United States Patent [19]

Jouet et al.

[11] **3,854,530**

[45] **Dec. 17, 1974**

[54] **HEAT EXCHANGER**

[76] Inventors: **Etienne Jouet,** 19 Rue du Panorama, 95 Montigny-les-Cormeilles; **Pascal Rebuffe,** 18 Rue de Sevres, Boulonge-Billancourt, both of France

[22] Filed: **Sept. 20, 1972**

[21] Appl. No.: **290,518**

Related U.S. Application Data

[62] Division of Ser. No. 888,591, Dec. 29, 1969.

[52] **U.S. Cl.** **165/163**

[51] **Int. Cl.** **F28f 3/00**

[58] **Field of Search** 165/166, 163, 164

[56] **References Cited**

UNITED STATES PATENTS

3,543,844 12/1970 Jordan 165/166

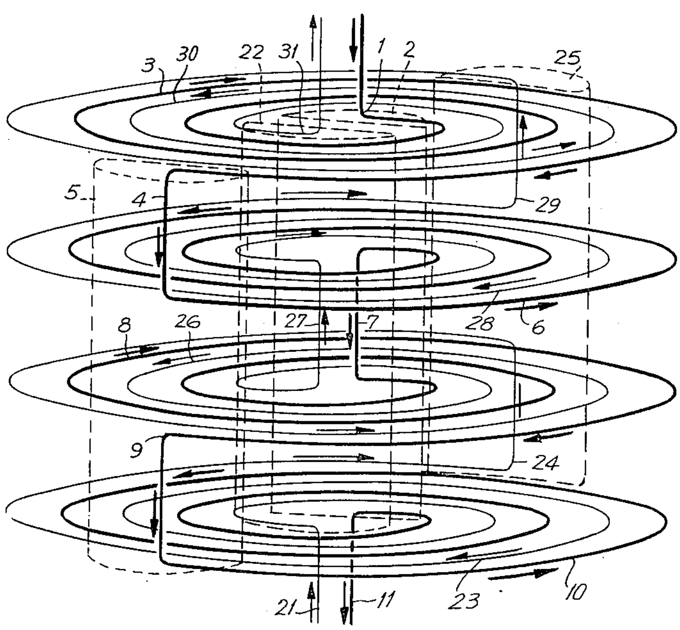
Primary Examiner—Charles Sukalo

Attorney, Agent, or Firm—Waters, Roditi, Schwartz & Nissen

[57] **ABSTRACT**

Heat exchangers of generally cylindrical shape, including structure having at least two chambers being wound on themselves in self-enclosing spirals, baffles forming passageways through said chambers to facilitate the flow of heat-exchanging media through said chambers in alternate centripetal and centrifugal relationship.

8 Claims, 38 Drawing Figures



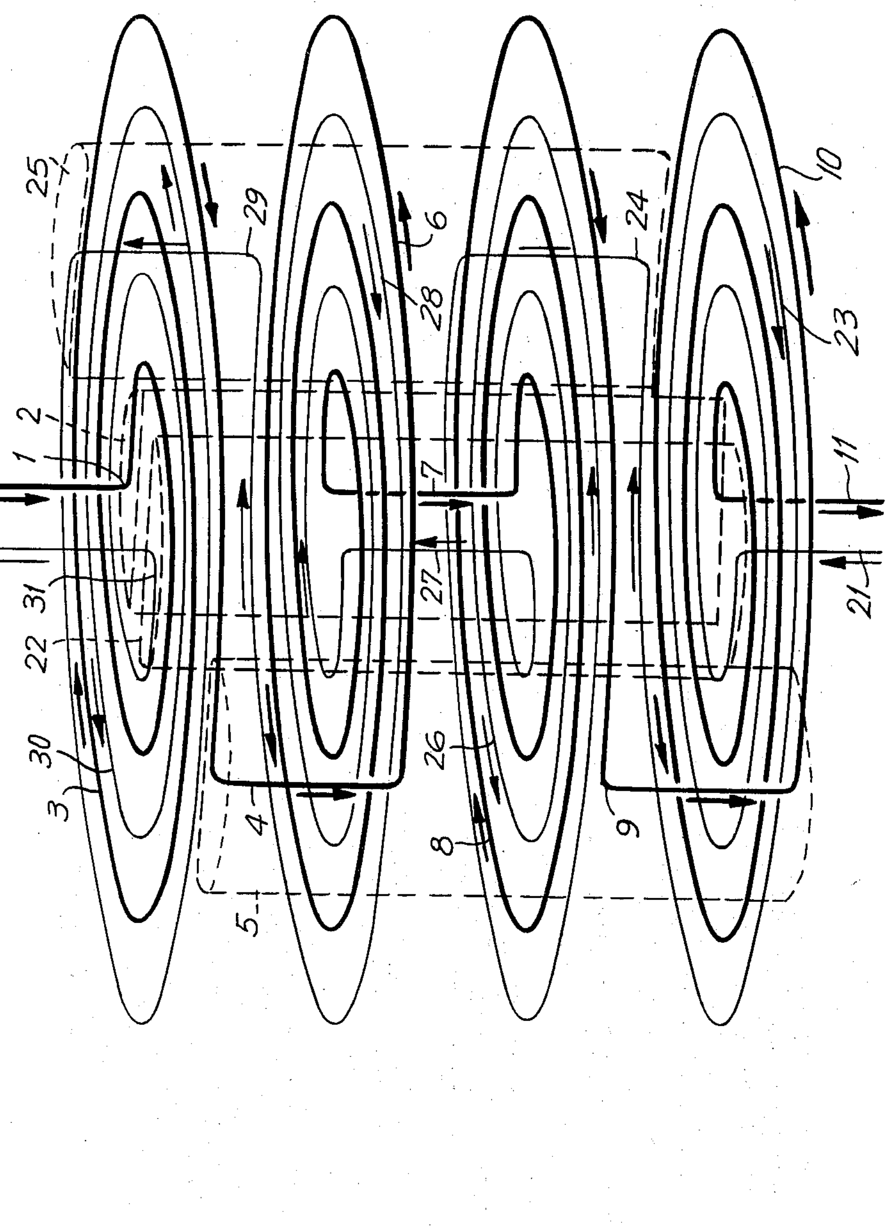


FIG. 1

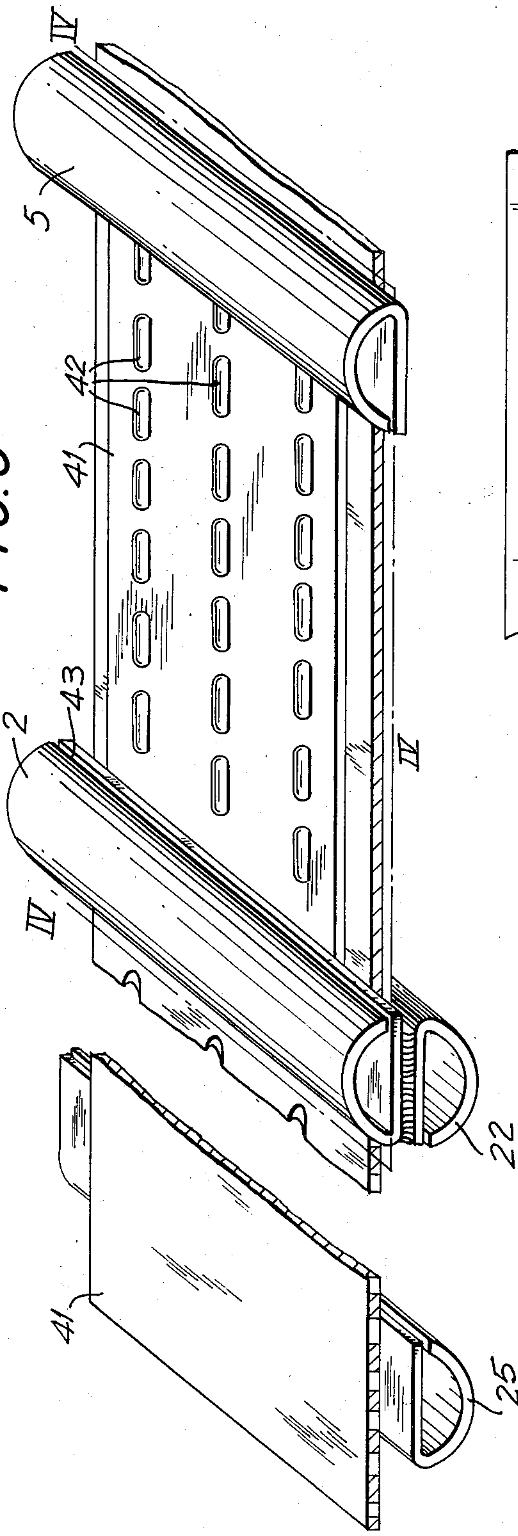


FIG. 3

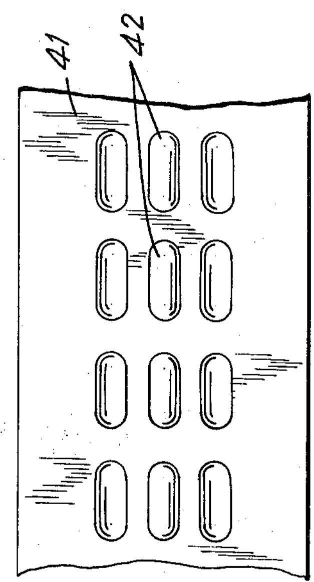
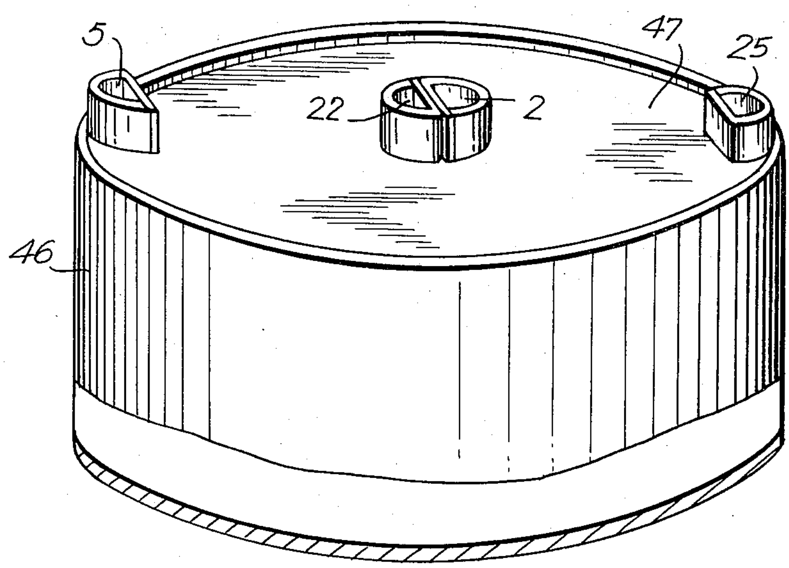


FIG. 2

FIG. 6



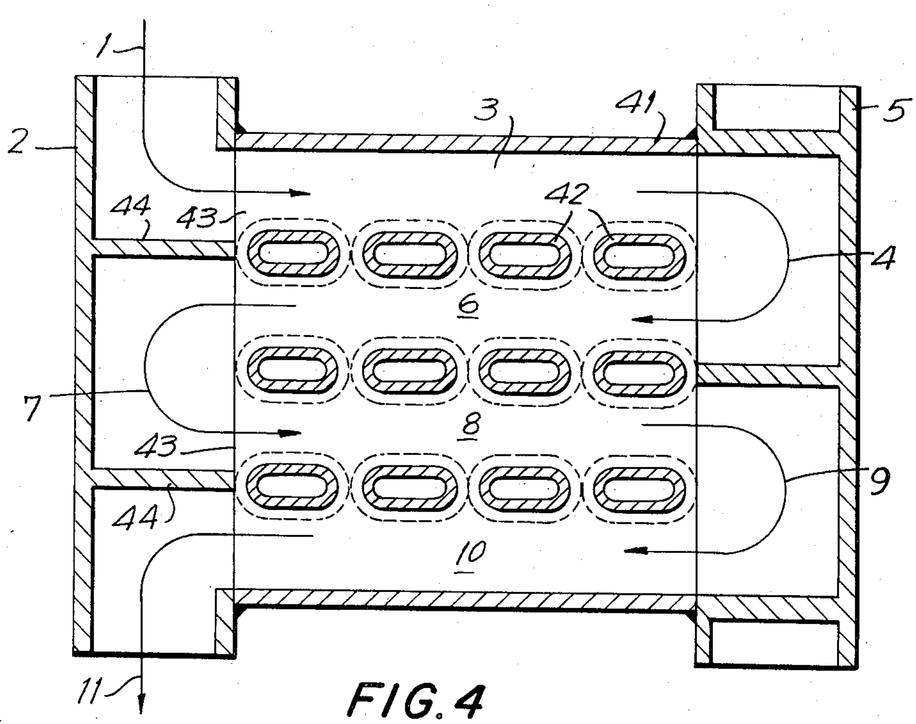


FIG. 4

FIG. 11

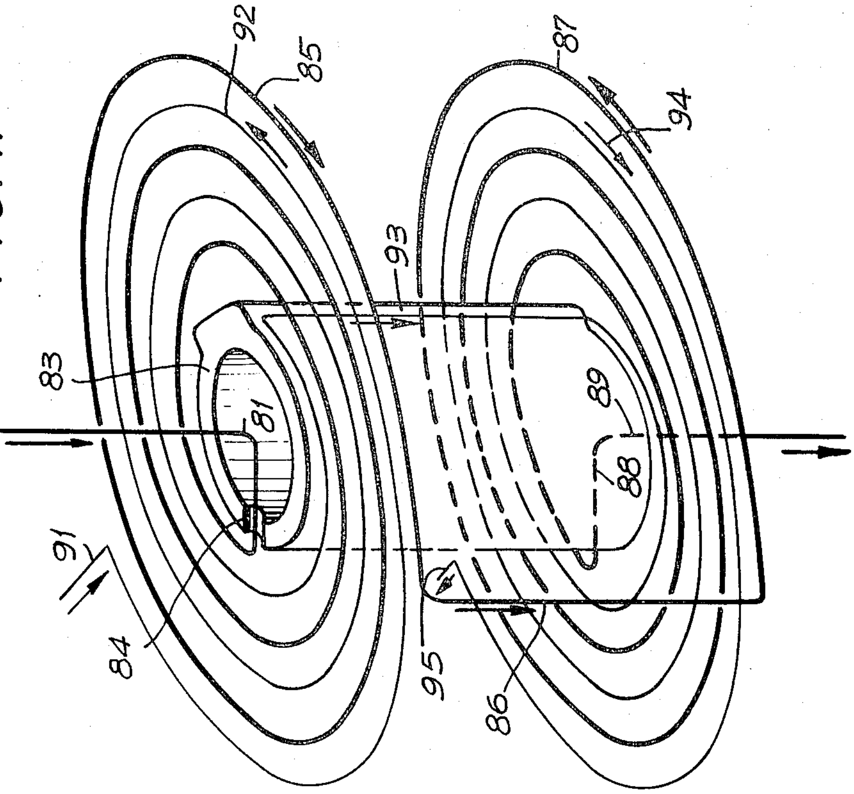


FIG. 5

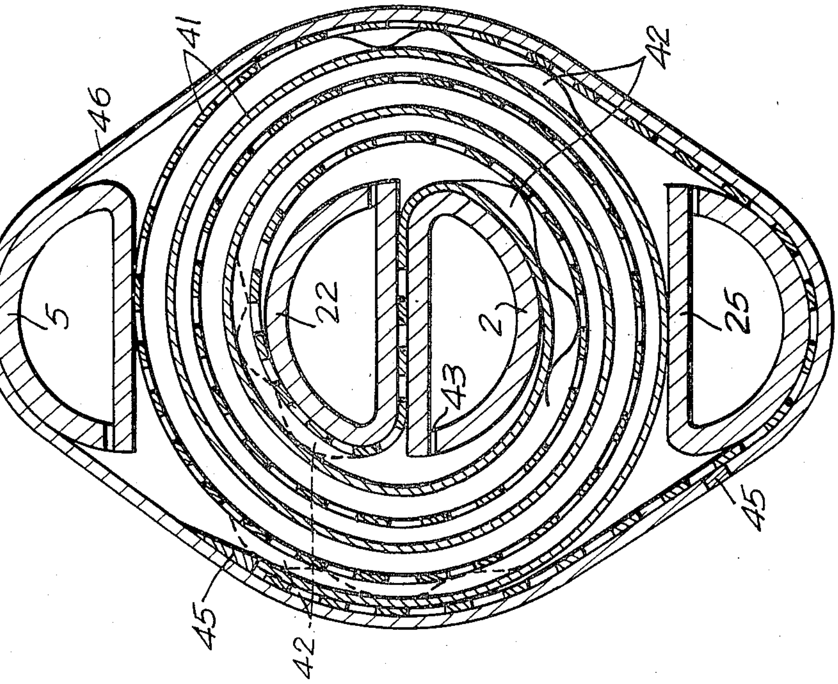


FIG. 7

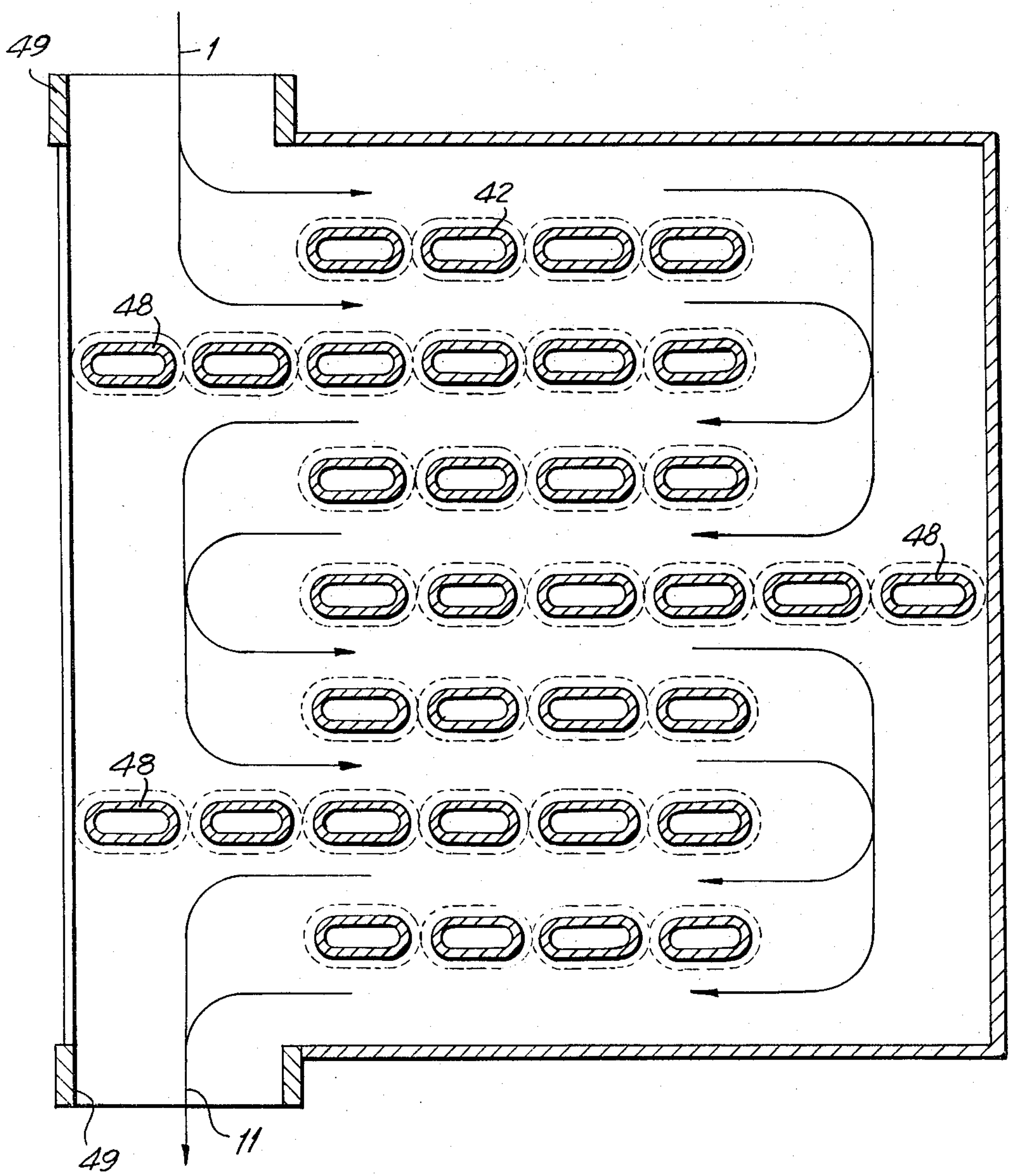


FIG. 9

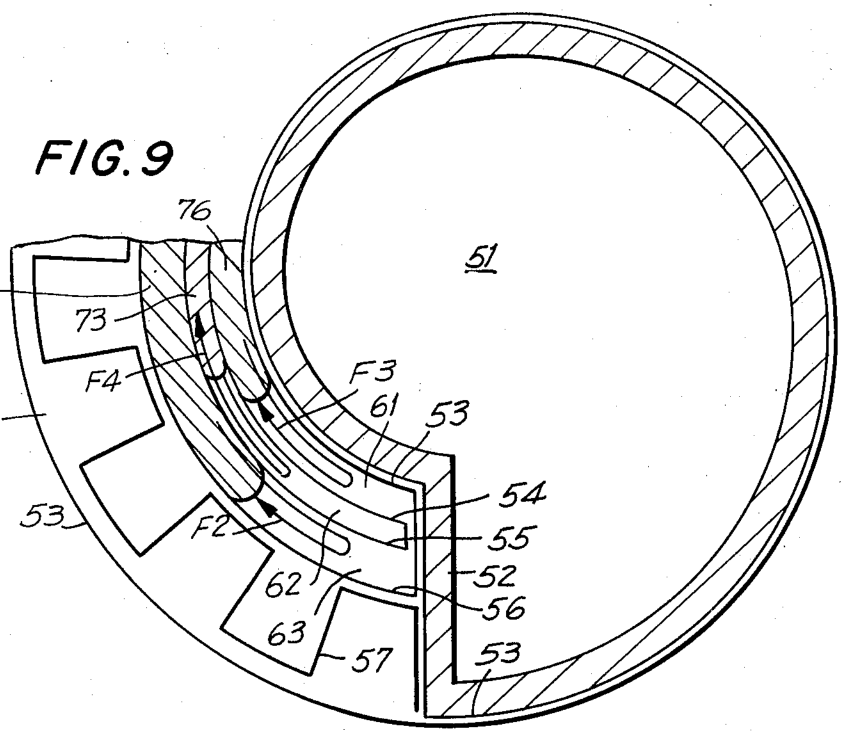

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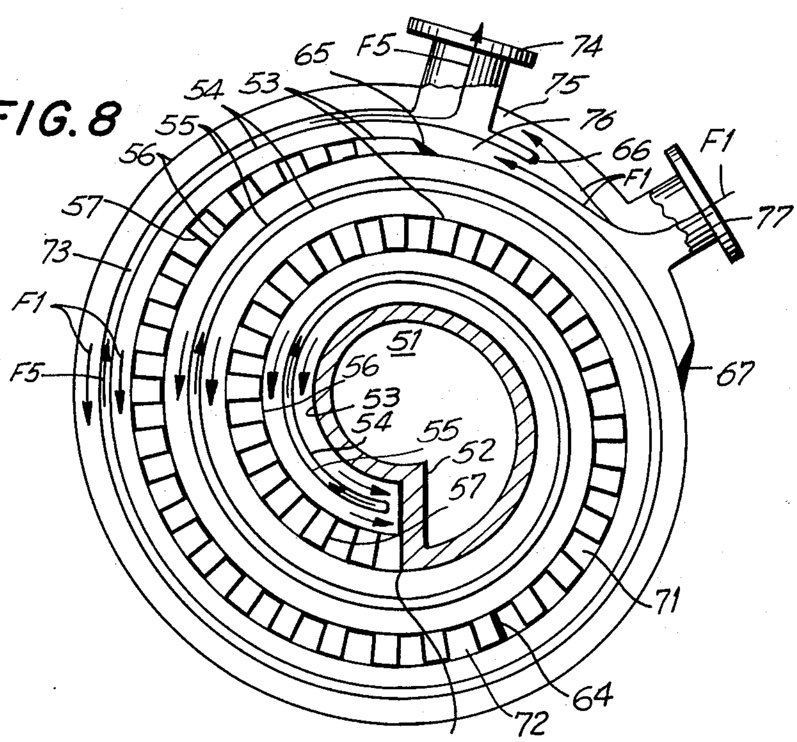
FIG. 8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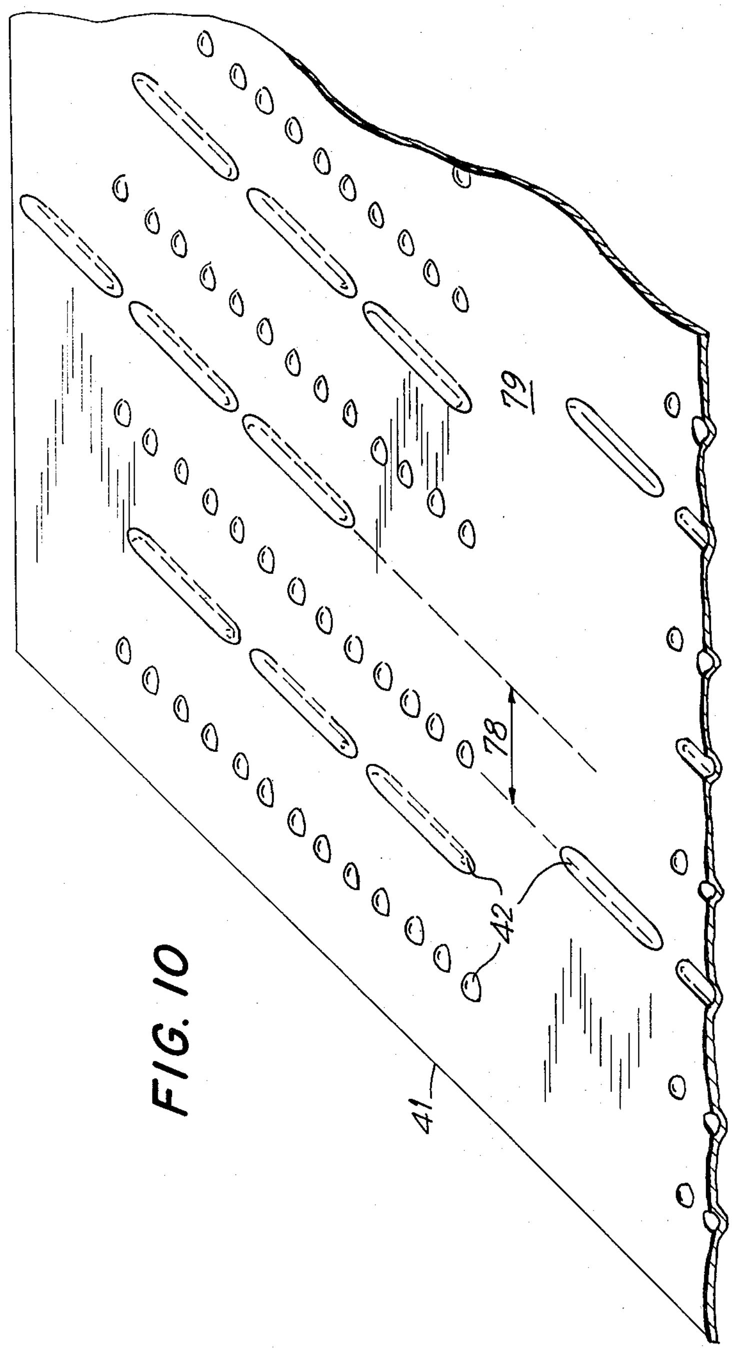


FIG. 10

FIG. 12

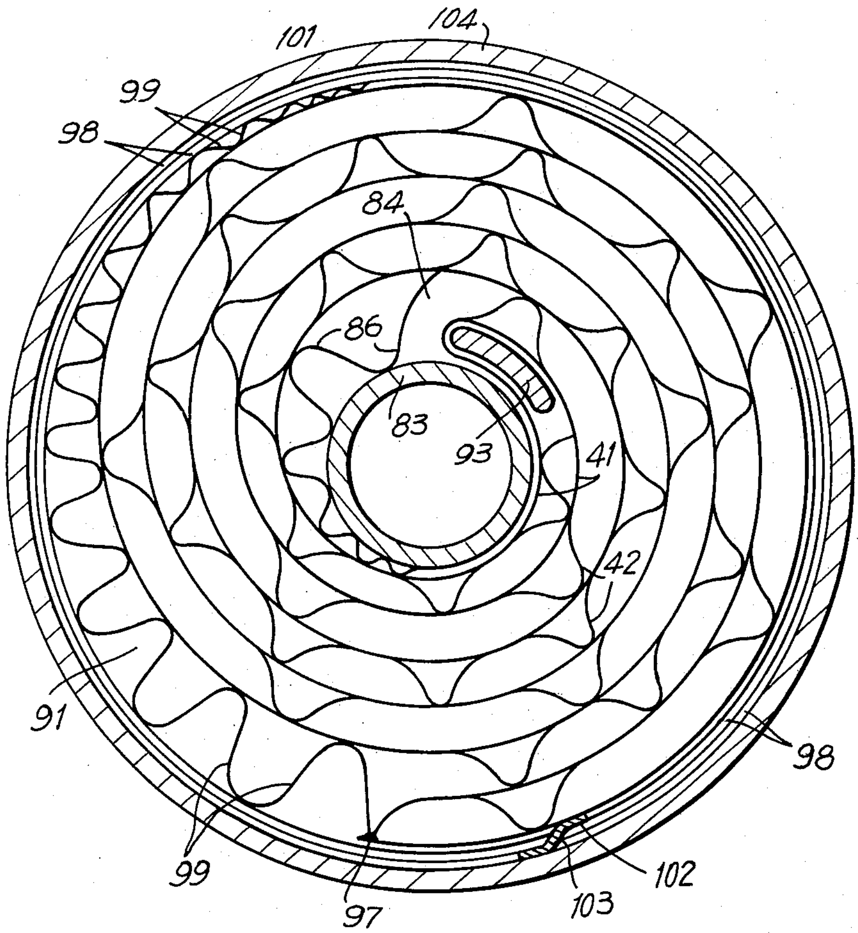
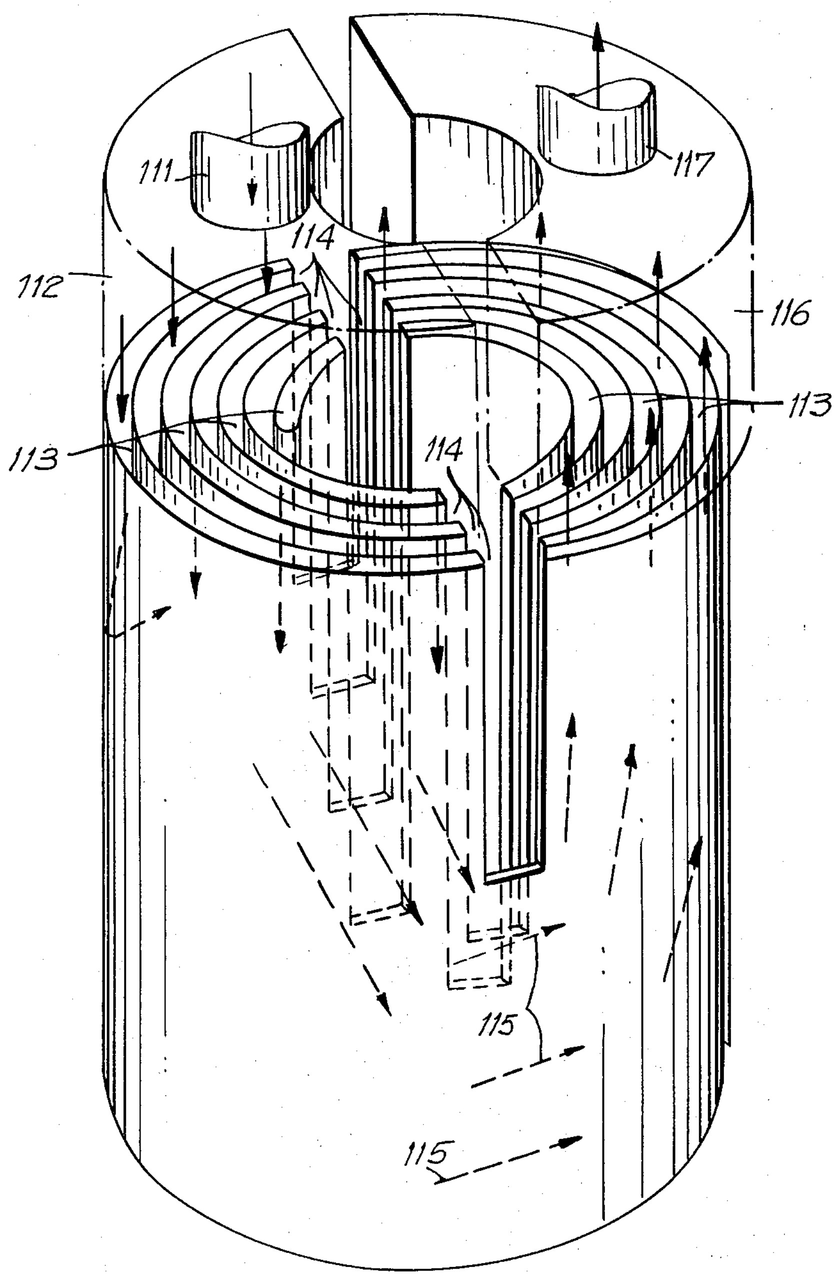


FIG. 13



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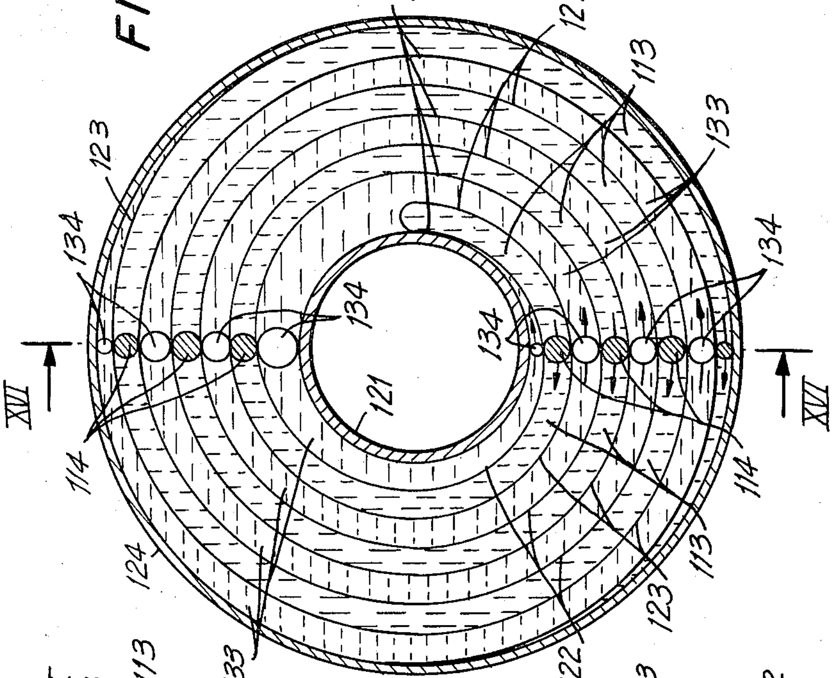
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FIG. 14

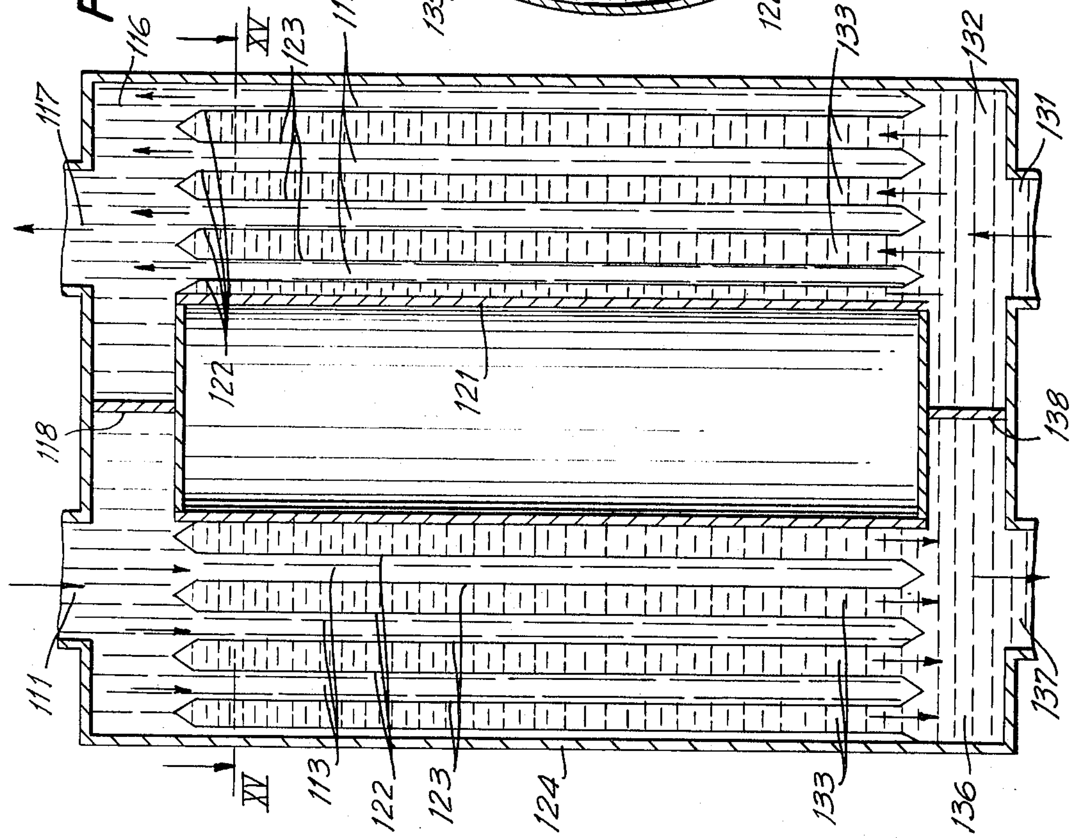
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FIG. 17

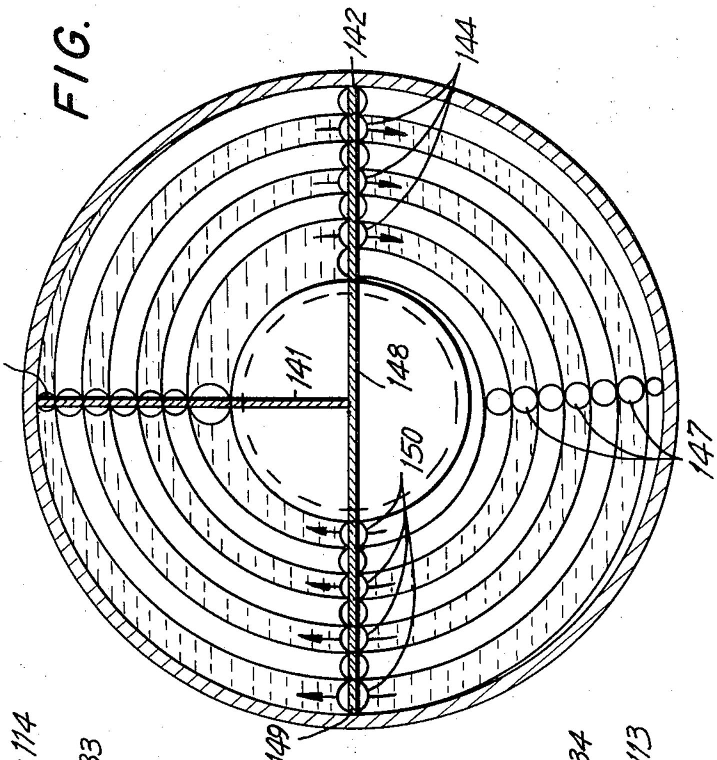
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FIG. 16

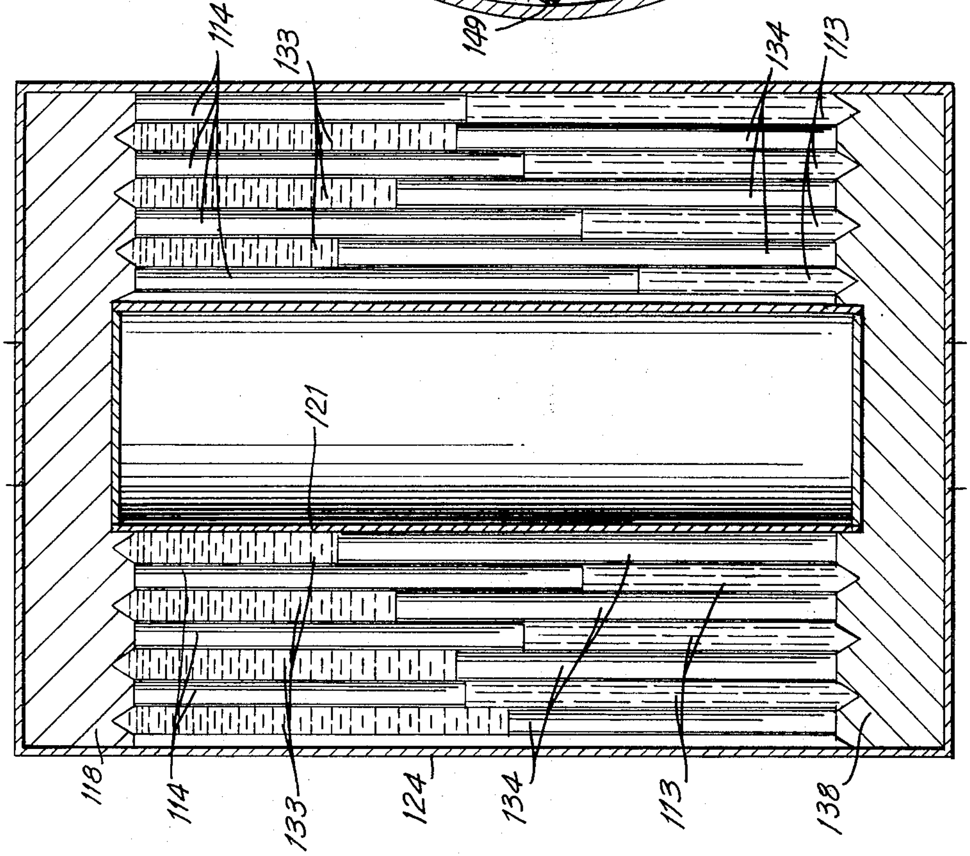
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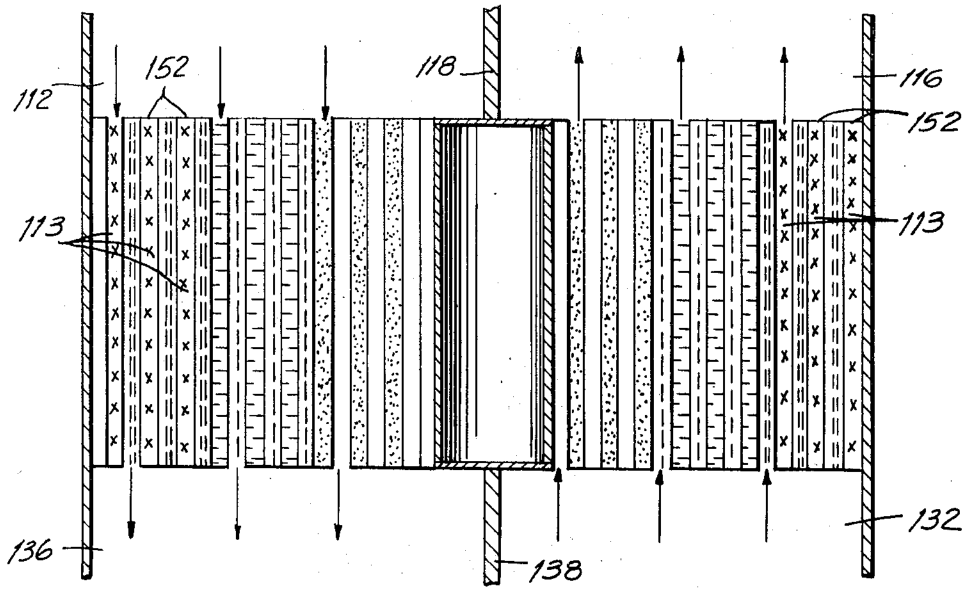
FIG. 18



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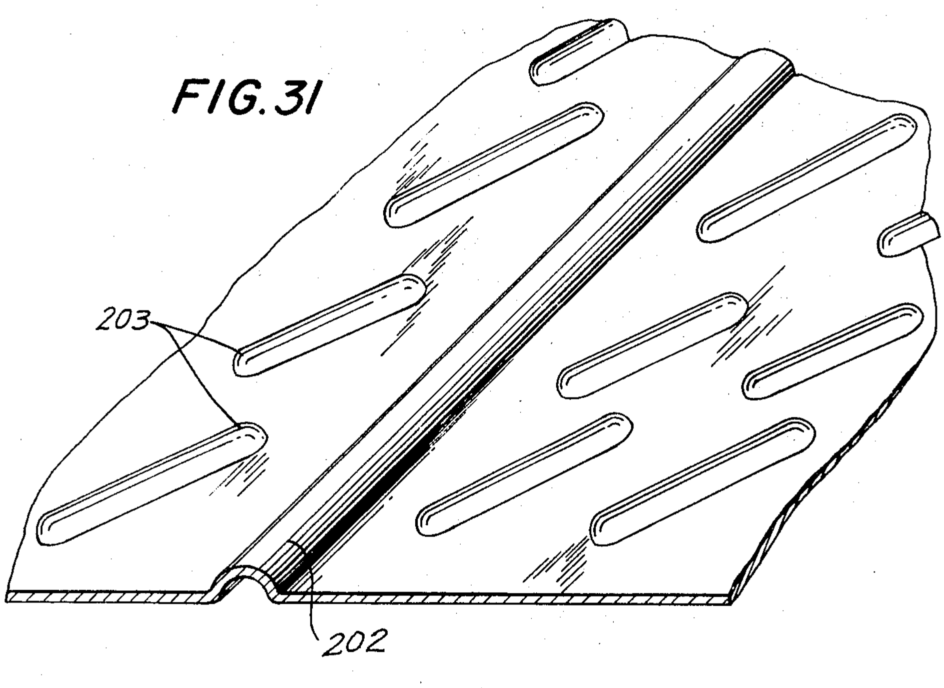


FIG. 19

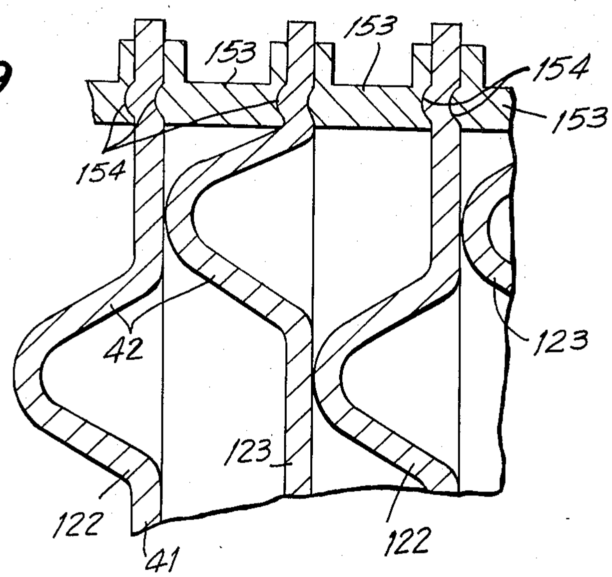
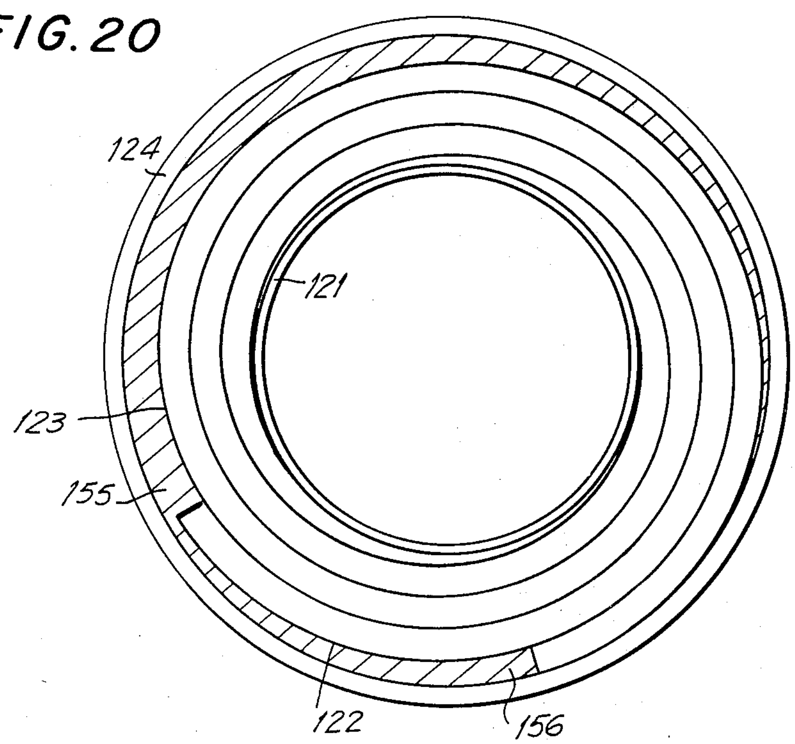


FIG. 20



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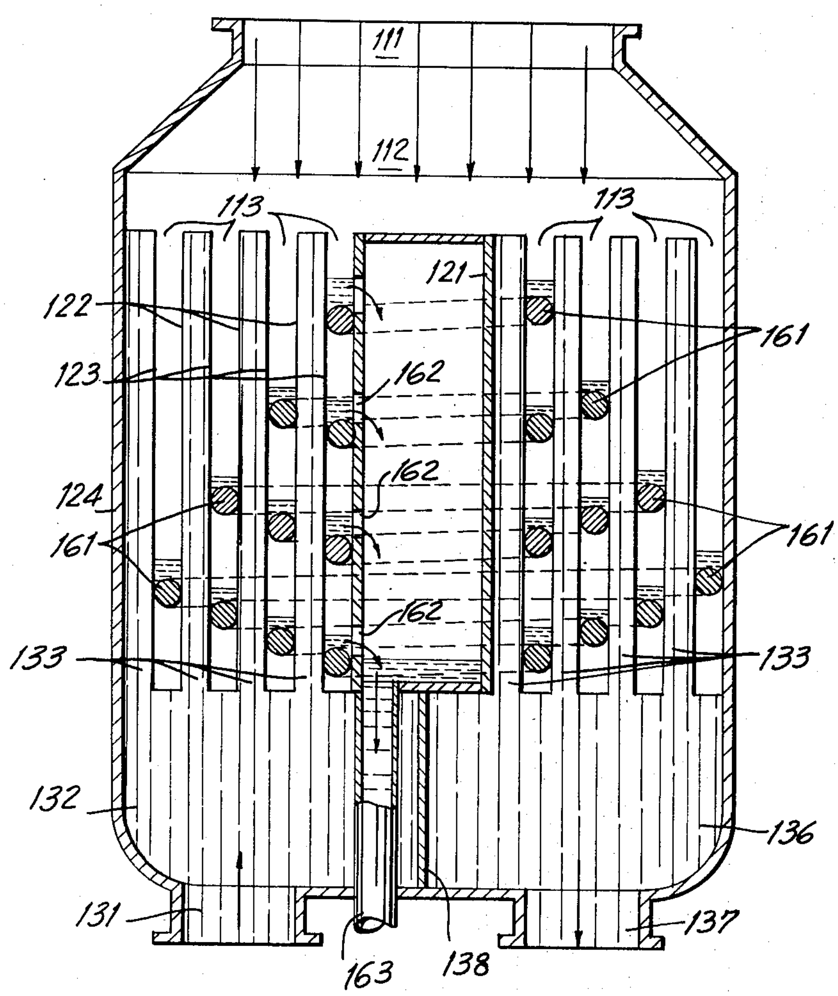
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FIG. 23

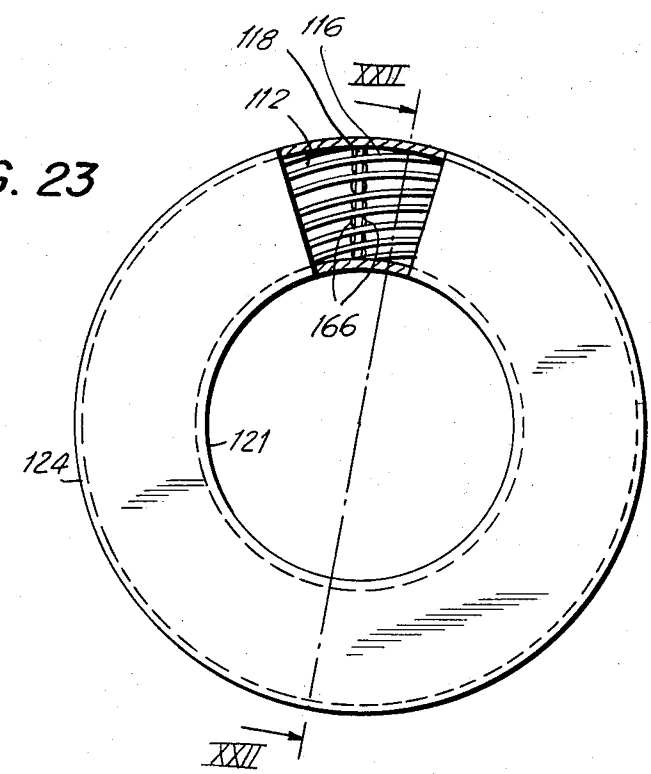
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FIG. 22

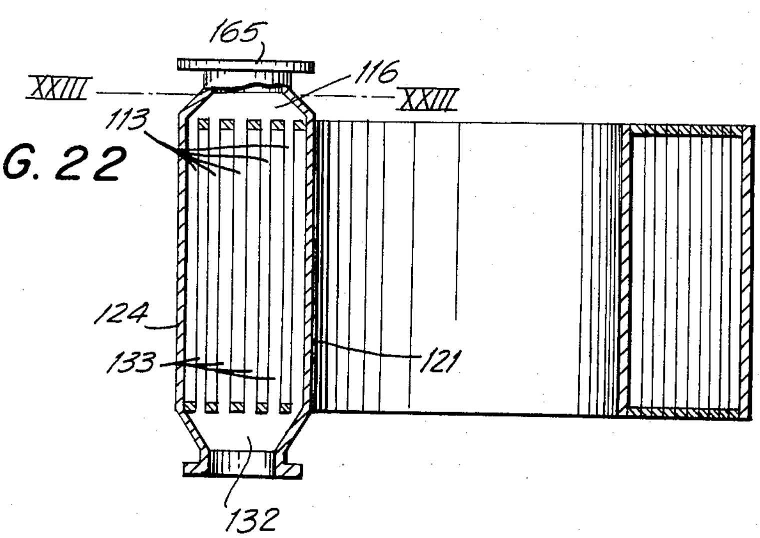
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FIG. 24

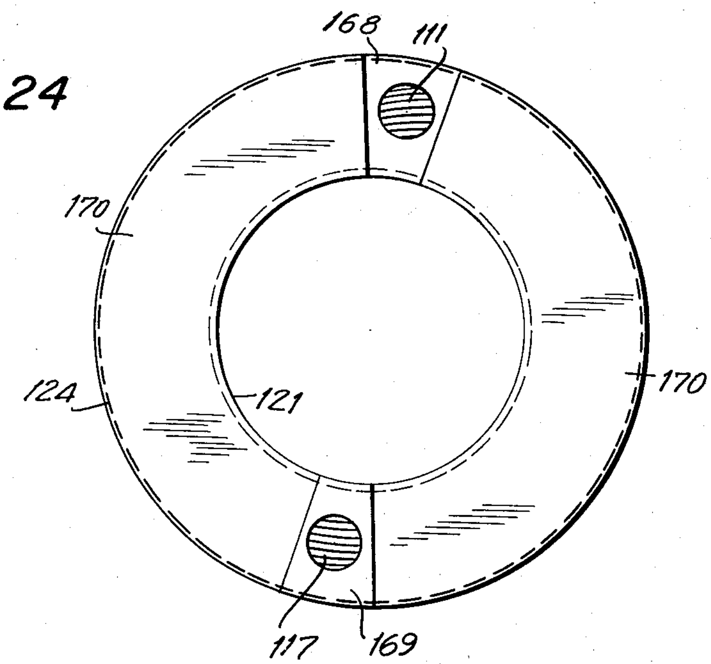
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FIG. 25

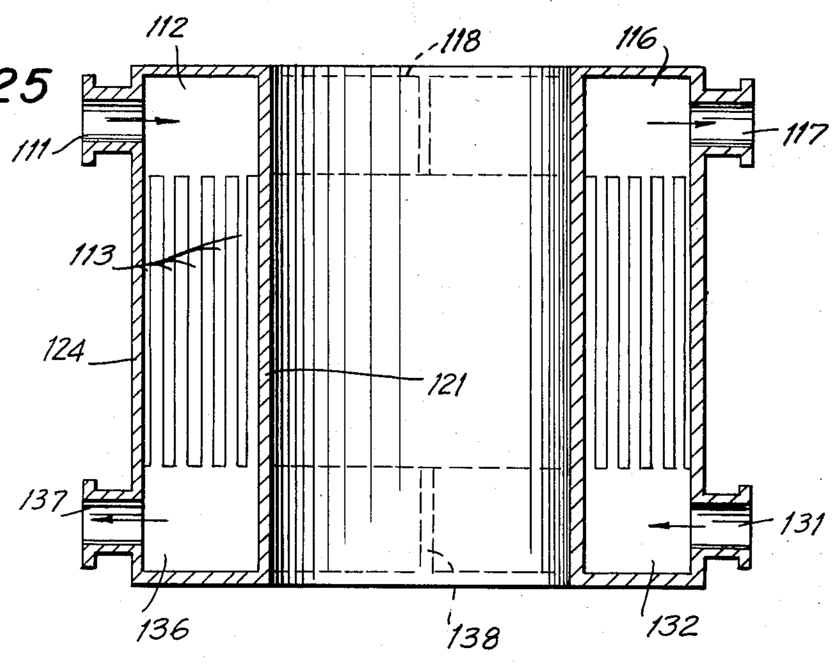
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FIG. 26

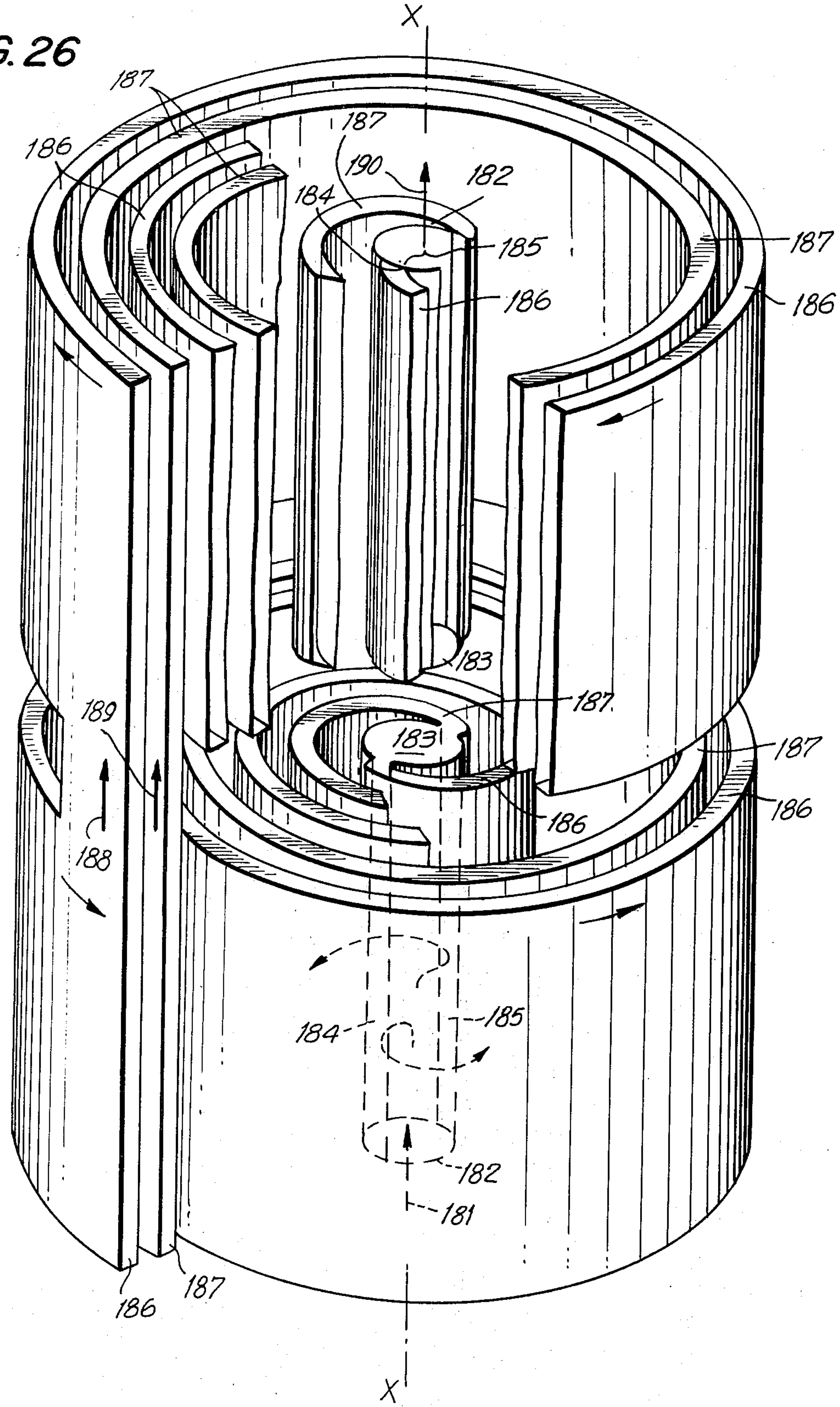
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FIG. 27

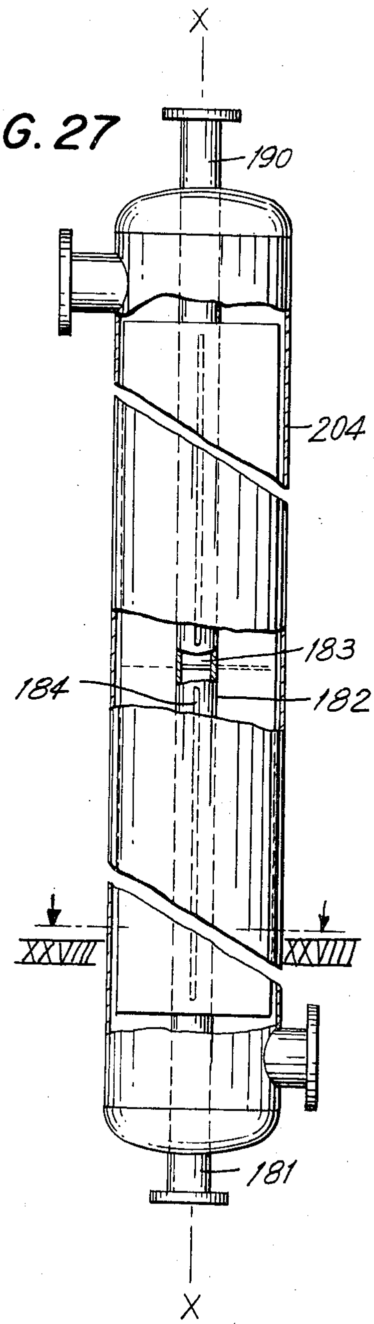
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FIG. 29

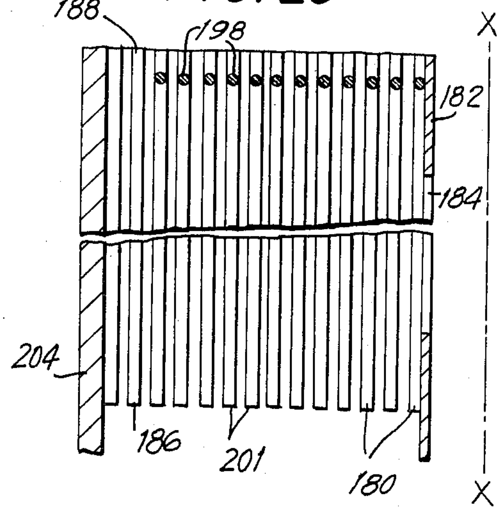
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FIG. 28

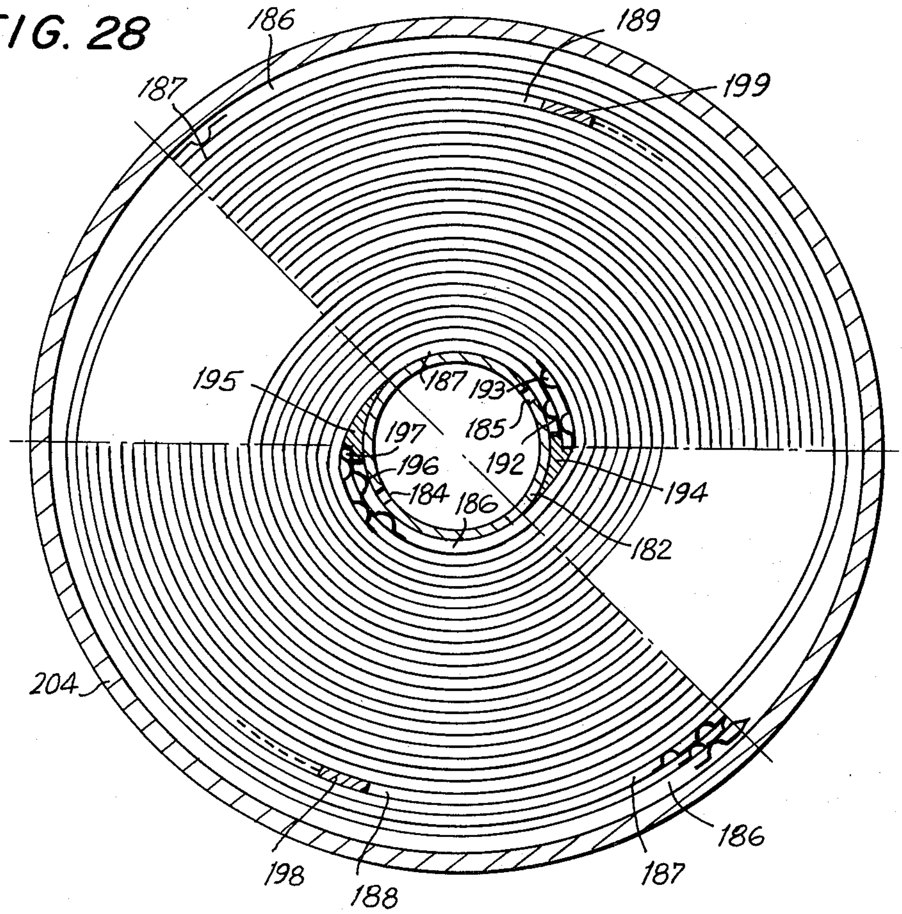
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FIG. 30

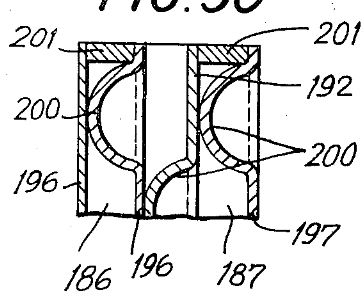
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FIG. 32

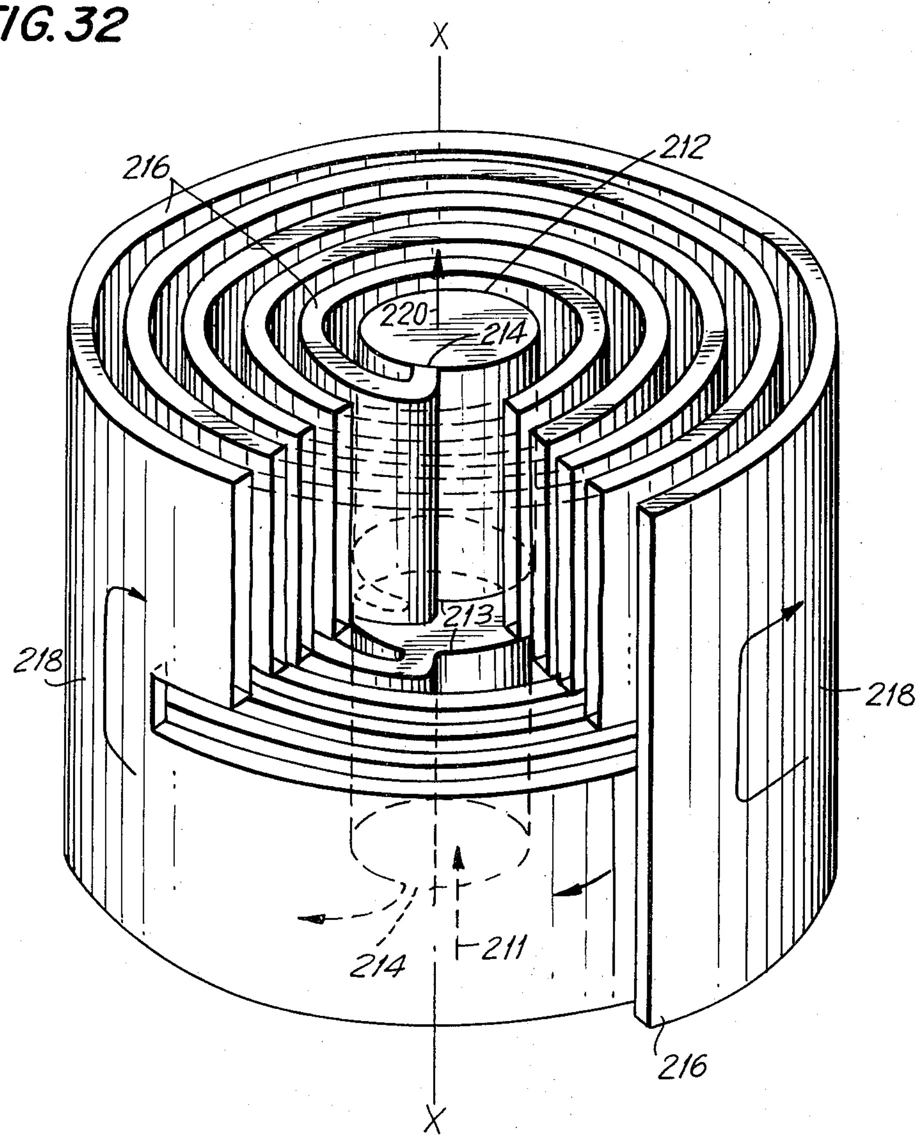


FIG. 33

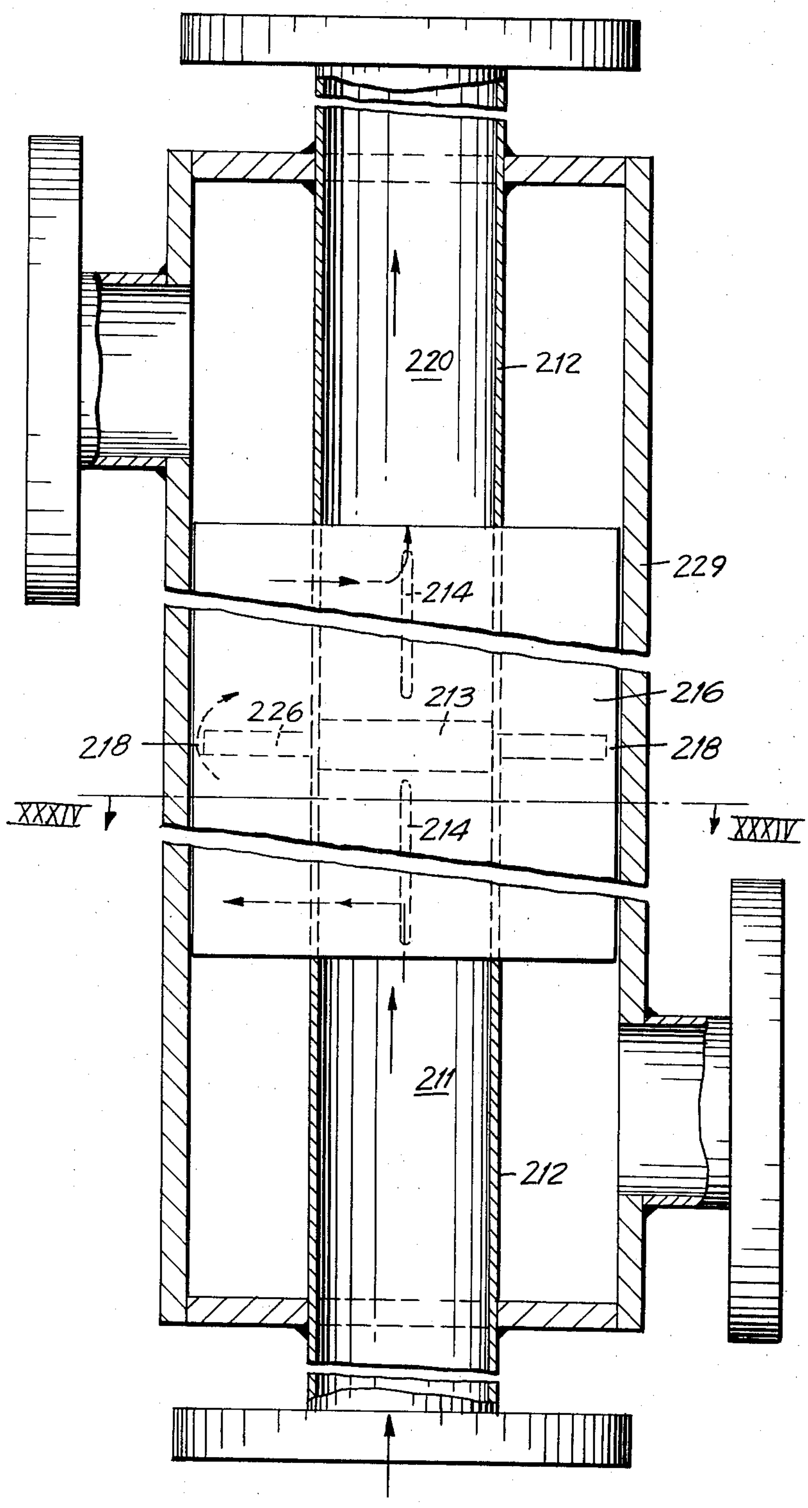


FIG. 35

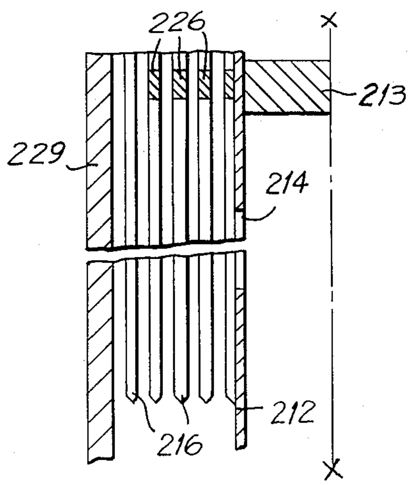


FIG. 36

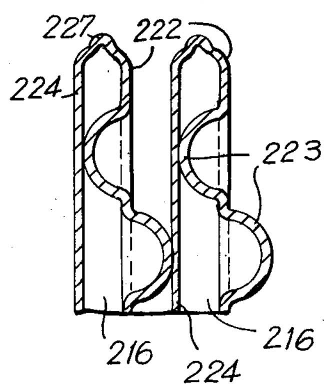


FIG. 34

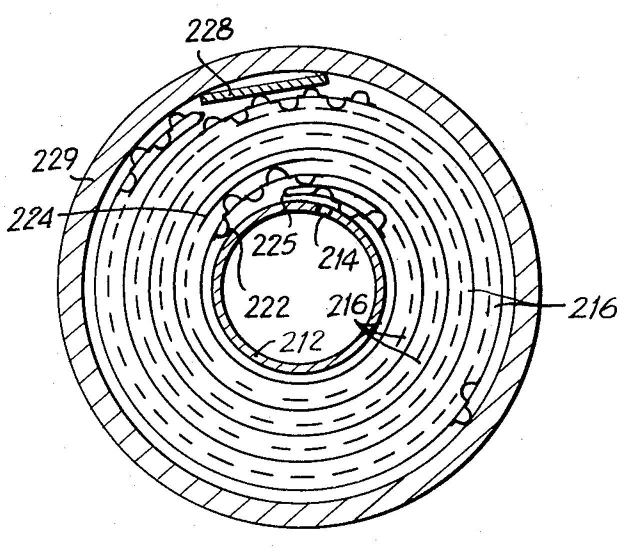


FIG. 37

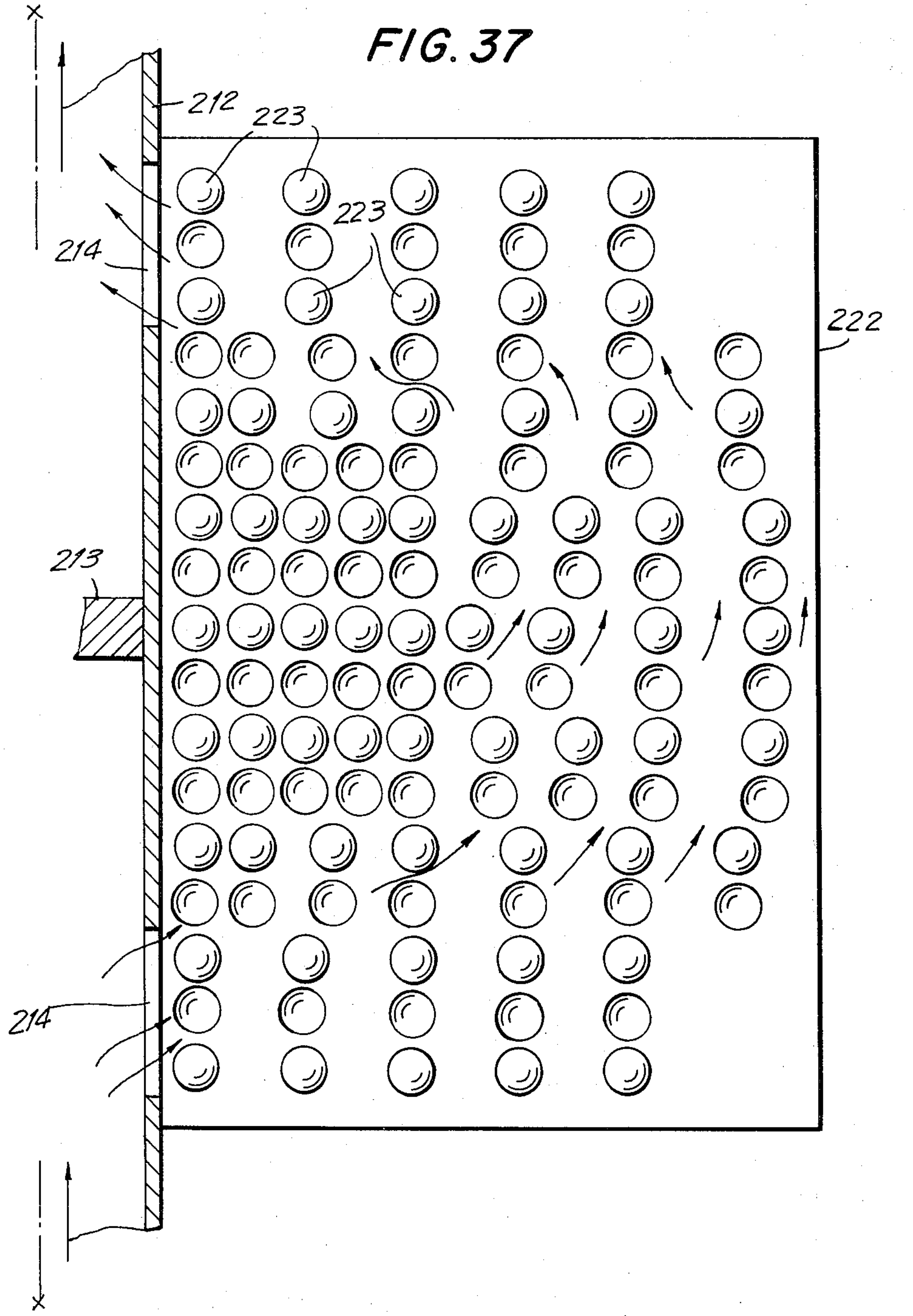
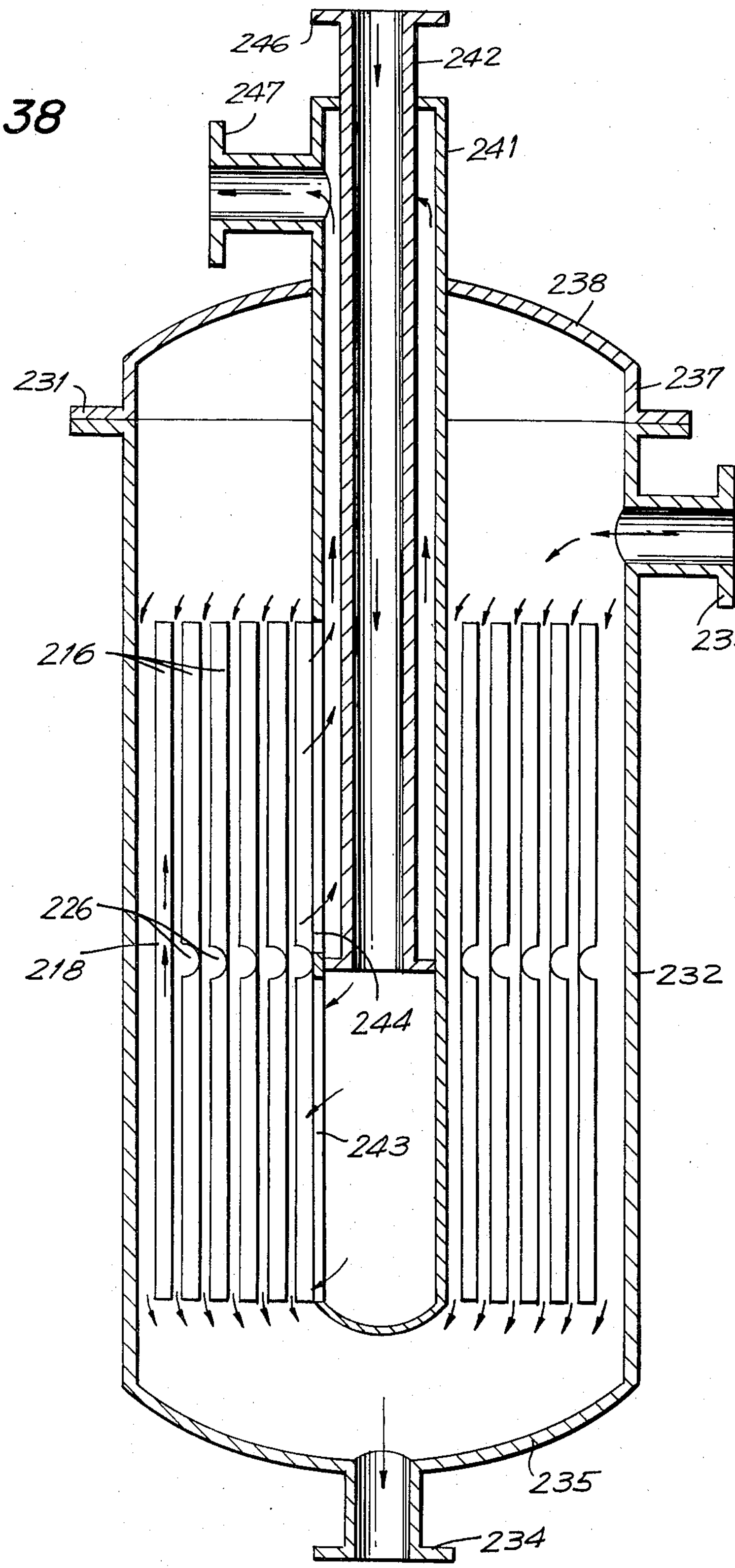


FIG. 38



HEAT EXCHANGER

This application is a divisional application of Ser. No. 888,591; filed Dec. 29, 1969.

The invention relates to the exchange of heat between at least two fluids. More precisely, the invention relates to heat exchangers comprising at least two chambers, these chambers being wound on themselves in self-enclosing spirals, the exchanger being of generally cylindrical shape.

In the present state of the known art, exchangers of this kind have already been proposed, in which at least one of the fluids passes into (or out of) its chamber through the intermediary of a capacity located at the centre of the spirals, and passes out (or comes in) at the periphery into another capacity placed at the exterior of the spirals. In order to withstand the pressures of the fluids, it is necessary to employ either an outer shell which supports the spiral nest, it being observed that the passage of the fluid through the shell causes a considerable loss of pressure, or alternatively to build the chambers with sheet metal of fairly large thickness in order that the last turn, suitably bent back and welded to itself, achieves the same result with external reinforcements.

The first solution results in costly and almost inextricable difficulties of practical construction of fluid-tight coupling between the exchange surface and the external capacity through the shell, these members having substantially different thicknesses and being subjected to dissimilar thermal variations which create large stresses at the most awkward points. The second solution is heavy and not very economical. Neither of the two solutions can be adapted for high pressures. Thus, it is found that the production cost of exchangers of the spiral type does not in any way enable them to replace other types of exchangers, for example the multitubular type.

At the same time as reducing the production cost to half or one-third that of conventional exchangers, the object of the invention is to dispense with their capacity or volume located outside the shell, which has been referred to above, either by winding the exchange walls round the inlet and outlet capacity of the same fluid, or by providing for the passage of the fluids through lateral openings formed in the sides of the spiral body (for high flow-rates). By this means, all the disadvantages indicated above are eliminated in the two cases.

There is thus obtained a spiral nest independent of the outer shell intended to contain the pressures, and in which the invention provides simple guiding means yo be produced so as to cause at least one fluid to follow a complicated path. The fact of having separated the nest from the shell constitutes an essential advantage which makes it possible to use very thin exchange walls, even with high pressures, by making use of the two central capacities as a frame intended to withstand the thrust of the internal pressures directed towards the centre and an external shell intended to contain the thrust of the internal pressures directed towards the periphery.

It is advantageous to make use of spacing means for the walls so as to assist in the guiding of the fluids. Thus, in accordance with a preferred form of construction, the exchange walls are held apart from each other by bosses intended to assist in the guiding of the fluid, either directly or in order to position partitions, at the same time having four other functions: to keep the sheets at a distance, to increase the exchange surface (by elongation of the metal) to reinforce the rigidity of the sheet metal, which makes it possible further to reduce its thickness, to induce turbulence intended to increase the coefficient of thermal exchange.

Finally, another object of the invention is to be capable of treating, with these exchangers, fluids in which the inlet temperatures are very different, which is possible with a concentric arrangement of the central capacities, completely eliminating all stress due to thermal expansion, and rendering the apparatus easy to dismantle.

In another alternative form of the invention, a supplementary sheet is employed as a spacing means, this sheet serving at the same time to considerably increase the exchange surface in contact with the said fluid. Boilers and air-coolers are constructed in this way.

From the advantages listed above, it follows that the exchangers according to the invention have an exceptional thermal efficiency, are very compact, are constructed with only half or one-third the amount of material and can be readily manufactured by mass production, being well adapted to all heat-exchange problems. Their production costs is one-third to one-half that of known exchangers, while at the same time their performance is better.

Forms of embodiment of the present invention will now be described with reference to the accompanying drawings, given by way of examples and not in any limitative sense; in these drawings:

FIGS. **1** to **6** relate to a heat exchanger between two fluids, in which:

FIG. **1** is a perspective view of the path represented as thread-like in heavy lines for one of the fluids, the path of the other fluid being shown in fine lines;

FIG. **2** shows part of the thin metal wall;

FIG. **3** is a perspective view showing the manufacture of the exchanger;

FIG. **4** is a cross-section taken along the line IV—IV of FIG. **3**;

FIG. **5** is a transverse section of the exchanger;

FIG. **6** is a perspective view of the extremity of the exchanger;

FIG. **7**, similar to FIG. **4**, relates to an alternative form of the previous exchanger;

FIG. **8** is a transverse section of a heat exchanger between three fluids, a central heating boiler, for example, of which FIG. **9** is an explanatory detail;

FIG. **10**, similar to FIG. **2**, shows a portion of another thin metal wall;

FIGS. **11** and **12** relate to another heat exchanger between two fluids, for which:

FIG. **11**, similar to FIG. **1**, is a perspective view of the paths of the two fluids;

FIG. **12**, similar to FIG. **5**, is a transverse section of the exchanger;

FIGS. **13** to **16** relate to another heat exchanger between two fluids, for which:

FIG. **13** is a perspective view of the path of one of the fluids;

FIG. **14** is an axial section of the exchanger;

FIG. **15** is a transverse section taken along the line XV—XV of FIG. **14**;

FIG. **16** is another axial section taken along the line XVI—XVI of FIG. **15**;

FIG. 17 represents a transverse section similar to that of FIG. 15; and relates to an alternative form of the above exchanger;

FIG. 18 is an axial section similar to that of FIG. 14, and relates to a further alternative form of the said exchanger;

FIG. 19 is a detail in axial cross-section, showing a construction of the top and bottom partitions of the above exchangers;

FIG. 20 is a transverse section similar to that of FIG. 15, and shows a construction of the peripheral turns of the above exchangers;

FIG. 21 is an axial section similar to that of FIG. 14, and concerns a further heat exchanger suitable for use as a condenser, evaporator, or boiler;

FIGS. 22 and 23 show, in axial and transverse section respectively, a further arrangement of the collectors of the above exchangers;

FIG. 24 is a plan view showing still another arrangement of the collectors of the above exchangers;

FIG. 25 is an axial section showing a further arrangement of the collectors of the above exchangers;

FIGS. 26 to 31 are concerned with a preferred construction of a heat exchanger according to the invention:

FIG. 26 is a perspective view with numerous parts broken away, of the diagram of circulation of a fluid in this exchanger;

FIG. 27 is a general view in elevation;

FIG. 28 is a transverse section taken along the line XXVIII—XXVIII of FIG. 27;

FIG. 29 is a half-radial section of the lower portion;

FIG. 30 is a detail showing the closure of the spiral sheets;

FIG. 31 is a detail showing a ribbed metal sheet suitable for the said exchanger;

FIGS. 32 to 37 relate to another preferred form of construction of a heat exchanger according to the invention:

FIG. 32 is a perspective view with numerous parts broken away, of the circulation diagram of a fluid in this exchanger;

FIG. 33 is a general view in elevation;

FIG. 34 is a transverse section taken along the line XXXIV—XXXIV of FIG. 33;

FIG. 35 is a half-radial section of the lower portion;

FIG. 36 is a detail showing the closure of the spiral sheet;

FIG. 37 shows another stamped metal sheet suitable for the said exchanger;

FIG. 38 is an axial section of a dismantlable exchanger fairly similar to that previously described.

With reference to FIG. 1, this heat exchanger according to the invention provides for the circulation of two fluids, each following four identical spirals which are successively traversed in opposite directions, the spirals for the two fluids being inserted one in the other in pairs and traversed in opposite directions by the two fluids.

In more detail, the path of one of the fluids, shown in heavy lines, causes it to pass at 1 into the upper part of a collector or header 2 (shown in broken lines) passing then in the centrifugal direction through a spiral 3, after which it moves down at 4 into a part of another header 5, passes through a spiral 6 in the centripetal direction, moves down at 7 into another part of the header 2, passes in the centrifugal direction into a spiral 8, flows-down at 9 into another part of the header 5, passes through a spiral 10 in the centripetal direction, and finally passes out at 11 at the lower portion of the header 8.

Symmetrically, the path of the other fluid, shown in fine lines, causes it to pass at 21 into the lower portion of a header 22 (shown in broken lines), to traverse in the centrifugal direction, a spiral 23 identical with the spiral 10, but displaced by half a revolution, each turn of one being placed between two turns of the other, to move upwards at 24 into another header 25, to traverse in the centripetal direction a spiral 26 placed in the same manner in the said spiral 8, to rise at 27 into another part of the header 22, to traverse in the centrifugal direction a spiral 28 housed in the said spiral 6 in the same manner, to rise at 29 into another part of the header 25, to pass in the centripetal direction through a spiral 30 housed in the same manner in the said spiral 3, and to pass out at 31 at the upper portion of the header 22.

It will be observed that the path of each fluid is at every point in the opposite direction to the path of the other fluid at the two points of each side of the said point, and that this is obtained by a structure of identical spirals having the same direction, and therefore of a practical construction which will now be described with reference to FIGS. 2 to 6.

In this form of a structure which provides for the two fluids, the paths which have been described above with reference to FIGS. 1, these two fluids circulate on each side of a thin metal wall 41. Generally speaking, this thin wall is a sheet on which has been impressed, by stamping or goffering, impressions, for example the elongated bosses 42 arranged in line, as shown in FIG. 2. These impressions have a three-fold purpose, on the one hand the mechanical function of spacing apart from each other the turns of the wall 41 (as will be seen later), on the other hand the thermal function of increasing the heat exchanges through the wall 41, at the same time by increasing the surface area and by creating local turbulence in the fluids, and finally the function of positioning the partitions intended to guide the circulation of the fluid.

With reference to FIG. 3, which is a perspective view of the structure in course of manufacture, and to FIG. 4 which is a half-section just above the plane of the wall 41 (plane IV—IV of FIG. 3): the sheet 41 with the bosses 42 in relief on the straight portion (the edge of which has been shown as a heavy continuous line, and underneath the left hand-side (the edge of which has been shown as a heavy broken line) with margins without bosses, reveives, for example by welding, the four headers 2, 5, 22, 25 already referred to; they are of semi-circular section, each with a longitudinal lateral slot and transverse internal partitions, which are mounted facing the lines of bosses 42. For example, the header 2 is provided with a slot 43 and with two internal partitions 44 (see FIG. 4); the same thing applies to the header 5, which ensures for one of the two fluids the path of oppositely-directed spirals described with reference to FIG. 1 and which are again shown, unwound flat, in FIG. 4.

After the said welding, the assembly is wound and there is obtained the structure of spirals shown in cross-section in FIG. 5 (in which the two right-hand and left-hand portions of the wall **41** before winding are again shown respectively in heavy continuous lines and in heavy broken lines for the sake of clearness of the drawing). Extremity welds **45** stop the turns and fix the whole in a casing **46.** This latter is not essential and may be replaced by additional turns of the wall **41.** FIG. **6** shows a perspective view of one extremity of this exchanger; it may comprise a welded end-plate **47** as shown, or it may be closed by welds of the edges of the wall **41** or by filler metal, brazing or welding, or by a polymerized material which has set into a block.

It is clear that in the description which has been given above, the number of spirals, the number of the rows of bosses and internal partitions of the headers may be modified according to considerations of choice or opportunity, without departing from the scope of the invention.

For example, when the pressures contemplated are not too high, for example when the difference of the pressures between the two fluids does not exceed **20** bars, it is not only possible to simplify the casing as already explained, but also to eliminate the headers as shown in FIG. **8.**

Certain lines **48** of the bosses **42** of the sheet **41** (those which have to vary the path of the fluid) are then extended so as to be substituted for these headers in their function of guiding of the fluid, and only the inlet and outlet orifices **49** are required.

There will now be described another embodiment of the invention relating to a boiler for a flat or a building, that is to say for heating by means of combustion gases, on the one hand water for heating by radiators and on the other hand water for domestic purposes. With reference to FIG. **8,** which is a transverse section in the upper portion, and to FIG. **9** which is an explanatory detail in transverse section towards the central portion, this boiler comprises an axial header **51** in the form of a volute with a single turn closed by a radial partition **52.** On this volute there are wound simultaneously: a first goffered metal wall **53,** a second goffered metal wall **54,** the gofferings of which are displaced with respect to those of the first wall **53,** a third goffered metal wall **55,** the gofferings of which are displaced with respect to those of the second wall **54,** a flat metal wall **56** and a sheet with rectangular ribs **57.**

Preferably, but not necessarily, as very clearly shown in FIG. **8,** the walls **54** and **55** form part of the same metal sheet folded back on itself along the wall **52,** and similarly, the walls **53** and **56** form part of another single metal sheet folded back on itself around the previous sheet along the partition **52.** As shown in FIG. **9,** the bosses of the walls **53, 54** and **55** and the partitions which direct the flow of the fluids along the transverse spirals, are interrupted at a certain distance from the partition **52,** leaving vertical passages **61, 62** and **63** along this partition. Towards the middle of the winding (FIG. **8**), a longitudinal partition **64** reinforces or extends, at its two extremities, one of the ribs of the sheet **57,** which defines a first chamber **71** containing half the sheet **57** with rectangular ribs, between the partitions **52** and **64.** At the periphery, the last turn of the wall **53** is welded at **65** on the last turn but one of the wall **56,** which defines a second chamber **72** containing the other half of the sheet **57** with rectangular ribs, between the partitions **64** and the weld **65.** A little farther on at the periphery, the ends of the walls **54** and **55** are welded together at **66,** which defines a third chamber

73 open at its upper portion on an orifice **74** and at its lower portion on an identical orifice (not shown on the drawing). A little further still on the periphery, the last turn of the wall **56** is welded at **67** on its last turn but one, which defines a fourth chamber **75** and a fifth chamber **76** which open together at their upper portion on an orifice **77** and at their lower portion on an identical orifice (not shown on the drawing).

The hot combustion gases coming from a furnace below the plane of FIG. **8** pass up through the interior of the header **51,** are sent back by a partition (above the plane of the drawing) and pass down again through the chamber **71,** in contact with the rectangular ribs of the sheet **57,** are again sent back by a partition (below the plane of the drawing) and rise again through the chamber **72** passing over the rectangular ribs of the other half of the sheet **57,** and are then evacuated to the chimney. The water for heating by radiators enters the upper portion through the orifice **77** (arrows **F1**), and divides between two spiral centripetal paths in the chambers **75** and **76.**

It will be observed that each turn of the chamber **71** or **72** for the hot gases is housed between a turn of the chamber **75** and a turn of the chamber **76.** This water, coming in towards the centre (FIG. **9**) moves down, for the chamber **75,** through the passage **63** (arrow **F2**) and for the chamber **76** by the passage **61** (arrow **F3**). At the lower portion, the water than follows the same chambers **75** and **76** but in the opposite direction (the direction opposite to that of the arrows **F1** for the upper portion, as in FIG. **8**) and in this case also, each turn of the chamber **71** or **72** is housed between one turn of the chamber **75** and a turn of the chamber **76,** and passes out downwards through the orifice corresponding to the orifice **77.**

Finally, the water for domestic use passes in at the bottom through the orifice corresponding to the orifice **74,** circulates in the lower part of the chamber **73** (in the opposite direction to the arrows **F5** of FIG. **8**), moves upwards (FIG. **9**) through the passage **62** (arrow **F4**), circulates in the opposite direction (arrows **F5** of FIG. **8**), in the upper portion of the chamber **73** and passes out at the top through the orifice **74.** It will be noted that for the bathroom water also, each turn of the chamber **73** is housed between a turn of the chamber **75** and a turn of the chamber **76** in which the central heating water circulates in the opposite direction.

According to the invention, the bosses **42** of the goffered metal sheet **41** may also be of the elongated shape shown for example in FIGS. **2, 4** and **7,** as well as other forms. For example, in the case of the bosses in line of the ribs shown in FIG. **10,** and for the other bosses with hemispherical impressions, the whole in relief for one-half of the sheet **41** and recessed as regards the other half, preferably and as shown in FIG. **10,** with a transverse displacement **78** between the two halves. For the purpose of winding, it is then only necessary to utilize two mandrels each comprising a flat strip applied one above and the other below the central area **79** of the sheet **41** so as to obtain, after winding and removal of the mandrels, a heat exchanger of the above-mentioned type.

Naturally, it remains within the scope of the invention to eliminate the chamber **73.** In this case there may be contemplated the use of the exchanger as an air cooler, the gases passing for example directly in one direction only through the whole chamber **71** and **72.**

The ribbed sheet **57** plays the part of a secondary surface, and there is an advantage in improving its connection to the exchange walls **53** and **56**, by dipping the apparatus into a bath of metal with a low melting point, for example zinc. Without departing from the scope of the invention, it is also possible to arrange the inlet and the outlet of fluid passing spirally through its chamber, at the centre.

Another embodiment of the invention will now be described with reference to FIGS. **11** and **12**, which relate to a heat exchanger between two fluids, with a central tube divided into two parts by a central horizontal separation, thus forming the inlet capacity and the outlet capacity of the first fluid.

FIG. **11** is a perspective view of the path shown as being of thread-like form in heavy lines of this fluid, the path of the other fluid being shown in fine lines. The first fluid enters at **81** into the inlet capacity, at the upper portion of the central tube **83**, passes out at **84**, describes a spiral **85** in the centrifugal direction, flows down at **86**, describes a spiral **87** in the centripetal direction, returns into the tube at **88** and passes out at **89** through the lower part of the central tube **83**, that is to say through the outlet capacity. The second fluid enters peripherally at the top at **91**, describes a spiral **92** in the centripetal direction, identical with the spiral **85**, each turn of one being placed between two turns of the other, flows down along a vertical wall **93**, describes a spiral **94** in the centrifugal direction, identical with the spiral **87**, each turn of one being placed between two turns of the other, and passes out peripherally at the bottom at **95**.

It will be observed in this case also that the path of each fluid is, at each point of each spiral, of opposite direction to the path of the other fluid on both sides of the said point, and that this is obtained by a structure of identical spirals having the same direction, and therefore of practical construction, which will now be described with reference to FIG. **12**. It is furthermore advantageously possible to cause the two fluids to follow the same path, but in opposite directions, the inlet being made at **95** and the outlet at **91**, thus producing a counterflow exchanger.

With reference to FIG. **12**, which shows a transverse section of this heat exchanger, the winding can be carried out round the header **83**, after having arranged this latter on a goffered sheet **41**, approximately at its centre, and after having fixed the extremities of the header **83**, which extend slightly beyond the sheet **41**, to a flat strip **93**. This flat strip is slightly curved so as to follow the radius of curvature of the header **83**, and the goffered sheet **41** can be provided with additional impressions **96** which give it a spiral form at the outset. At the midheight of each chamber (not shown in FIG. **12**) a blade or a joint forming a partition separates each chamber into two superimposed zones which give the paths of the two fluids the form of double spirals, described in connection with FIG. **11**.

When the winding is completed, the two extremities of the sheet **41** are cut and welded at **97** along a generator line. A goffered sheet **98** can then be wound with several turns, the bosses **99** of this sheet having a height which decreases from the generator line **97** ot the generator line **101** so as to give the whole a generally cylindrical form. The goffered sheet **98** is welded at **102** on the sheet **41** and at **103** on itself. The assembly is then inserted into a casing **104** and the edges of the sheet **41** are welded to each other except for the outer portion between the generator lines **97** and **101** which leaves open, at the top, the said inlet **91** for one of the two fluids, and at the bottom, the said outlet **85** (not shown in FIG. **12**) of this fluid. The other fluid passes in at the top at **84** and passes out at the bottom, at **88** (not shown in FIG. **12**).

There will now be described the embodiments of the invention which are particularly suitable for high flowrates of fluid. With reference to FIG. **13**, this drawing shows a perspective view of the sheets in the form of spiral cylinders followed by one of the fluids, and in fine lines at the upper portion, the inlet and outlet headers for this fluid. The other fluid follows identical sheets, each of two sheets of the first fluid and its headers are at the lower portion, but FIG. **13** does not show these for the sake of clearness of the drawing (they are shown on the figures which follow). The first fluid passes at **111** into the header **112**, in the form of a half-cylinder opening at its lower portion on a plurality (in this case 4) of spiral cylindrical sheets **113**, passes through each of these sheets on both sides in a double spiral, passing under staggered central baffles **114** (arrows **115**) and passes out through the header **116** and the outlet **117**.

With reference to FIGS. **14**, **15** and **16**, which are cross-sections of the construction of the heat exchanger ensuring the conditions which have been specified in connection with FIG. **13**, these sections being respectively axial in passing through the inlet **111** and outlet **117**, transverse along the line XV—XV of FIG. **14** and axial passing through the baffles **114** along the line XVI—XVI of FIG. **15**.

The exchanger comprises a central tube **121** of cylindrical shape, closed at its extremities, on which is wound double, as already described for other exchangers, a thin goffered metal wall **41**. This double wound wall can be replaced by two walls **122** and **123**, each stamped for example with impressions of small spherical caps of increasing height on the first turn and then of constant height, their goffering being displaced from one wall to the other and the two walls being welded at their starting point close to the central tube **121**, together and to this tube.

The baffles **114** may be constituted by lines of bosses such as those already described with reference to FIGS. **7** and **10**.

Along the length of the last turn of each wall, the gofferings are of decreasing height so as to restore the circular form. The walls are welded into an outer tube **124** of generally cylindrical shape and substantially higher so as to form the headers **112** and **116** which are separated by a partition **118** (FIG. **14**). The chamber **113** is closed at the bottom by a weld which may be made automatically after having brought the edges of the walls **122** and **123** together by means of a knurling tool, following a spiral passing from one tube to the other.

Symmetrically, the other fluid enters at **131** into the header **132**, circulates in the chamber **133** (closed at the top in FIG. **14**), passing above the baffles **134** (FIG. **15**) and passes out through the header **136** at **137**. The baffles **114** and **134** are of progressively variable heights and leave a passage for the fluid, the size of which varies with the opening section of the sheet considered on its header.

If for one of the two fluids it is desired to reduce the section of passage while increasing the length of the path travelled in the exchanger, additional baffles and partitions may be utilized as shown in FIG. 17 (similar to FIG. 15). The fluid coming into the upper right-hand quadrant between the partitions 141 and 142 flows down into the sheets, passes into the lower right-hand quadrant underneath the partition 142 by passing round the baffles 144, and then into the lower left-hand quadrant, avoiding the baffles 147 by the chamber defined in the header by the partitions 142, 148 and 149, passes into the upper left-hand quadrant, underneath the partition 149 while passing round the baffles 150, and passes out through the header. It is clear that the length of the path can be increased by multiplying the number of baffles and partitions, by providing in succession a partition which completely closes the section of the turn and baffles which only leave a section of passage for the fluid which is lower or higher; this arrangement can be applied to a different extent for each chamber, and this makes it possible to provide, for each fluid, a path having a section and length appropriate to the thermal problem considered.

With reference to FIG. 18, this other exchanger according to the invention is, for reasons of choice or opportunity, of larger diameter with respect to its axial length. For the path of one or both fluids, there are then provided several turns traversed successively, quite simply by closing these turns on the side which was open to the header. Thus, the spiral sheet 113 which is outermost in FIG. 18, comprises a turn open at the top to the inlet header 112, and then several turns, for example two as shown, closed at the top at 152, for example by a partition or by welding, these turns being successively traversed by the fluid while passing round the baffles which they comprise (not shown in FIG. 18), and finally a turn open at the top to the outlet header 116. The other spiral sheets 113 comprise the same closures 152 at the top, which may, as shown, be common to several of them. Similar closures may be provided, but at the bottom as shown, for the other fluid.

It has been stated that these closures may be effected by bringing the edges together with a knurling tool, followed by welding, or by a partition. A closure of this kind by a partition will be described with reference to FIG. 19, which is an axial section of a detail. The consecutive turns of the thin metal wall 41 (bent back in a double spiral on itself), or alternatively the consecutive turns of the two sheets 122 and 123 with their bosses 42, are closed by metal strips 153 inserted between the edges of the spirals and secured by insetting at 154 in the winding, and/or by welding. These strips 153 are of course interrupted at the desired places so as to permit the fluid to pass into or out of the corresponding chamber 113 or 123. In this construction of the closures 152, in order to avoid difficulties towards the outer end of the spirals, these interstitial spaces 155 and 156 (FIG. 20) are filled with a mouldable material such as concrete, fusible metal or plastic.

This lateral closure of the chambers, like the fixing of the nozzles, can advantageously be carried out by the solidification into a mass of a polymerized material or of an alloy with a lower melting point, this setting into a mass forming an end-plate imprisoning the lateral extremities of the exchange walls, the edges of the nozzles in contact with the said extremities, and the extremities of the internal and external cylindrical tubes.

The heat exchangers according to the invention can be employed to effect the change of state of one of the fluids when this change of state takes place from the gaseous state to the liquid state (condensers). It may take place at the points of condensation of the local depressions, and similarly, when this change of state takes place from the liquid state to the gaseous state (evaporators and boilers) it could take place at the points of vaporization of the local excess pressures. In order to prevent this, the invention gives to the two-phase fluid (to be condensed or vaporized) a large direct access to the spiral sheets.

With reference to FIG. 21, which is an axial section similar to that of FIG. 14, there can again be seen the spirals of goffered walls 122 and 123, de-limiting the spiral sheets 113 for one fluid and 123 for the other fluid, and the internal tubes 121 and external tubes 124. In this case, the chamber 113 provided for the two-phase fluid, is opened directly at the top of all the spiral sheets 113 on the header 112 of the inlet of gas to be condensed in the case of a condenser; the condensates are collected by spouts or by lines of bosses 161, preferably as shown, aligned in descending spirals and preferably, as shown, having a greater length for the lower spouts. At the bottom points of these spouts, the condensation liquid is evacuated into the internal tube 121 through the orifices 162, and from there to the exterior through a conduit 163.

Conversely, in the case of an evaporator or boiler, the liquid comes in through the conduit 163 in the direction opposite to the arrows, passes through the internal tube 121 and the orifices 162, passes over the spouts 161, and then passes out in the gaseous state through the header 112.

The circulation of the cooling (or heating) fluid in the spiral sheets 133, remains the same as that already described. The temperatures of operation are regulated by adjusting the path of the cooling (or heating) fluid by the arrangement of the spiral spouts in particular; in certain sections, it is only necessary to arrange shorter paths for the fluid in order to produce a more powerful cooling (or heating).

The headers of the exchangers described above may be given other arrangements according to the invention. With reference to FIGS. 22 and 23, which are respectively an axial section taken along the line XXII—XXII of FIG. 23 and a transverse section taken along the line XXIII—XXIII of FIG. 22, the inlet headers 112 and outlet header 116 of one of the two fluids only occupy part of the upper end-plate of the exchanger. In a common nozzle 165, they are placed on each side of the partition 118, below which partitions 166 such as lines of bosses 42 separate the turns. Thus the fluid which has entered at 112 passes through the assembly of the turns and passes out at 116. The same arrangement can be adopted at the lower portion for the other fluid.

With reference to FIG. 24 which is a plan view, one of the fluids passes into the exchanger at 111 through a nozzle 168, passes into the spiral sheets (not shown) while being divided between the right-hand and left-hand halves, and passes out at 117 through a nozzle 169. The two nozzles are rigidly fixed to an end-plate 170 in the form of a ring which assembles together the tubes **121** and **124**. The same arrangement can be provided at the lower portion for the other fluid.

With reference to FIG. **25** which is an axial section, the inlet **111** and outlet **117** of a fluid are also in this case diametrically opposite, but are placed on the outer tube **124** itself. The headers **112** and **116** are of semi-annular shape on each side of the partition **118.**

There will now be described a preferred embodiment of the invention. With reference to FIG. **26,** which represents a perspective view with a number of parts broken away in order to simplify and clarify the drawing, of the diagram of circulation of one of the fluids, in principle the cold fluid. This cold fluid passes in at **181** to the bottom portion of an axial tube **182,** closed at its middle **183** and open laterally by two diametrically-opposite slots **184** and **185** which each open into a spiral sheet **186** and **187,** these two sheets being identical and displaced by a half-turn so as to be housed spaced apart from each other. These sheets are closed at the top, at the bottom and at their extremities. In the interior, in a central horizontal plane passing through **183,** they are provided with a partition starting from the central tube and stopping at a certain distance from the peripheral extremity of the sheet, so as to leave between the said extremity and the partition a section of passage **188** or **189** substantially equal to the slots **184** and **185.**

Thus, each half of the cold fluid describes a spiral sheet in the centrifugal direction. On arrival at the periphery, each half of the fluid rises into the top portion of the exchanger at **188** or **189,** by a wide communication formed between the lower portion and the upper portion of the spiral sheets **186** and **187,** and describes these sheets in the reverse direction, that is to say in the centripetal direction. On arrival at the centre, each half of the fluid passes through the upper portion of the slots **184** or **185** into the upper half of the tube **182** and passes out of the exchanger at **190.**

Thus the cold fluid has described two spiral sheets successively in opposite directions. The other fluid, in principle the cold fluid, passes from the top to the bottom, parallel to the general axis X—X, passing through the spaces between the spiral sheets **186** and **187.**

The construction of this heat exchanger will now be described with reference to FIG. **27,** which is a general elevation drawing, FIG. **28,** which is a transverse section taken along the line XXVIII—XXVIII of FIG. **27,** FIG. **29** which is a radial half-section of the lower portion, and FIG. **30,** which is a detail of the closure of the sheets.

The start of the spiral windings of the goffered sheets **192** and **193** is effected from a part **194** fixed on the axial tube **182** (FIG. **28**), and similarly, the start of the goffered sheets **196** and **197** is made from a part **195.** The axial tube **182** is divided into lower and upper portions by a closure device **183** (FIG. **27**); the spiral sheets **186** (between the goffered sheets **193** and **196,** and **187** (between the goffered sheets **192** and **197**) are similarly divided into upper and lower portions by a horizontal separation **198** and **199,** which stops before the end of the spirals (FIG. **28**) so as to leave the abovementioned communications **188** and **189.**

The said goffered sheets may be those already described. In particular, they may comprise hemispherical impressions as shown in FIG. **30.** At the top and the bottom of the exchanger, the spiral sheets are closed, as already described, by bringing together and welding, or by the insertion of metal strips **201** (FIGS. **29** and **30**). At the central portion, the separations **198** and **199** are advantageously formed by a joint of rubberized asbestos, for example of round or better still rectangular shape, held in position by the bosses.

By way of another example of bosses, FIG. **31** shows ribs **203** formed obliquely so as to still further increase the local turbulence and to facilitate mechanical cleaning. After winding, the assembly is inserted (FIGS. **27** and **28**) in an external tube **204,** with flanges for the two fluids. Without departing from the scope of the invention, the number of sheets may be increased or the slots of the central tube may be replaced by any other orifices which provide an equivalent section of passage.

There will now be described still another preferred embodiment of the invention. With reference to FIG. **32,** which shows in perspective, with numerous parts broken away in order to simplify and clarify the drawing, the diagram of circulation of one of the fluids, in principle the cold fluid. The cold fluid passes at **211** into the lower portion of an axial tube **212** closed at its middle **213** and open along a generator line by a slot **214** which opens into a spiral sheet **216.** This sheet is closed at the bottom and the top and contains a separation in a central horizontal plane similar to **198** and **199,** towards the centre of the exchanger. The fluid describes the spiral sheet in the centrifugal direction. When it reaches the periphery, the fluid passes upwards into the upper portion of the exchanger through a wide communication **218** formed between the lower portion and the upper portion of the spiral sheet **216,** and describes this sheet in the reverse direction, that is to say in the centripetal direction. When it reaches the centre, the fluid passes through the upper half of the slot **214,** into the tube **212** and passes out of the exchanger at **220.**

Thus the cold fluid has described successively, in opposite directions, two spiral sheets. The other fluid, in principle the hot fluid, passes from the top to the bottom through the spaces between the turns of the spiral sheets **216,** either directly as explained in the construction comprising two sheets, as in FIG. **26,** or by passing by means of a central separation along a similar path in counter-flow, as explained for the construction of FIG. **11,** or again by dividing the chamber into several sections, as explained for the construction of FIG. **18.**

The construction of this heat exchanger will now be described with reference to FIG. **33** which is a general elevation, to FIG. **34** which is a transverse section taken along the line XXXIV—XXXIV of FIG. **33,** to FIG. **35** which is a radial half-section of the lower portion, and to FIG. **36** which is a detail of the closure of the sheets. The goffered sheet **222** is provided with bosses **223,** for example hemispherical, as shown in FIG. **36,** and in relief alternately on one side of the sheet and on the other. This goffered sheet **222** and a flat sheet **224** are wound together, their edges welded together along a generator line **225** (FIG. **34**) placed just in front of the slot **214** of the axial tube **212.** The axial tube **212** is divided into upper and lower portions by a closure device **213** (FIG. **33**). The spiral sheet **216** is similarly divided into upper and lower portions by a horizontal separation **226** which stops before the end of the spiral (FIG. **35**) so as to leave the abovementioned communication **218.**

At the top and the bottom of the exchanger, the spiral sheet is closed at **227** by bringing the edges together with a knurling tool and welding as shown; this closure could be effected by inserting a metal strip as already described in connection with FIG. **30.** The end of the spiral winding is fixed by a flat strip **228** (FIG. **34**) and the assembly is inserted into an outer tube **229** with flanges for the two fluids.

The goffered sheet **222** and its horizontal separation **226** may be produced in one of the ways already described, but with bosses on both faces of the sheet. It may also be produced by the method indicated in FIG. **37** which shows it by the side of the axial tube **212** and not yet wound. The bosses **223** are distributed in a variable manner; they are relatively close together in the central region near to the closure device **213** of the tube **212,** and they are relatively spaced apart towards the top and the bottom of the peripheral edge (to the right of FIG. **37**).

This arrangement which effects in a simple manner the horizontal separation **226** obtains, at the same time as local turbulence, the correct proportion of the times of transit for the various fluid streams passing from the lower part of the slot **214** to its upper portion.

The heat exchangers which have been described above, and in particular the two preferred constructions shown in FIGS. **24** and **33,** lend themselves well to a diamantlable construction, with the advantage not only of being able to be cleaned, but also of being unaffected by the different thermal expansions of different metals with its constructional and economic advantages.

With reference to FIG. **38,** which is an axial section of an exchanger fairly similar to that shown in FIG. **33,** the external tube is in this case in two parts, on each side of a flange **231** with a joint. The body **232** contains, without being fixed thereto, the spirals **216,** and it is provided with an inlet flange **233** and an outlet flange **234** for the hot fluid, preferably with a standard domed bottom **235.** The head **237,** preferably also with a standard domed end **238,** is fixed to an axial tube **241** in which is secured another coaxial tube **242.** The assembly of these two tubes is rigidly fixed to the spiral sheet **216** into the bottom of which the tube **242** delivers, through a slot **243** along a generator line, and which opens at the top into the tube **241** through a similar slot **244.** The cold fluid enters through the flange **246** into the central tube **242,** passes through the slot **243** into the lower portion of the spiral sheet **216** through which it passes in the centrifugal direction, flows upwards at **218** into the upper portion of the spiral sheet **216** through which it passes in the centripetal direction, passing out through the slot **244** into the outer tube **241,** and passes out of the exchanger through the flange **247.**

A similar construction but having two jointed flanges, the outer tube being in three parts, is quite obvious and will not therefore be described.

It will be clear to those skilled in the art that, without departing from the scope of the invention which has just been described, various modifications may be made thereto, and in particular there may be provided other associations of the various arrangements which have been described.

What we claim is:

1. A heat exchanger of generally cylindrical form acting between two fluids, comprising:

a. first and second chambers wound in juxtaposed and enclosing spirals; and a thin metal wall separating said chambers from each other, said metal wall having gofferings formed thereon and abutting against the wall of an adjacent chamber;

b. a central cylindrical tube, said chambers spirally encompassing said tube, fluid inlet and outlet means for said second chamber being formed by said tube;

c. an external cylindrical hoop concentrically encompassing said central tube and forming an annular space therebetween, said hoop and tube forming the supporting framework of said heat exchanger, said chambers being located in said annular space between said hoop and said tube, and said external cylindrical hoop axially extending beyond the level of said spirally coiled chambers;

d. closure caps attached to said cylindrical hoop so as to form two enclosures, said enclosures being in direct communication with said first chamber through the open lateral ends thereof and forming respectively inlets and outlets to said first chamber;

e. obturation means dividing into two portions forming, respectively, a distribution portion and a collector portion, said second chamber communicating with the distribution portion at its central portion and with the collector portion at the other end thereof;

f. and guide means being positioned within said second spirally coiled chamber and adapted to guide the fluid in said chamber to flow therealong in a centrifugal direction from the distribution portion of the tube substantially to the periphery of said chamber, and in a centripetal direction from the periphery of said chamber to the collector portion of said tube.

2. A heat exchanger as claimed in claim **1,** said gofferings being bosses formed in said thin metal wall.

3. A heat exchanger as claimed in claim **1,** said guide means being in the form of partitioning means internally following the spiralled shape of the second chamber and arranged in a plane extending perpendicular to the axis of the central tube, said partitioning means being discontinuous in the region of the outer periphery of the coiled chamber so as to divide said second chamber into lower and upper portions and forming a passage between the two portions of said chamber.

4. A heat exchanger as claimed in claim **1,** the walls of said second chamber being formed of goffered metal sheets having corrugations impressed thereon, and spaced at a proximity so as to cause the fluid flowing through said second chamber to be distributed equally throughout the space of said chamber.

5. A heat exchanger as claimed in claim **1,** said first chamber comprising a spiral partition extending in a plane perpendicular to the axis of the hoop, said partition having an aperture therein, and two lateral, spiral shaped sides forming closure means having an aperture in the radially inner portion thereof, said closure means and said partition forming guide means causing the fluid to flow in a path spiralling first in a centrifugal direction and then in a centripetal direction in countercurrent flow to the fluid flowing in said second chamber.

6. A heat exchanger as claimed in claim **5** the walls of the second chamber being made of a goffered metal.

7. A heat exchanger as claimed in claim **1**, comprising a jacket made of a metal foil wound about said spirally coiled chambers, and a packing of moldable substance poured between said hoop and the outer wall of the jacket filling the interstitial space between the outer wall and said hoop, said packing eliminating the spiralled chambers to be exactly ajusted to the dimensions of the hoop and facilitating the pressure inside the chambers to be absorbed both by the hoop and the central tube.

8. A heat exchanger as claimed in claim **1**, comprising a first cylindrical tube, said chambers spirally encompassing said tube, an internal secondary tube contained in said first tube, the first chamber being in communication with the annular section of the first cylindrical tube at one end and with the secondary internal tube at the other end thereof, said annular section and said secondary internal tube forming, respectively, an entry and an exit for a fluid passing through said first chamber, and both concentric tubes comprising respectively an inlet and outlet disposed on the same sectional face of the heat exchanger.

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