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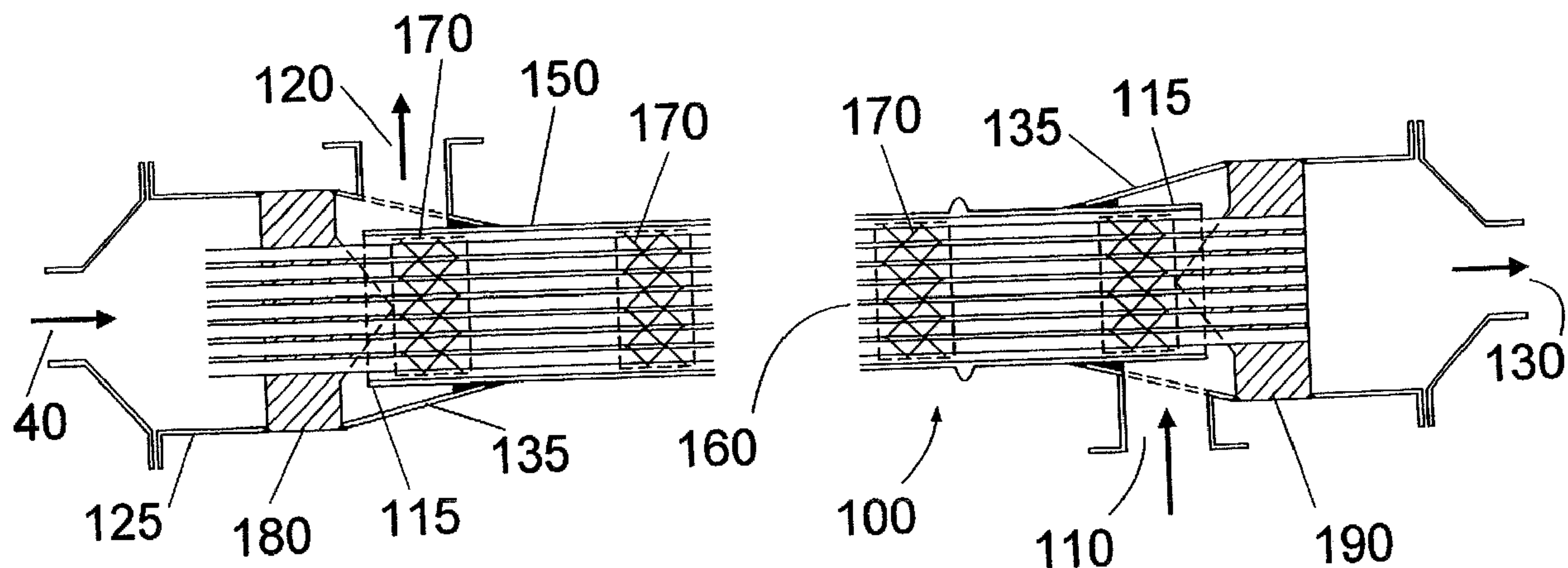
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(54) Title: IMPROVED HEAT EXCHANGER WITH REDUCED FOULING



(57) Abrégé/Abstract:

A heat exchanger configuration in which dead zones and areas of stagnation are significantly minimized or eliminated and in which inlet region tube erosion is addressed by providing a sacrificial portion of tube length so as to make repair and replacement of the eroded portion of tubes significantly cheaper, easier and with minimal process interruption. The exchanger preferably uses the axial flow direction for the shell-side fluid to reduce tube.

ABSTRACT OF THE DISCLOSURE

A heat exchanger configuration in which dead zones and areas of stagnation are significantly minimized or eliminated and in which inlet region tube erosion is addressed by providing a sacrificial portion of tube length so as to make repair and replacement of the eroded portion of tubes significantly cheaper, easier and with minimal process interruption. The exchanger preferably uses the axial flow direction for the shell-side fluid to reduce tube.

IMPROVED HEAT EXCHANGER WITH REDUCED FOULING

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

5 [0001] The present invention relates generally to heat exchangers and more particularly to design aspects of heat exchanger components.

 [0002] Heat exchangers were developed many decades ago and continue to be extremely useful in many applications requiring heat transfer. While many
10 improvements to the basic design of heat exchangers have been made over the course of the twentieth century, there still exist tradeoffs and design problems associated with the inclusion of heat exchangers within commercial processes.

 [0003] One of the problems associated with the use of heat exchangers is
15 the tendency toward fouling. Fouling refers to the various deposits and coatings which form on the surfaces of heat exchangers as a result of process fluid flow and heat transfer. There are various types of fouling including corrosion, mineral deposits, polymerization, crystallization, coking, sedimentation and biological. In the case of corrosion, the surfaces of the heat exchanger can become corroded as a result of the
20 interaction between the process fluids and the materials used in the construction of the heat exchanger. The situation is made even worse due to the fact that various fouling types can interact with each other to cause even more fouling. Fouling can and does result in additional resistance with respect to the heat transfer and thus decreased performance with respect to heat transfer. Fouling also causes an increased pressure
25 drop in connection with the fluid flowing on the inside of the exchanger.

 [0004] One type of heat exchanger which is commonly used in commercial processes is the shell-and-tube exchanger. In this type, one fluid flows on the inside of a large number of tubes, while the other fluid is forced through the shell and over the
30 outside of the tubes. Typically, baffles are placed to support the tubes and to force the fluid across the tube bundle in a serpentine fashion.

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[0005] Fouling can be decreased through the use of higher fluid velocities. In fact, one study has shown that a reduction in fouling in excess of 50% can result from a doubling of fluid velocity. It is known that the use of higher fluid velocities can substantially decrease or even eliminate the fouling problem. Unfortunately, sufficiently high fluid velocities needed to substantially decrease fouling are generally unattainable on the shell side of conventional shell-and-tube heat exchangers because of excessive pressure drops which are created within the system because of the baffles. Also, when shell-side fluid flow is in a direction other than in the axial direction and especially when flow is at high velocity, flow-induced tube vibration can become a substantial problem in that various degrees of tube damage may result from the vibration.

[0006] Higher fluid velocities associated with tube-side flow may also create difficulties. For example, in the traditional shell-and-tube arrangement, the higher fluid velocities associated with tube-side flow tend to cause erosion of the tube's inner surface particularly at the tube inlet. At a fluid velocity of, for example, 2.4 m/sec (8 feet per second) the inner surface of a brass tube may erode over the length beginning at the inlet and extending for 15 cm. (6 inches) or more into the tube. As fluid velocities increase, the problem worsens both in terms of the length of tube subject to erosion and the speed at which erosion occurs.

[0007] Tube erosion could eventually undermine the integrity of the tube-to-tubesheet joints. At the extreme, erosion can cause perforation of the tube which ultimately results in mixing between fluids on the shell side and tube side of the exchanger.

[0008] Inner surface tube erosion is especially problematic in the shell-and-tube arrangement since once a significant amount of erosion takes place, it becomes necessary to replace or repair the tube. Since, in conventional shell-and-tube heat exchangers, the majority of the tube length subject to erosion is embedded within the interior of the tubesheet, repairs and replacement of the tubes are costly and time consuming. For example, it may be necessary to cut the tube adjacent to the interior

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surface of both tubesheets, extract the remaining pieces within the interior of the tubesheets, extract the middle portion of the tube (between the two tubesheets), and then clean the surfaces and install a new tube. As is known in the art, this is an arduous process which generally results in significant process downtime.

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[0009] In addition to the tube erosion problem discussed above, existing shell-and-tube heat exchangers suffer from the fact that "dead zones" and areas of fluid stagnation exist on the shell side of the exchanger. These dead zones and areas of stagnation generally lead to excessive fouling as well as reduced heat-transfer performance. One particular area of fluid stagnation which exists in conventional shell-and-tube heat exchangers is the area near the tubesheet proximate to the outlet nozzle for the shell side fluid to exit the heat exchanger. Because of known fluid dynamic behavior, there tends to exist a dead zone or stagnant region which is located in the region between the each tubesheet and each nozzle. This area of restricted fluid flow on the shell side can cause a significant fouling problem in the area of the tubesheet because of the nonexistent or very low fluid velocities in this region. As is known in the art the same problem as described above also exists within the region adjacent to the inlet nozzle.

20 SUMMARY OF THE INVENTION

[0010] The present invention provides a heat exchanger configuration which preferably uses the axial flow direction for the shell-side fluid. In this exchanger, dead zones and areas of stagnation are significantly minimized or eliminated and the tube erosion in the inlet region is addressed by providing a sacrificial portion of tube length so as to make repair and replacement of the eroded portion of tubes significantly cheaper, easier and with minimal process interruption. Because axial flow is employed with respect to the shell-side fluid according to a preferred embodiment of the present invention, tube vibration problems are generally eliminated.

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[0011] In one embodiment, the heat exchanger has a plurality of tubes contained within the heat exchanger each of which extends a predetermined distance

beyond the exterior surface of the tubesheet. The extension of the tubes in this manner permits a length of the tubes located near the inlet portion of the tubes to be employed as a sacrificial section which may be easily replaced prior to the point in time at which inner surface erosion reaches a problematic level. Further, if tube erosion does occur in the sacrificial section, it is not as significant a cause for concern from the operational standpoint.

[0012] In another embodiment of the present invention, a cone section which connects the shell to the tubesheet assembly is provided in order to allow shell side fluid traveling towards the tubesheet to uniformly and circumferentially exit the tube bundle while minimizing low-flow zones.

[0013] The heat exchanger may be formed with a shell extension which extends beyond the location where the heat exchanger cone meets the shell and further towards the shell-side face of the tubesheet located near the shell side fluid outlet. This shell extension serves to force shell side fluid flow toward the tubesheet in order to further minimize dead zones and regions of low or non-existent fluid flow at or around the center-facing surface of the tubesheet in the region located near the shell side fluid outlet and shell side fluid inlet. The shell extension also limits and/or eliminates shell-side erosion problems because it provides a 360-degree entry and exit path for shell-side fluid flow instead of a configuration where shell-side fluid flows directly against the tube bundle.

[0014] The heat exchanger tubesheet may be formed with a conical extension which is preferably centered at the center of the shell-side face of the tubesheet. This conical section serves to further reduce and/or eliminate a small region of stagnation which would otherwise be present in the heat exchanger of the present invention as a result of directional flow caused by the aforementioned cone section and shell extension of the present invention.

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[0015] Standard size "off-the-shelf" heat exchanger modules may be employed to maximize the reduction in fouling and to allow for very significant

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reductions in design time. A number of smaller standard size heat exchangers may be employed in parallel or in series or in both parallel and series to achieve necessary heat-transfer requirements.

5 [0016] As will be explained in further detail below, the present invention provides advantages including a significant reduction of dead zones and low-fluid-velocity regions which would otherwise lead to significant fouling problems.

10 [0016.1] In another embodiment of the present invention, there is provided a heat exchanger comprising: a tube bundle having a plurality of tubes for transporting a tube-side fluid therethrough; a shell substantially surrounding the tube bundle, wherein a shell-side fluid is capable of being transported in a space between the shell and the plurality of tubes, wherein the shell having a shell diameter; at least one tubesheet having a plurality of apertures formed therein, wherein each aperture receiving one of the
15 plurality of tubes therein, wherein each tubesheet having a first side and a second side, wherein the first side facing toward the shell and the second side facing away from the shell, wherein at least one of the at least one tubesheet having a conical tubesheet extension extending from the first side toward the interior of the shell, wherein the diameter of the conical tubesheet extension is substantially the same as the diameter of the
20 tube bundle, wherein at least a portion of the plurality of tubes extending through the conical tubesheet extension; and at least one conical assembly connecting the shell to the at least one tubesheet, wherein the at least one conical assembly extending from an outer surface of the shell to an outer perimeter of the at least one tubesheet, wherein each conical assembly having a first diameter adjacent the shell and a second diameter adjacent
25 the tubesheet, wherein the first diameter is less than the second diameter.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0017] Figure 1 is a side elevation cutaway view of a single-tube-pass heat exchanger having a non-removable tube bundle and representing a first embodiment of the present invention; and

[0018] Figure 2 is a side elevation cutaway view of a two-tube-pass heat exchanger having a removable tube bundle and representing a second embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0019] Figure 1 illustrates a heat exchanger 100 constructed according to the teachings of the present invention. In the figure, the shell portion is broken away to illustrate the tube bundle construction more clearly. While Figure 1 shows a shell-and-tube exchanger in the form of a single-pass embodiment, the present invention is equally applicable to many other forms of shell-and-tube exchangers such as, for example, multi-pass and U-shaped implementations. The heat exchanger 100 of the present invention includes a shell 150 and a tube bundle 160 in the shell.

[0020] Tube bundle 160 includes a pair of tubesheets 180 and 190 located, respectively, at each end of the tube bundle 160. The tubes contained in tube bundle 160 are fastened to apertures contained within tubesheets 180 and 190 by conventional means such as by welding or by expanding the tubes into tubesheets 180 and 190.

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Tube side inlet 140 and corresponding tube side outlet 130 provide a means for introducing a first fluid into the tubes in tube bundle 160, and for expelling the first fluid from exchanger 100, respectively. Shell side inlet 110 and shell side outlet 120 provide a means for a second fluid to enter and exit the shell side of heat exchanger 100, respectively, and thus pass over the outside of the tubes comprising tube bundle 160.

[0021] Preferably, the tubes in tube bundle 160 are supported by the novel coil structure which is disclosed in U.S. Patent No. 6,874,572 entitled "Heat Exchanger Flow Through Tube Supports" which eliminates the need for baffles and allows for high-velocity fluid flow. Alternatively, the tubes in tube bundle 160 may be supported by conventional means such as by "rod baffles", "twisted tubes" or "egg crate" style tube supports. Segmental baffles are not preferred because they generally do not allow high-velocity fluid flow and they further create dead zones.

[0022] In a preferred embodiment of the present invention, axial flow is used for the shell side fluid. In addition, it is also preferable that a countercurrent flow arrangement be employed as between the two different fluids although a non-countercurrent (i.e. cocurrent) flow may also be implemented.

[0023] In Figure 1, the tubes in tube bundle 160 extend some length beyond the surface of tubesheet 180 in the direction of and towards tube side inlet 140. Preferably, the extension is at least 15 cm (6 inches) beyond the surface of tubesheet 180 and possibly more depending upon the intended fluid velocities and the tube metallurgy. The extended tube length serves as a sacrificial length which may be easily replaced when necessary or desirable so as to avoid the effects of inlet tube erosion which is most prevalent at higher fluid velocities. The more rapid the intended fluid velocities, the longer the tube length extension should be. The only practical limitation on the tube length extension is the requirement that the tube length not extend so much such that unfavorable velocity profiles are created within channel 125.

[0024] The tube length extension may typically be 15 cm. (6in) beyond the surface of tubesheet 180. This length of extension is satisfactory for tube materials such as carbon steel, copper nickel and other metals or other materials which are subject to erosion at levels that can cause perforation problems. In the case of brass or
5 other tube materials which are especially susceptible to erosion, tube lengths are preferably extended further. Varying extension lengths may be used and the extension length should increase as the tube material's susceptibility to erosion increases.

[0025] Although not shown in Figure 1, the tubes in tube bundle 160 may
10 also be extended in the direction of outlet nozzle 130 and through tubesheet 190. By extending the tubes and providing a sacrificial section that extends beyond both tubesheet 180 and tubesheet 190, a sacrificial section is available if flow direction is reversed and outlet nozzle 130 is employed as an inlet nozzle.

[0026] The use of extended tube lengths allows for periodic replacement of
15 the sacrificial tube section as erosion occurs or at selected time intervals. The sacrificial section may be cut off and a new sacrificial section may be welded on or otherwise fastened by expanding a new section within the remaining portion of the tube length which extends outward from the tubesheet. Other welding and other techniques
20 may also be employed in order to replace sacrificial tube lengths as may be required.

[0027] Dead zones and low-flow areas may be eliminated consistent high-velocity fluid flow allowed through the heat exchanger 100 of the present invention by the construction illustrated in Figure 1. Shell extensions 115 are included so as to
25 extend shell 150 laterally past the point at which the shell 150 meets cone 135 extending from the outer periphery of tubesheets 180 and 190 towards shell 150 and including nozzles 120 and 110, respectively. By extending the shell 150 through the use of shell extensions 115 as indicated in Figure 1, shell side fluid flow is directed towards the tubesheets 180 and 190 without the fluid having the opportunity to
30 immediately enter or leave the region immediately adjacent to the inlet and outlet nozzles 110 and 170, respectively, where fluid velocity would otherwise be slowed significantly. Further, shell extensions 115 minimize shell-side erosion problems due

to the fact that they prevent shell-side fluid from directly flowing against tube bundle 160 upon entry or upon exiting from heat exchanger 100.

[0028] The inclusion of cone 135 at either or both of the ends of shell 150 is also illustrated. Cone 135 preferably extends from the outer surface of shell 150 to tubesheet 180 and/or tubesheet 190. The size and shape of cone 135 is selected based upon fluid modeling studies but in most cases standard parts which are readily available may be selected for use as cone 135. Cone 135, together with shell extension 115, serves to direct fluid flow towards tubesheets 180 and 190 rather than permitting fluid to immediately exit outlet nozzle 170 or to immediately enter the interior of tube bundle 160 from inlet nozzle 110, as applicable. By doing so, the low-velocity fluid zones which would otherwise exist in the vicinity of tubesheets 180 and 190 are eliminated.

[0029] Figure 1 also illustrates the configuration with a conical tubesheet extension. Tubesheets 180 and 190 include a conical shaped extension which protrudes toward the interior of the heat exchanger cavity and away from inlet nozzle 140 and outlet nozzle 130 respectively. Preferably, the complete diameter of tubesheets 180 and 190 form the base for the conical protrusion extending from the surface of tubesheets 180 and 190. Alternatively, only a portion of the diameter of tubesheets 180 and 190 form the base for the conical protrusion. For example, according to this embodiment, the conical protrusion may be formed to have a base diameter of 10-16 cm (4-6 in.) while the diameter of the tubesheets 180 or 190 may be on the order of 30-60cm (12-24in.). It is preferable for the center point of the conical protrusion to be the same as the center point of the tubesheets themselves. In other words, the conical protrusion is preferably centered on the circular surface of the tubesheets 180 and 190.

[0030] The inclusion of conical protrusions described above results in the reduction and/or elimination of a small dead zone and low-flow area which would otherwise tend to be present in the present heat exchanger adjacent to the center of the interior tubesheet surface facing the heat exchanger cavity. The particular low-flow area which otherwise would be present in the heat exchanger of the present invention results from the inclusion of the shell extension 115 and cone 135 components of the

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present invention. By including the tubesheet protrusions in the heat exchanger 100 of the present invention, the spaces in heat exchanger 100 which are taken up by the protrusions which would otherwise be “dead zones” or low-flow areas are filled up with solid material so that the low-flow areas and “dead zones” are eliminated with negligible or no loss of heat-transfer capability.

[0031] The sizing and detailed shape of the conical protrusion may vary from the examples provided above while still remaining within the scope of the invention. Known fluid modeling methodologies may be employed to determine the particular sizes and shapes that meet the desired criteria for the specific design. The conical protrusion on one tubesheet need not be the same in terms of size or shape as another conical protrusion on another tubesheet within a particular heat exchanger. Sizing and shaping between and among protrusions on tubesheet surfaces may vary according to expected specific fluid flow velocities and tendencies.

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[0032] As shown in Figure 1, the preferred embodiment includes tube supports 170. Tube supports 170 are preferably metal coil structures as more fully disclosed in U.S. Patent No. 6,874,572 entitled “Heat Exchanger Flow Through Tube Supports”. By using these novel metal coil structures as tube supports 170, conventional baffles may be eliminated and higher fluid velocities may be employed.

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[0033] Figure 2 illustrates another form of heat exchanger configuration. The heat exchanger 200 illustrated in Figure 2 is a two-tube-pass configuration with U-shaped tubes. In addition, as opposed to the configuration of heat exchanger 100 in Figure 1 where tubesheet 180, conical section 135 and shell 150, for example, are welded together, the configuration of heat exchanger 200 is such that channel 225, tubesheet 280 and tube bundle 260 are easily removed from the heat exchanger shell body through the use of bolts 230.

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[0034] In a preferred embodiment, tube bundle 260 includes tubesheet 280 which is located at the end of the tube bundle 260 adjacent to channel 225. Tube side

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inlet 240 and corresponding tube side outlet 210 provide a means for introducing a first fluid into the tubes in tube bundle 260, and for expelling the first fluid from exchanger 200, respectively. As can be seen in Figure 2, pass partition plate 245 prevents fluid from entering exchanger 200 through inlet 240 and exiting exchanger 200 through outlet 210 without passing through the tubes in tube bundle 260. Shell side inlet 210 and shell side outlet 220 provide a means for a second fluid to enter and exit the shell side of heat exchanger 200, respectively, and thus pass over the outside of the tubes comprising tube bundle 260.

10 [0035] As is the case with the configuration of Figure 1, it is preferable for the tubes in tube bundle 260 to be supported by the novel coil structure which is disclosed in U.S. Patent No. 6,874,572 entitled "Heat Exchanger Flow Through Tube Supports" referred to above so that baffles may be eliminated and so that high-velocity fluid flow may be achieved. Alternatively, the tubes in tube bundle 260 may
15 be supported by conventional means such as by rod baffles, twisted tubes or egg crate style tube supports. Again, in this embodiment as in that of Figure 1, segmental baffles are not preferred because they generally do not allow high-velocity fluid flow and they also create dead zones.

20 [0036] Because the Figure 2 embodiment involves a "U-tube" and thus two tube passes, one of the two passes will be cocurrent with the shell-side flow. Axial flow is preferably used for the shell side fluid in the Figure 2 embodiment.

 [0037] As is the case in the Figure 1 embodiment, the tubes in tube bundle
25 260 of the Figure 2 embodiment extend some length beyond the surface of tubesheet 280 in the direction of and towards tube side inlet 240. In the Figure 2 embodiment of the present invention, the extension is at least 15 cm (6 in.) beyond the surface of tubesheet 280 and possibly more depending upon the intended fluid velocities and the tube metallurgy.

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 [0038] In the Figure 2 embodiment, the tube length extension may be, for example, 15 cm (6in.) beyond the surface of tubesheet 280 but varying extension

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lengths may be used: the extension length should increase as the tube material's susceptibility to erosion increases.

[0039] Figure 2 also illustrates another aspect serves to eliminate dead zones and low-flow areas and which allows consistent high-velocity fluid flow throughout heat exchanger 200. A first shell extension 215 (on the left side of Figure 2) extends shell 250 laterally past the point at which the shell 250 meets cone 235 extending from the outer periphery of tubesheet 280 towards shell 250. Cone 235 may also include a flange or ring portion which abuts tubesheet 280. A second shell extension 215 (on the right side of Figure 2) extends shell 250 laterally past the point at which shell 250 meets cone 235 and towards shell cover 295. Shell cover 295 may be welded to shell 250 as shown in Figure 2 or it may be attached to shell 250 through the use of bolts or other known fastening techniques. By extending shell 250 through the use of shell extensions 215 as indicated in Figure 2, shell side fluid flow is directed towards the tubesheet 180 and shell cover 295, respectively, without the fluid having the opportunity to immediately enter the region immediately adjacent to shell-side inlet nozzle 210 and outlet nozzle 220, respectively, where fluid velocity would otherwise be slowed significantly. As in the Figure 1 embodiment, this arrangement also service to minimize shell-side erosion problems.

[0040] Cones 235 may be included at either or both of the ends of shell 250. Cones 235 preferably extend from the outer surface of shell 250 to tubesheet 280 and/or shell cover 295. The size and shape of cones 235 are selected based upon fluid modeling studies, but in most cases standard parts which are readily available may be selected for use as cones 235. Cones 235 serve to direct fluid flow towards tubesheet 280 and shell cover 295 rather than permitting fluid to flow toward inlet nozzle 210 or outlet nozzle 220 as applicable. By doing so, the low-velocity fluid zones which would otherwise exist in the vicinity of tubesheet 280 and shell cover 295 are eliminated.

[0041] Figure 2 also illustrates a conical tubesheet extension. Tubesheet 280 includes a conical shaped extension which protrudes toward the interior of the heat exchanger cavity and away from channel 225. The complete diameter of tubesheet 280

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preferably forms the base for the conical protrusion extending from the surface of tubesheet 280. In another embodiment, only a portion of the diameter of tubesheet 280 forms the base for the conical protrusion. For example, according to this embodiment, the conical protrusion may be formed to have a base diameter of 10-15 cm (4-6 in.) while the diameter of tubesheet 280 may be on the order of 30-60 cm (12- 24in.). It is preferable in this embodiment for the center point of the conical protrusion to be the same as the center point of tubesheet 280 itself. In other words, the conical protrusion is preferably centered on the circular surface of the tubesheet 280. The sizing and detailed shape of the conical protrusion for this 2 embodiment may however vary according to operational requirements.

[0042] Figure 2 illustrates the preferred configuration which includes tube supports 270. Tube supports 270 are preferably metal coil structures as more fully disclosed in U.S. Patent No. 6,874,572 entitled "Heat Exchanger Flow Through Tube Supports" referred to above. By using these novel metal coil structures as tube supports 270, conventional baffles may be eliminated and higher fluid velocities may be employed.

[0043] It is preferable that a strainer of some form should be employed in connection with the use of the heat exchanger, at some point in the process line prior to reaching the heat exchanger. This is important in order to avoid any debris becoming trapped within the heat exchanger of the present invention either in a tube or on the shell side of the heat exchanger. If debris of a large enough size or of a large enough amount were to enter the heat exchanger of the present invention (or, in fact, any currently existing heat exchanger) fluid velocities can be reduced to the point of rendering the heat exchanger ineffective.

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CLAIMS:

1. A heat exchanger comprising:

a tube bundle having a plurality of tubes for transporting a tube-side fluid therethrough;

a shell substantially surrounding the tube bundle, wherein a shell-side fluid is capable of being transported in a space between the shell and the plurality of tubes, wherein the shell having a shell diameter;

at least one tubesheet having a plurality of apertures formed therein, wherein each aperture receiving one of the plurality of tubes therein, wherein each tubesheet having a first side and a second side, wherein the first side facing toward the shell and the second side facing away from the shell, wherein at least one of the at least one tubesheet having a conical tubesheet extension extending from the first side toward the interior of the shell, wherein the diameter of the conical tubesheet extension is substantially the same as the diameter of the tube bundle, wherein at least a portion of the plurality of tubes extending through the conical tubesheet extension; and

at least one conical assembly connecting the shell to the at least one tubesheet, wherein the at least one conical assembly extending from an outer surface of the shell to an outer perimeter of the at least one tubesheet, wherein each conical assembly having a first diameter adjacent the shell and a second diameter adjacent the tubesheet, wherein the first diameter is less than the second diameter.

2. The heat exchanger of claim 1, wherein the tube bundle having a sacrificial section extending in an axial direction away from the second side of one of the at least one tubesheet.

3. The heat exchanger of claim 1 or claim 2, wherein the at least one tubesheet comprising a first tubesheet and a second tubesheet, wherein the at least one conical assembly comprising a first conical assembly and a second conical assembly, wherein the first conical assembly extending from the outer surface of the shell to an outer perimeter of the first tubesheet and the second conical assembly extending from the outer surface of the shell to an outer perimeter of the second tubesheet.

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4. The heat exchanger of claim 3, wherein one of the first conical assembly and the second conical assembly having a shell-side fluid inlet for permitting the introduction of the shell-side fluid into the heat exchanger, wherein the shell-side fluid inlet is aligned to cause a fluid flow perpendicular to the fluid flow within the tubes.
5. The heat exchanger of claim 3 or claim 4, wherein one of the first conical assembly and the second conical assembly having a shell-side fluid outlet for permitting the removal of the shell-side fluid from the heat exchanger.
6. The heat exchanger of claim 3, wherein one of the first conical assembly and the second conical assembly having a tube-side fluid inlet for permitting the introduction of the tube-side fluid into the heat exchanger, wherein the tube-side fluid inlet is aligned to cause a fluid flow which is in the same axial direction as the fluid flow within the tubes.
7. The heat exchanger of claim 3 or claim 6, wherein one of the first conical assembly and the second conical assembly having a tube-side fluid outlet for permitting the removal of the tube-side fluid from the heat exchanger.
8. The heat exchanger of any one of claims 1 to 7, wherein the shell extends toward the at least one tubesheet beyond the point where the shell is connected to the at least one conical assembly.
9. The heat exchanger of any one of claims 1 to 8 in which the heat exchanger is a one-tube-pass heat exchanger.
10. The heat exchanger of claim 1, wherein the plurality tubes of the tube bundle are formed in a "U" shape and the at least one tubesheet has apertures for receiving both ends of each tube.
11. The heat exchanger of claim 10 further comprising a partition between the respective ends of the U shaped tubes separates a tube-side fluid inlet for the tube-side fluid from a tube-side fluid outlet for the tube-side fluid.

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12. The heat exchanger of claim 1, wherein the tube bundle having a sacrificial section extending in an axial direction away from the second side of one of the at least one tubesheet on the side of partition adjacent the tube-side fluid inlet.

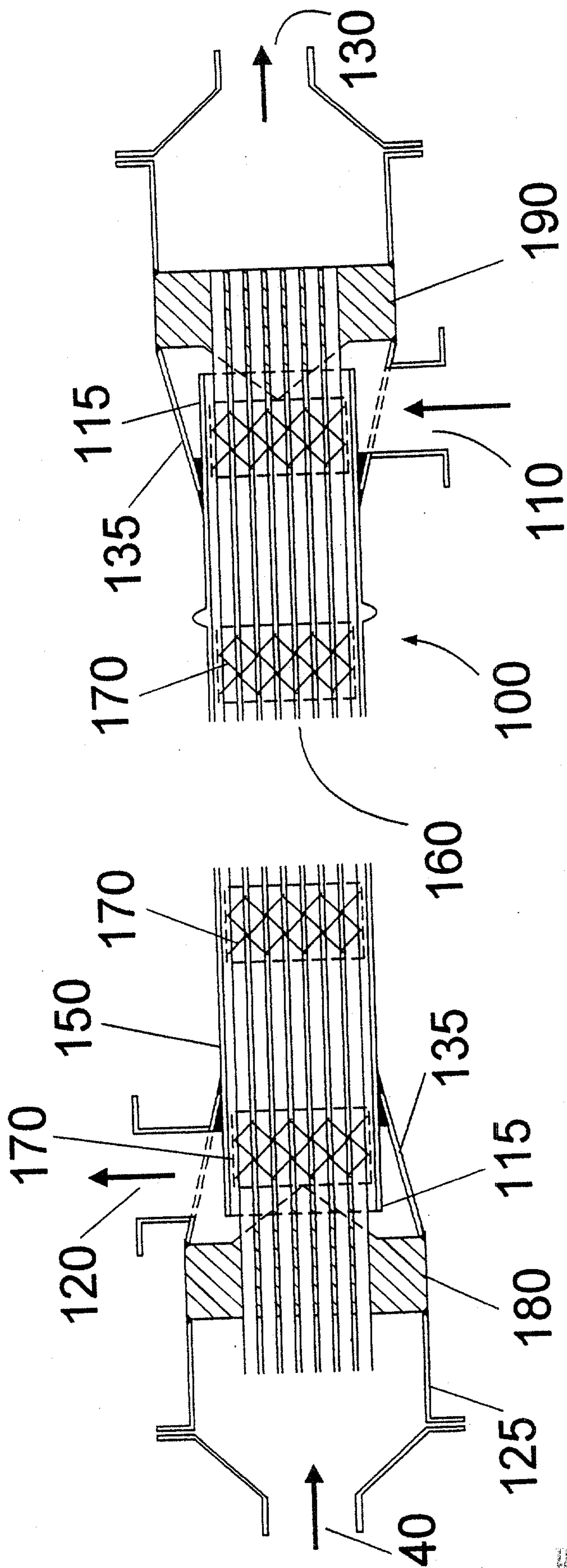


Fig. 1

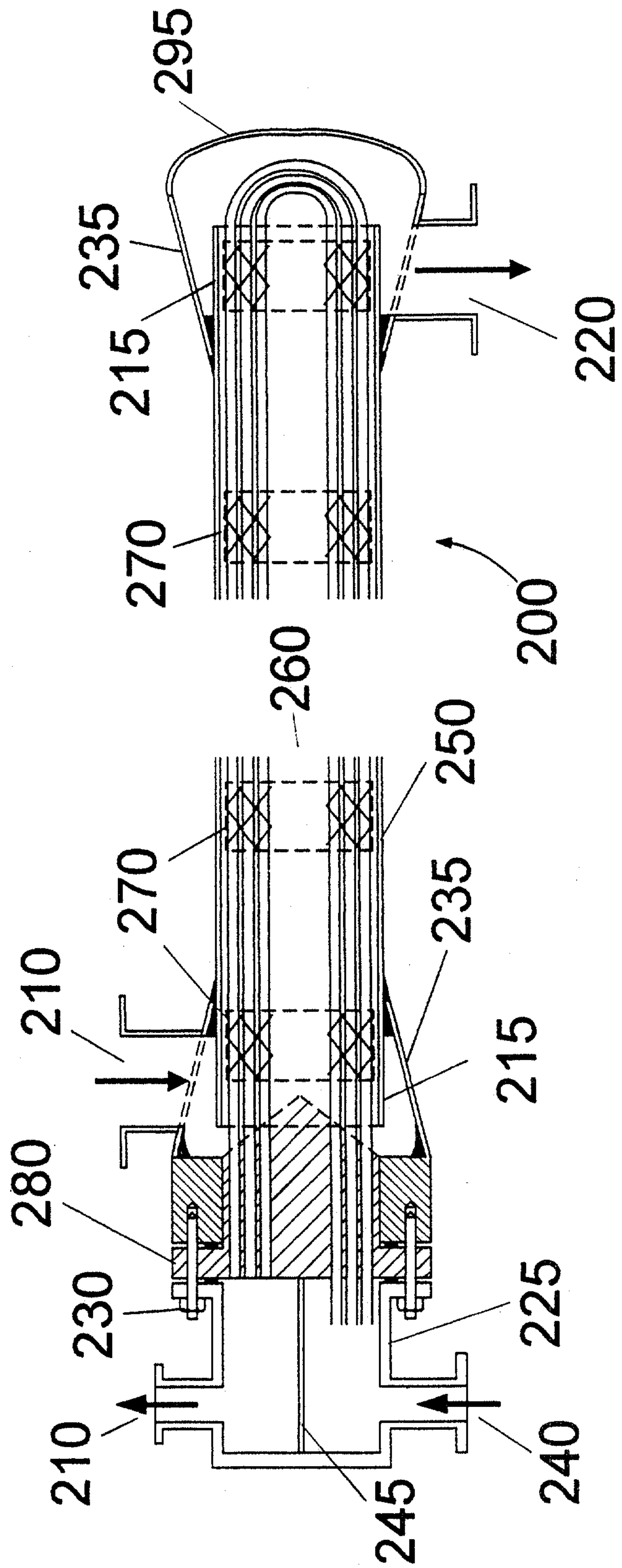


Fig. 2

