g. a spiral body comprising a protective sleeve as specified above.

**[0079]** The foregoing has described the principles, preferred embodiments, aspects and modes of operation of the present invention. However, the description should be regarded as illustrative rather than restrictive, and the invention should not be limited to the particular embodiments and versions discussed above. The different features of the various embodiments and versions of the invention can be combined in other combinations than those explicitly described. It should therefore be appreciated that variations may be made in those embodiments and versions by those skilled in the art without departing from the scope of the present invention as defined by the following claims.

## Claims

1. A spiral heat exchanger (1) including a spiral body

(2) formed by at least one spiral sheet (10a, 10b) wound to form the spiral body (2) forming at least a spiral-shaped first flow channel (14a) for a first medium and a spiral-shaped second flow channel (14b) for a second medium,

wherein the spiral body (2) is enclosed by a substantially cylindrical shell (4) being provided with first connecting elements (8a, 9a) communicating with the first flow channel (14a) and second connecting elements (8b, 9b) communicating with the second flow channel (14b),

wherein distance members (12) are provided to separate the windings of the spiral body (2), wherein each distance member (12) defines a first longitudinal direction (L) extending between two adjacent windings (10a, 10b) of said at least one spiral sheet (10a, 10b), wherein each distance member (12) also defines a transversal direction (T) extending perpendicular to the longitudinal direction (L),

wherein at least some of the distance members (12) are provided with a protective sleeve (20) at least partly covering the external surface of the distance member (12).

2. The spiral heat exchanger according to claim 1, wherein each distance member (12) is attached to an outer winding (11a) of said two adjacent windings (11a, 11b) as seen in a direction from the center of the spiral body.

3. The spiral heat exchanger according to claim 1 or 2, wherein each distance member (12) comprises a base section (13) attached to one of said at least one spiral sheets (10a, 10b), wherein the protective sleeve (20) covers at least the external surface of the base section (13) of the distance member (12).

4. The spiral heat exchanger according to any one of claims 1-3, wherein the protective sleeve (20) comprises a main portion (21) and a base portion (22), wherein the base portion (22) has a larger transversal extension than the main portion (21).

5. The spiral heat exchanger according to claim 4, wherein the base portion (22) comprises a first end (24) facing the main portion (21) and a second end (25) facing away from the main portion (21), wherein the base portion (22) has an increasing transversal extension from the first end (24) towards the second end (25).

6. The spiral heat exchanger according to claim 5, wherein the increasing transversal extension comprises a concave curvature (26).

7. The spiral heat exchanger according to claim 6, wherein the concave curvature comprises a concave radius (R1).

8. The spiral heat exchanger according to any one of claims 4-7, wherein the main portion (21) has a substantially cylindrical shape.
  
9. The spiral heat exchanger according to any one of claims 1-8, wherein each distance member (12) is attached to one of said at least one spiral sheets (10a, 10b) by means of a weld (18), wherein the base portion (22) covers the weld (18).  
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10. The spiral heat exchanger according to any one of claims 1-9, wherein the protective sleeve (20) is circular symmetric.
  
11. The spiral heat exchanger according to any one of claims 1-10, wherein the distance members (12) are distributed over a majority of the surface of at least one of said at least one spiral sheet (10a, 10b).  
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12. The spiral heat exchanger according to any one of claims 1-11, wherein the protective sleeve (20) is made of a first material and the distance member (12) is made of a second material, wherein the first material has a higher hardness and/or a higher elongation than the second material.  
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13. The spiral heat exchanger according to any one of claims 1-12, wherein the protective sleeve (20) is made of a material having a Vickers hardness of 230-330 HV, such as 250-330 HV, such as 270-320 HV such as 280-310 HV, such as 290-300 HV, such as about 295 HV.  
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14. The spiral heat exchanger according to any one of claims 1-13, wherein the protective sleeve (20) is made of a material having an elongation of 30-70%, such as 40-65%, such as 50-60%.  
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15. A method of making a spiral body (2) for a spiral heat exchanger (1), the method comprising  
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providing distance members (12) on a surface of at least one spiral sheet (10a),  
providing at least some of the distance members (12) with a protective sleeve (20) at least partly covering the external surface of the distance member (12),  
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and  
forming a spiral body (2) by winding said at least one spiral sheet (10a) and optionally a further spiral sheet (10b) forming at least a spiral-shaped first flow channel (14a) for a first medium and a spiral-shaped second flow channel (14b) for a second medium, where-  
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by the distance members (12) separate the windings of the spiral body (2).  
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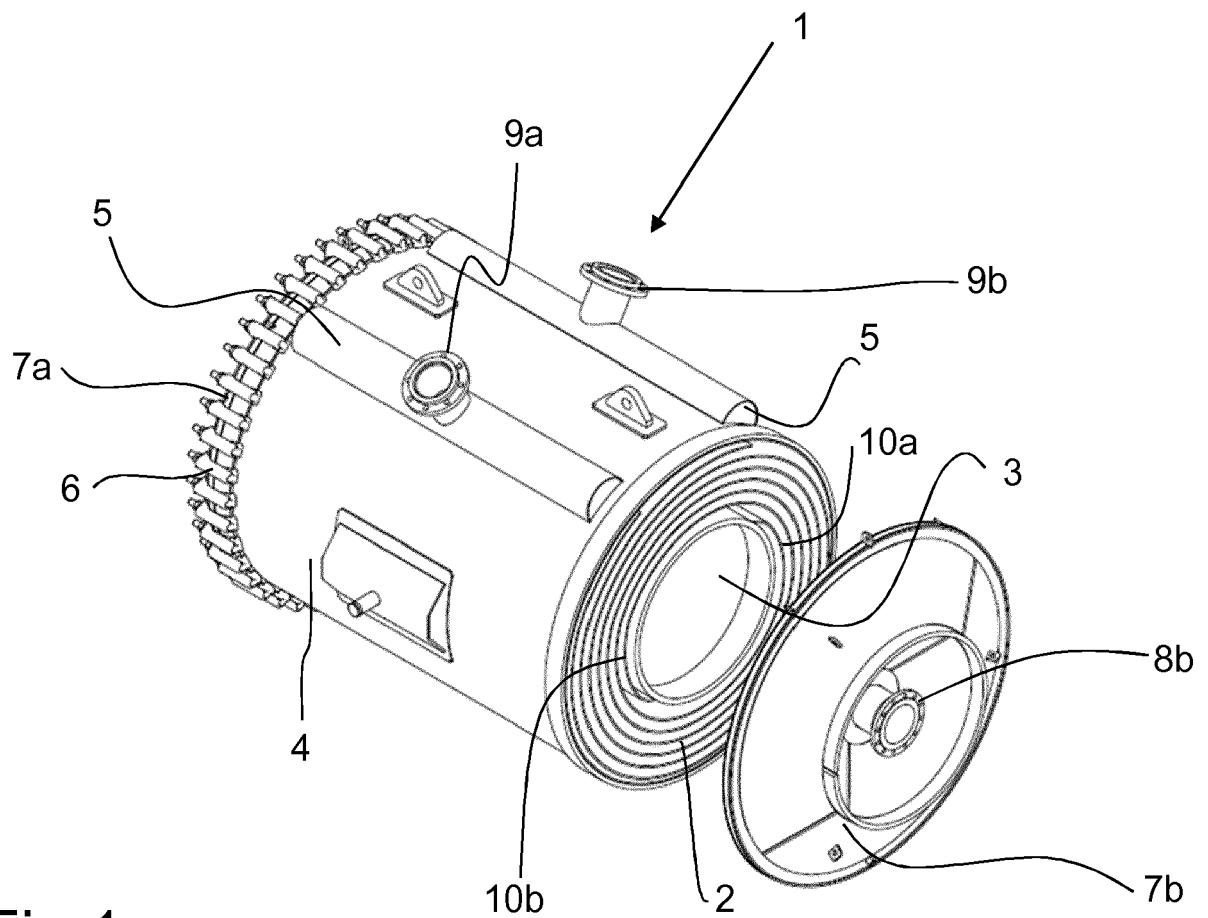


Fig.1

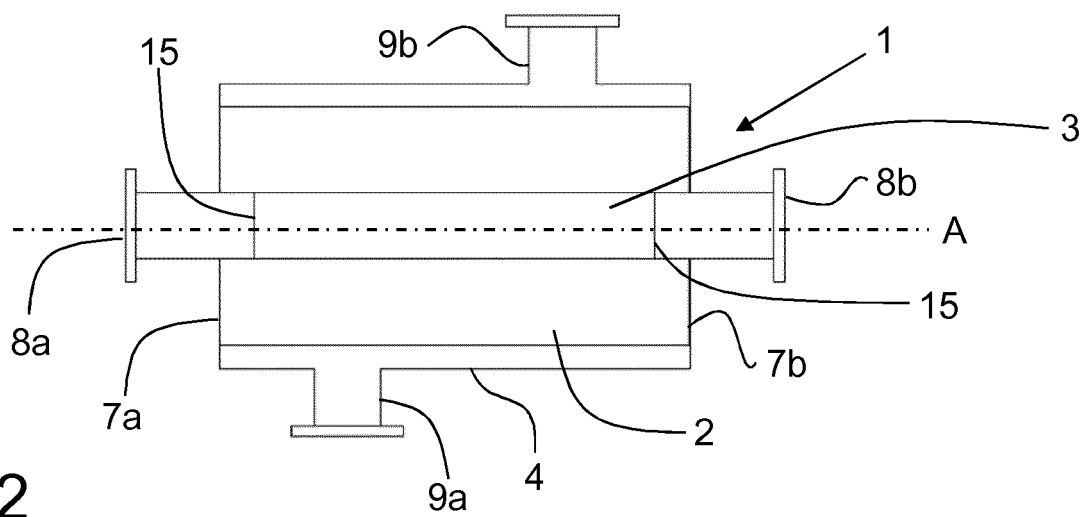


Fig.2

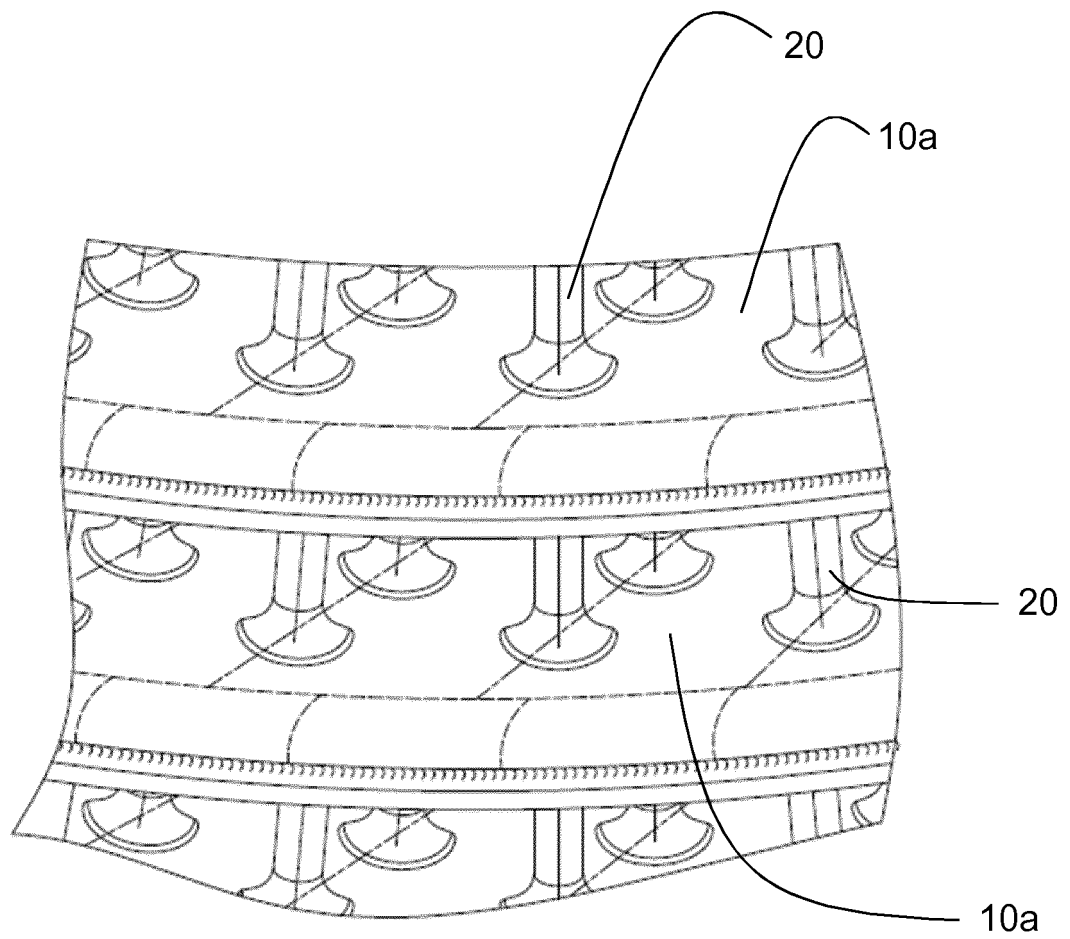


Fig.3

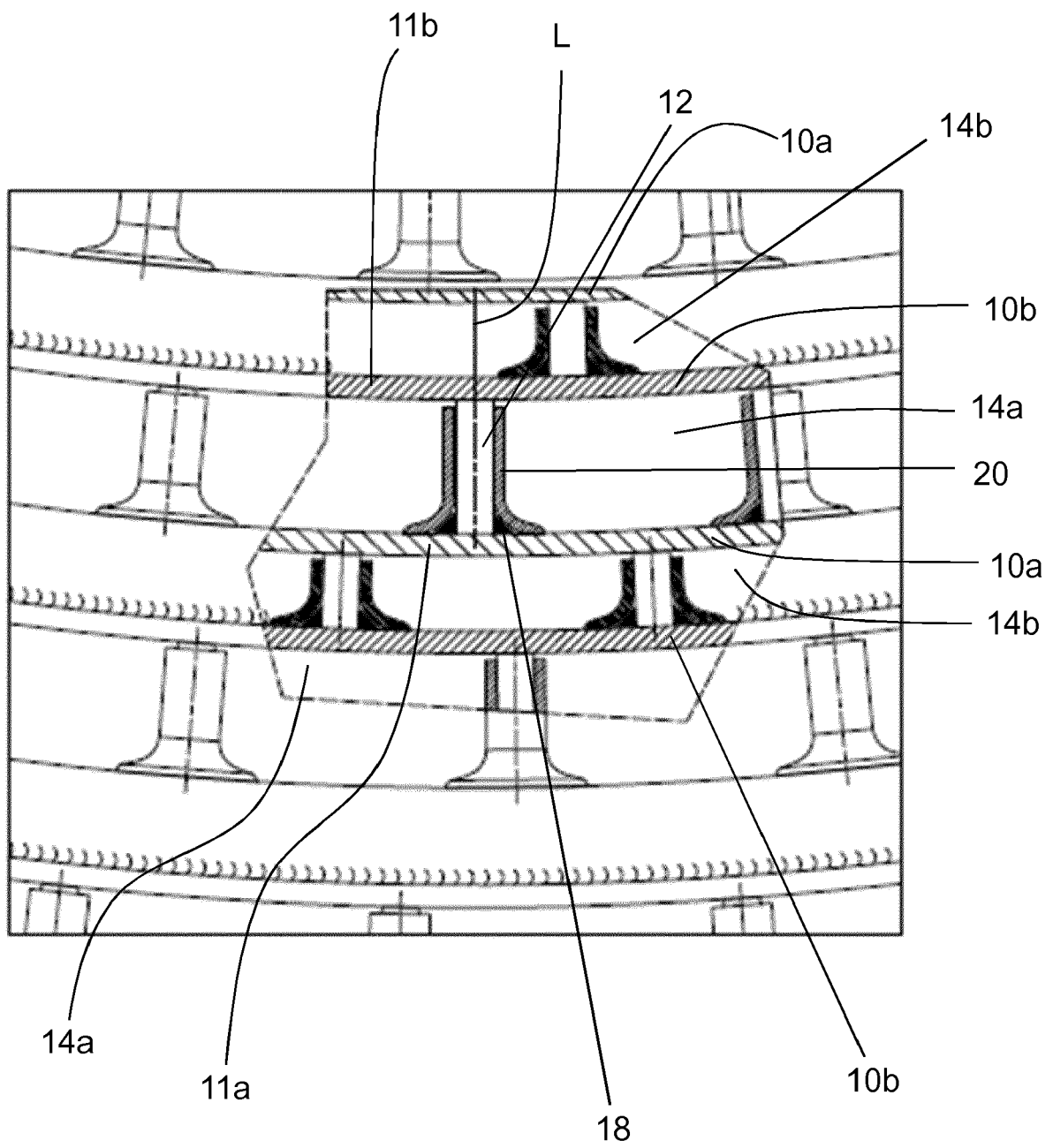


Fig.4

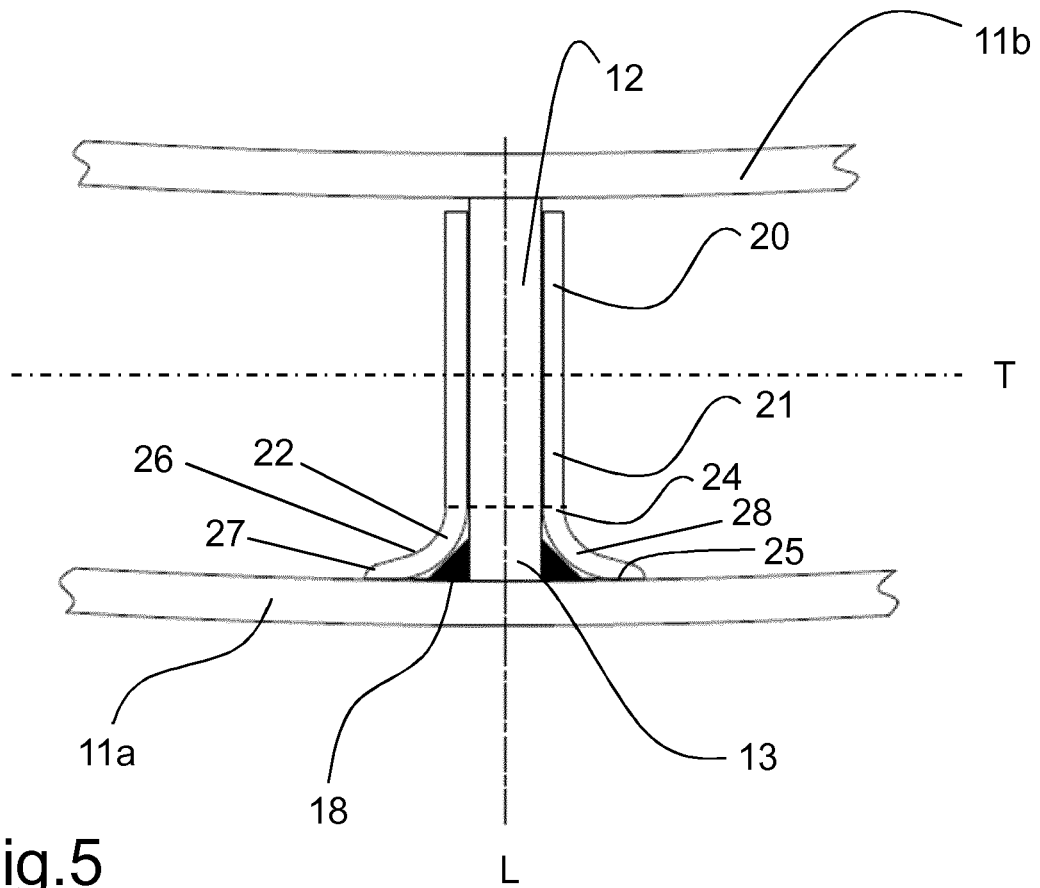


Fig.5

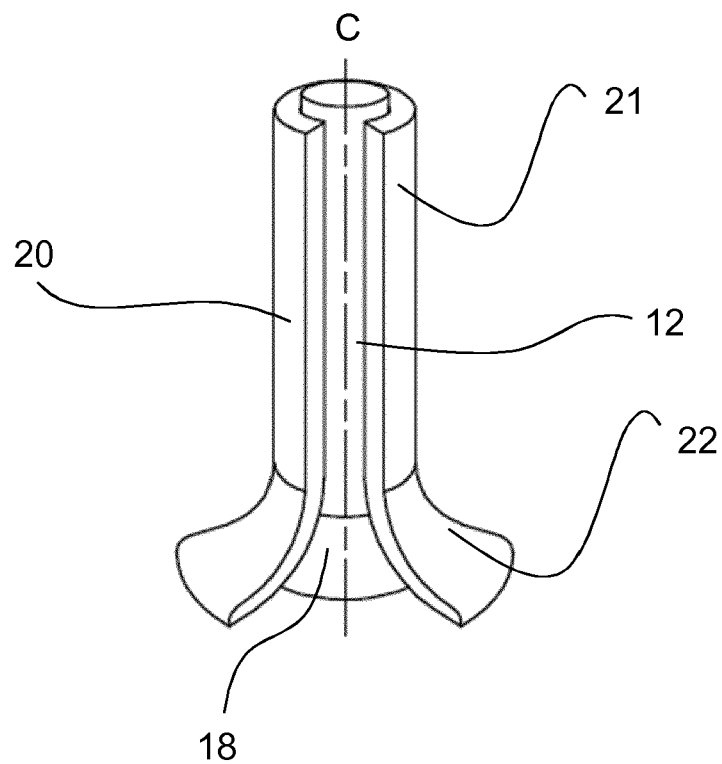


Fig.6

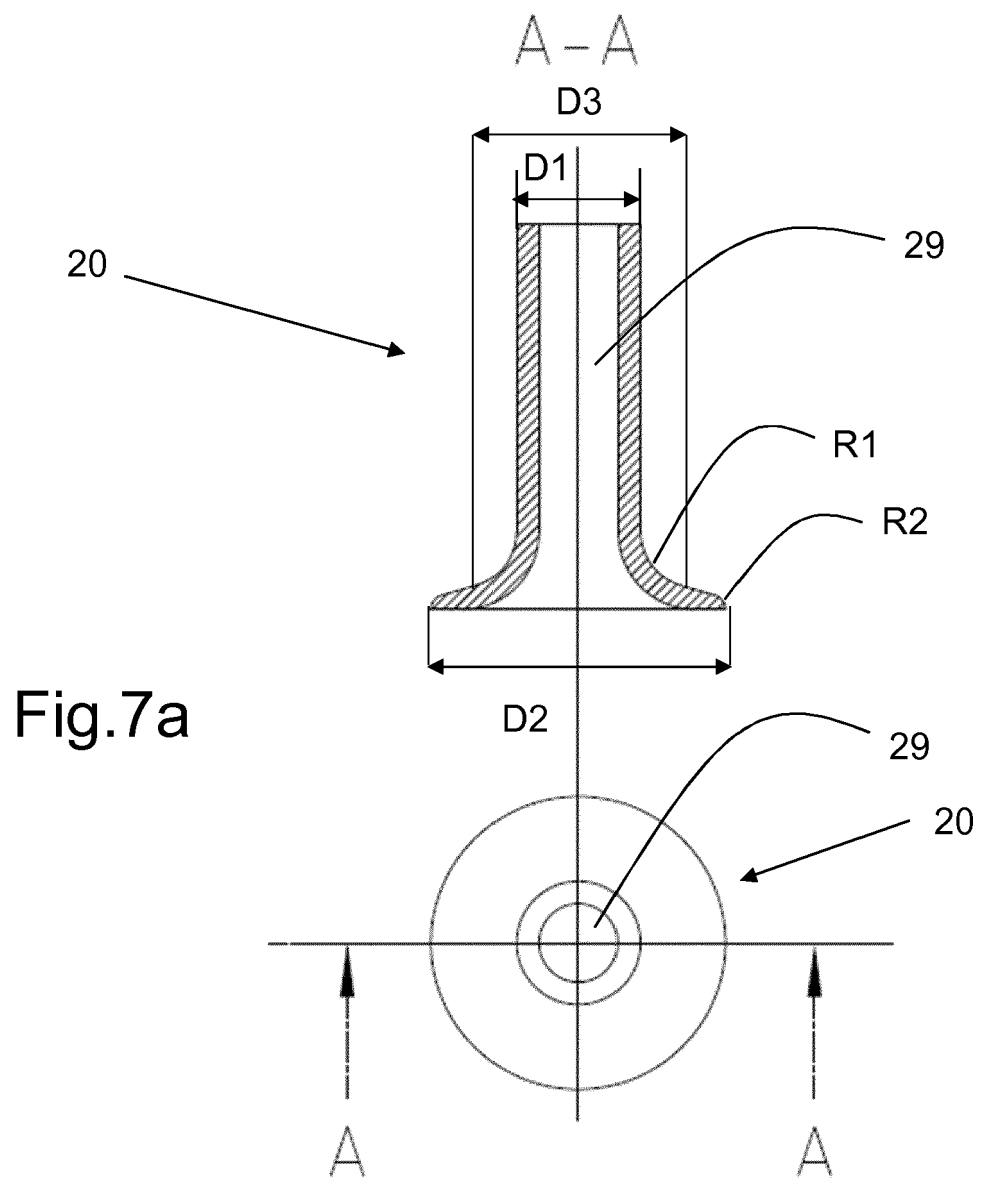


Fig.7a

Fig.7b



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