Nov. 9, 1954

J. R. GUALA

2,693,942

HEAT TRANSFER APPARATUS

Filed June 9, 1952

2 Sheets-Sheet 1

FIG. 1.

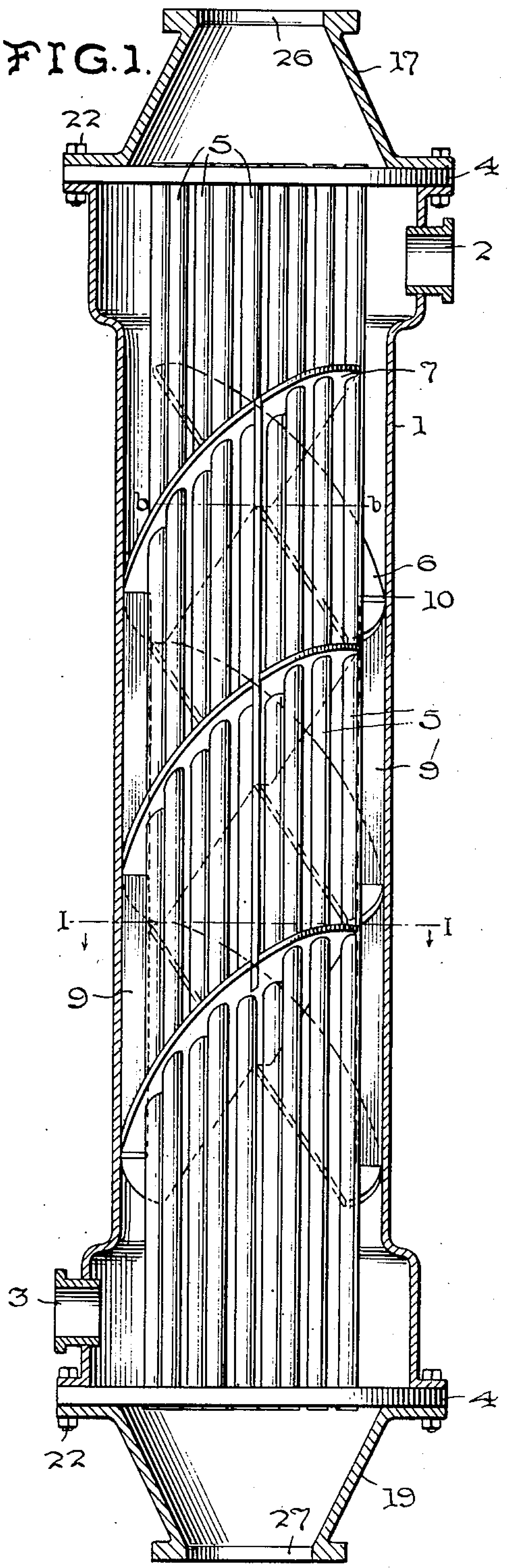
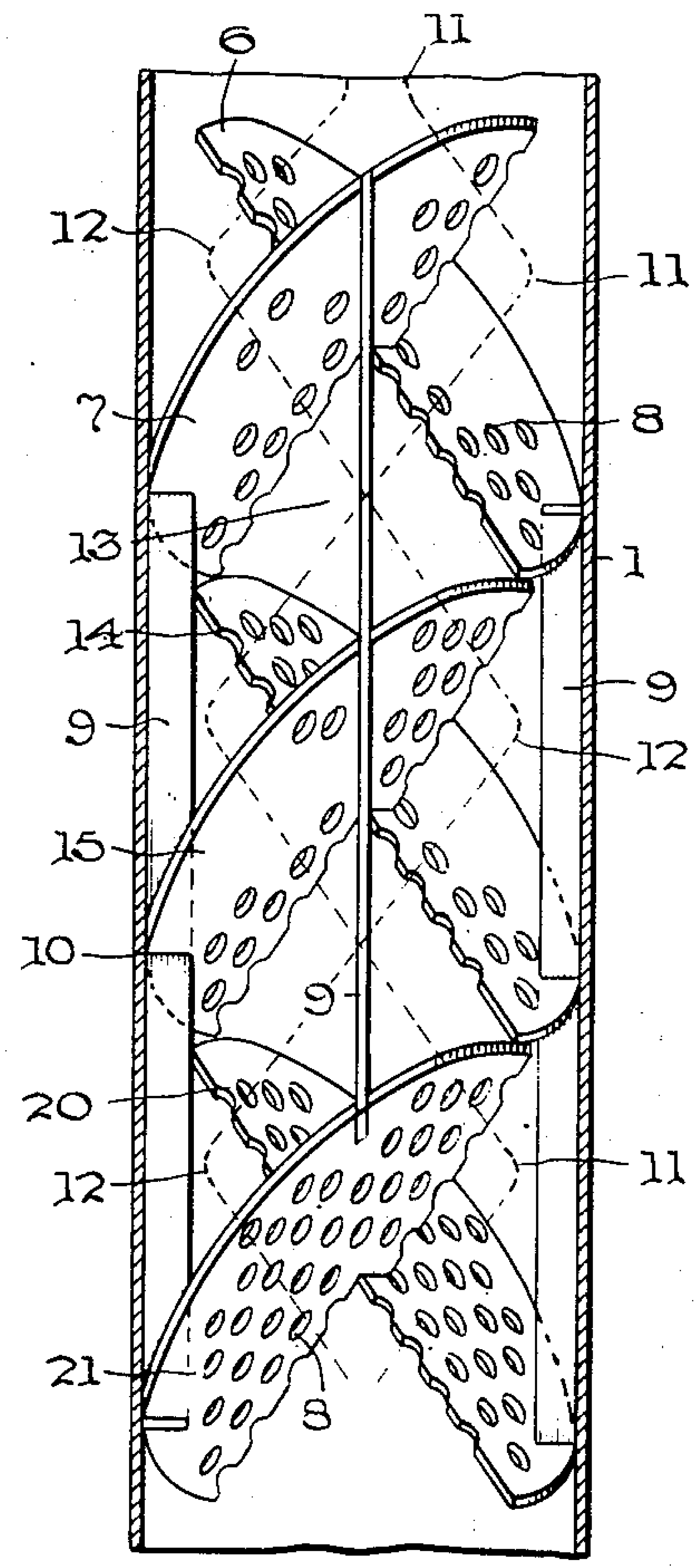


FIG. 2.



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HEAT TRANSFER APPARATUS

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2 Sheets-Sheet 2

FIG. 3.

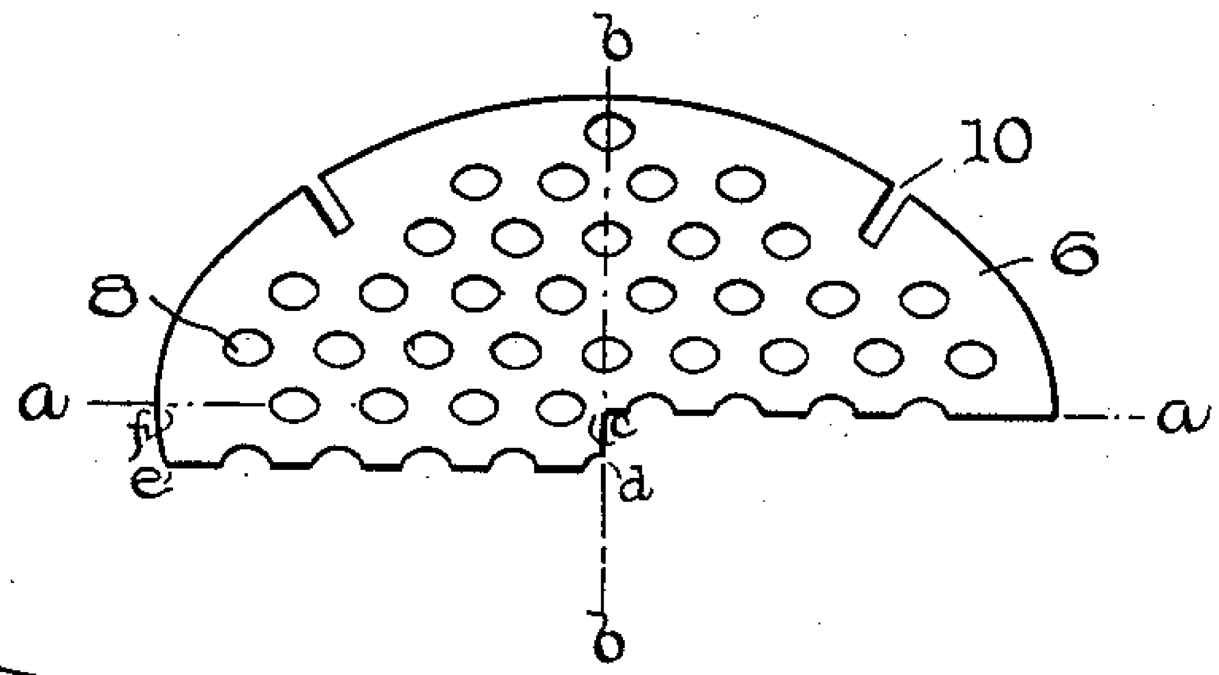


FIG. 8.

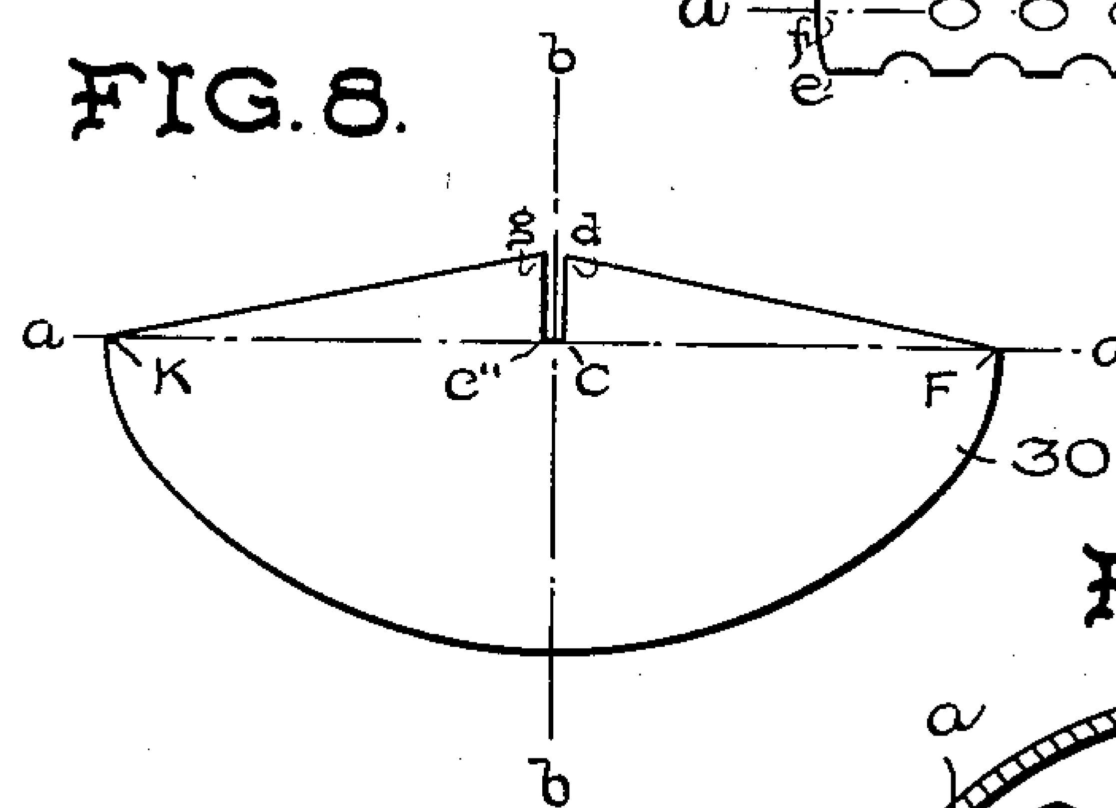


FIG. 9.

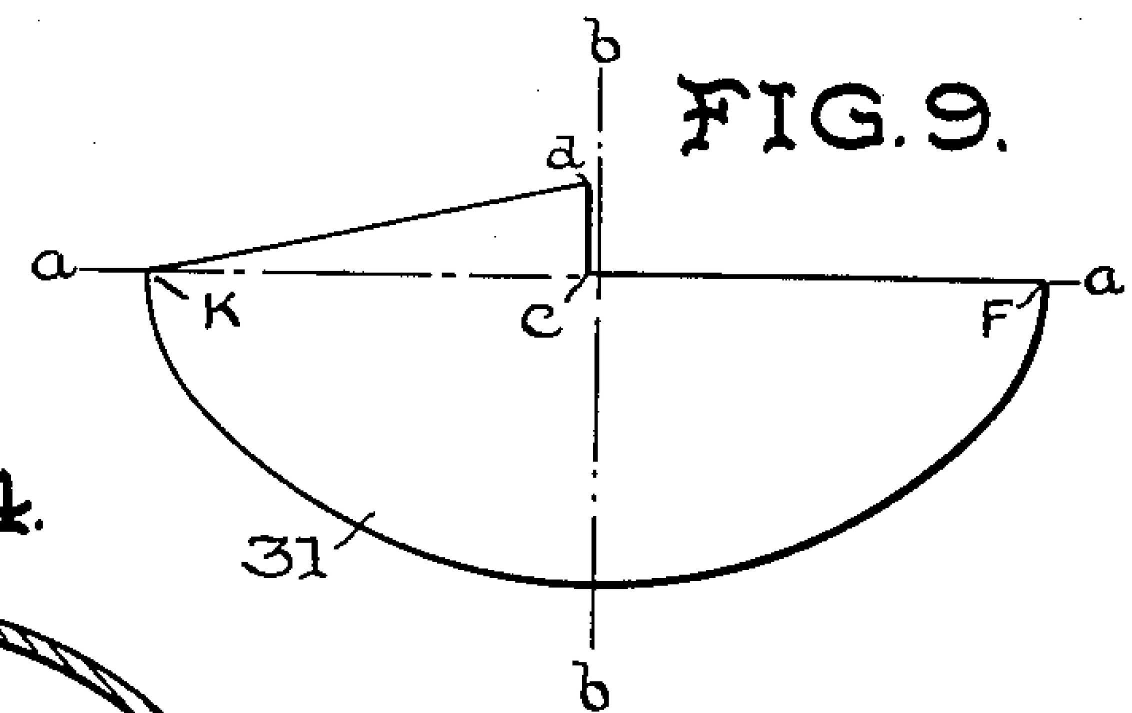


FIG. 4.

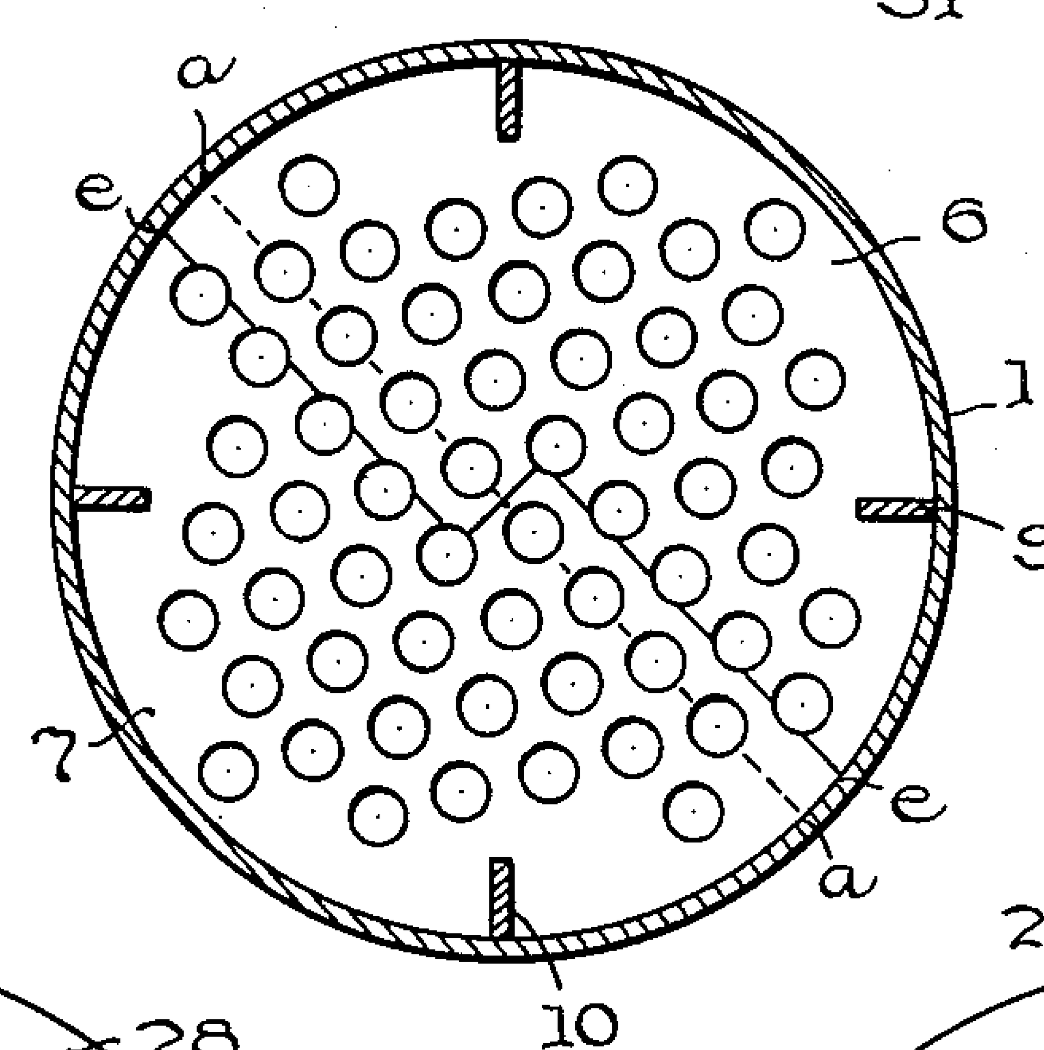


FIG. 6.

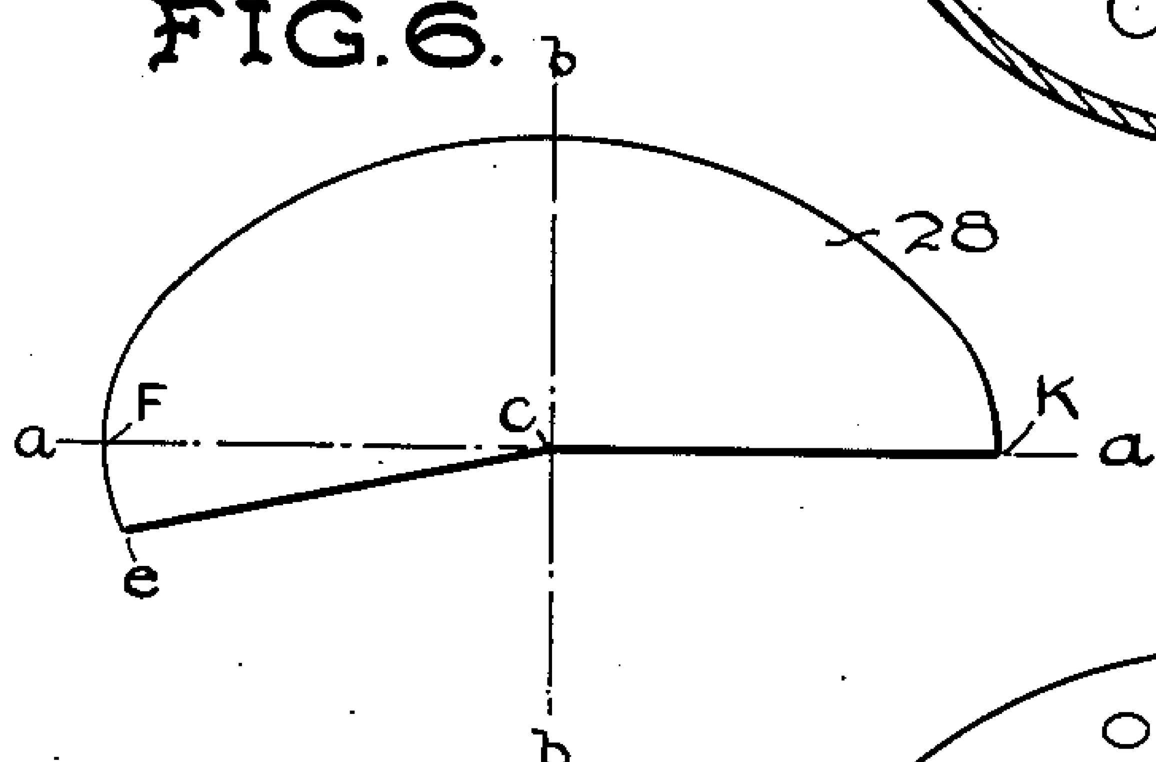
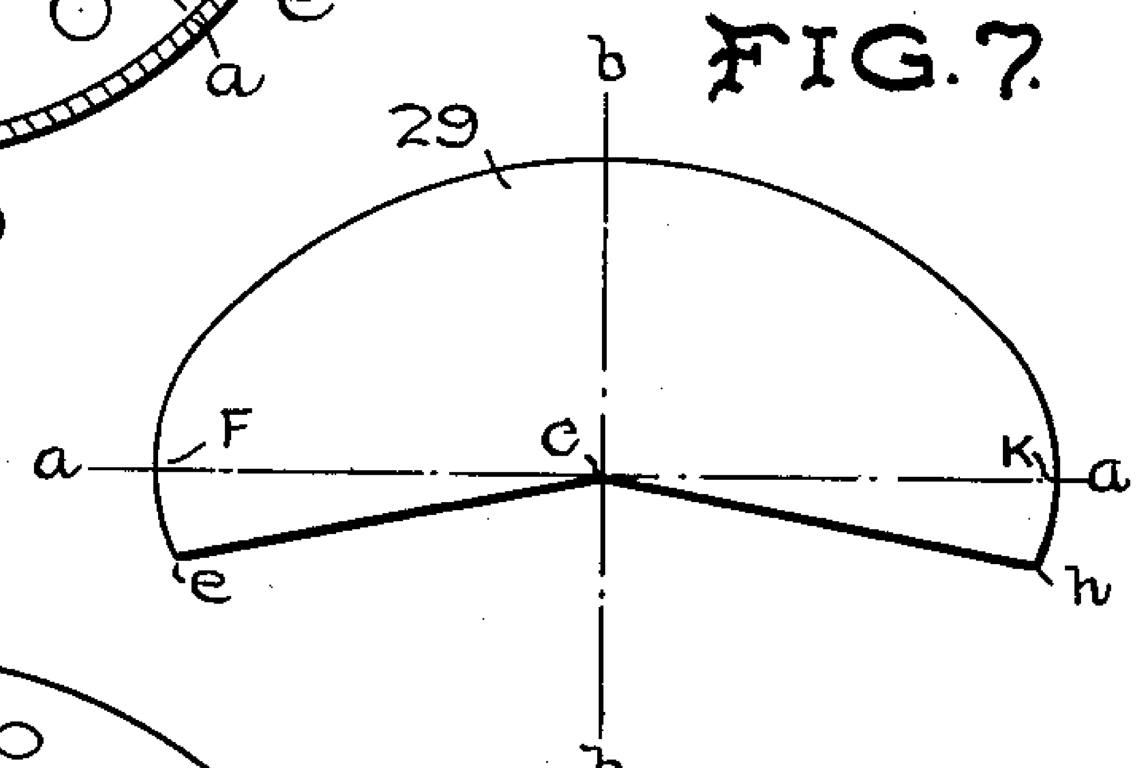


FIG. 7.



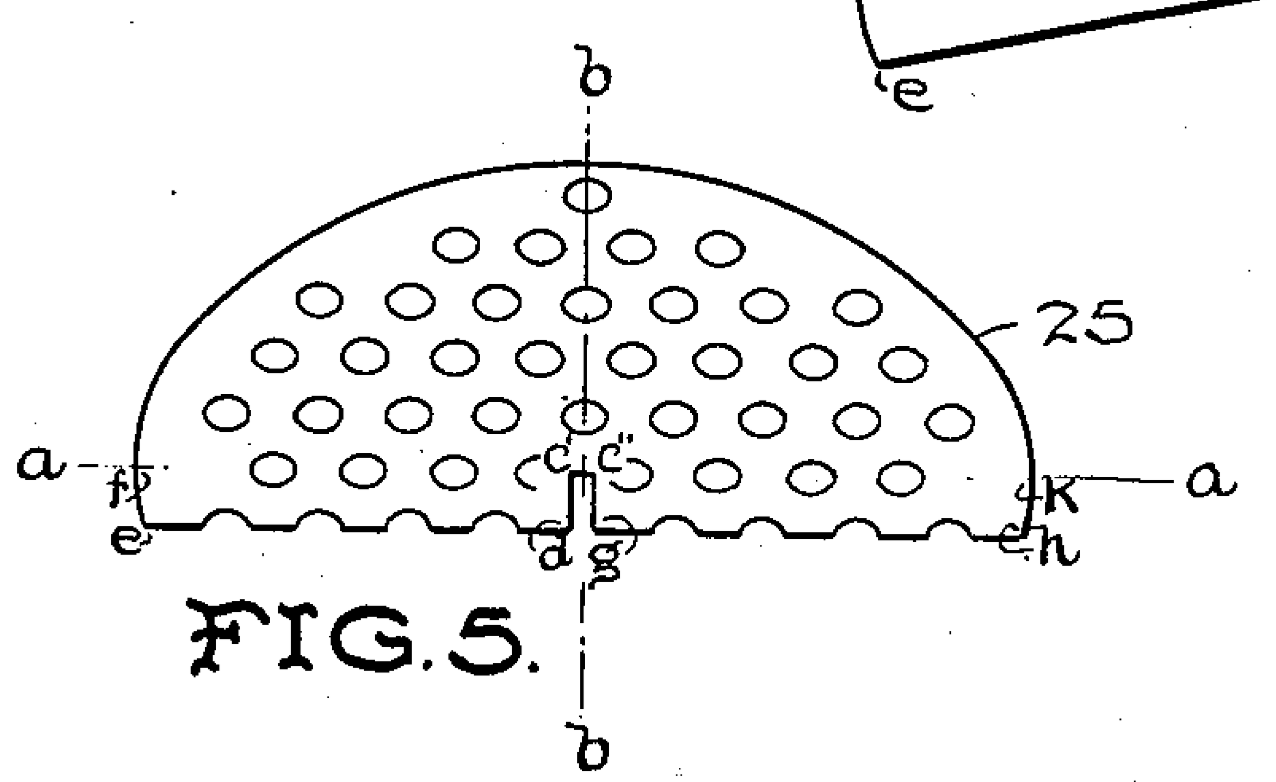


FIG. 5.

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United States Patent Office

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HEAT TRANSFER APPARATUS

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Application June 9, 1952, Serial No. 292,403

19 Claims. (Cl. 257—224)

This invention relates to a baffle system for heat exchange equipment, and more specifically to a system comprising a series of plates extending part way across a tube bank at an angle to the longitudinal axis of the heat exchange equipment, and designed to direct the fluid flowing outside the tubes in a plurality of balanced helical streams.

A common arrangement of baffles in heat exchange equipment is a succession of baffle plates extending part way across the shell perpendicular to the longitudinal axis of the shell, with alternate baffle plates extending from opposite sides of the shell.

Another common arrangement is a number of baffle plates placed parallel to one another and parallel to the longitudinal axis of the shell with alternate plates extending from opposite ends of the shell.

These types of baffles cause high resistance to the flow of the fluid medium, cause high localized precipitation of any fouling material that may be carried in the shell fluid or may be precipitated therefrom, and have several other practical disadvantages.

I find it distinctly advantageous both from the standpoint of pressure loss and heat transfer to direct the fluid outside of the tubes in a different manner. I have invented a system of baffles whereby the fluid is directed over the tubes in a plurality of helical paths, and in which the pressure in the various helical paths will automatically equalize.

It is an object of this invention to provide a heat exchange apparatus of the shell and tube type which effects heat transfer in a more efficient manner than heretofore.

Another object of this invention is to provide a shell and tube type heat exchanger in which the fluid outside the tubes is directed in separate but communicating paths throughout the shell.

Another object of this invention is to provide a baffle construction for shell and tube type heat exchangers which prevents the formation of stagnant pockets in the path of the fluid through the shell.

A particular object of this invention is to provide an apparatus which contributes to the equalization of pressure between the parallel streams of fluid within the shell.

A still further object of this invention is to provide a baffle structure which substantially reduces scale and sediment deposits.

The foregoing and other objects which will be apparent from the following description are obtained by the invention disclosed and claimed herein.

Referring to the accompanying drawings,

Figure 1 is a longitudinal sectional view of a heat exchanger fitted with the baffle system which constitutes my invention;

Figure 2 is a longitudinal sectional view similar to Figure 1, but the arrangement of the baffle plates and their supporting means has been emphasized in this view by omitting the exchanger tubes;

Figure 3 is an individual plate of a baffle, of the same design as those shown in Figures 1 and 2;

Figure 4 is a cross sectional view taken on line I—I of Figure 1; and

Figures 5, 6, 7, 8 and 9 are specific forms of baffle plates within my invention, all being somewhat different from the specific form shown in Figures 1, 2, 3 and 4, and each different from one another, the distinction being obvious from the figures themselves. Descriptions

of these embodiments of my invention will be found in a subsequent portion of this specification.

Referring to the figures, the same numbers and letters will indicate the same elements in the various views.

Referring to the drawings, in Figures 1 and 2, numeral **1** indicates the enclosing shell of a heat exchanger. At each end of the shell is a tube-sheet **4**, and these tube sheets are perforated to receive tubes **5**. The tubes are fastened into the tube sheets by being rolled thereinto, by being individually packed, or by any other conventional means of fastening. Headers **17** and **19** are positioned at opposite ends of shell **1**, and the shell and tube sheets and headers are fastened together into a unit by bolts **22**. Headers **17** and **19** provide means, conduit connections **26** and **27**, for introducing and conducting away the fluid which is to be passed through the tubes. This fluid is referred to hereinafter as "tube fluid." Headers **2** and **3** are similarly provided for introducing and conducting away the fluid which is to be passed outside the tubes. This fluid is hereinafter referred to as "shell fluid." The number, diameter and length of tubes **5** to be used in the heat exchange apparatus, as well as the diameter of the shell **1**, will be varied to meet the requirements of individual cases. For purposes of illustration, a simple form of heat exchanger has been shown in Figure 1. Additional features such as the floating head could of course be included, but have been omitted for simplicity of presentation.

Throughout the length of shell **1**, I place a succession of baffles, each consisting of two plates as indicated by numerals **6** and **7**. The individual plates of the baffles illustrated in Figures 1 and 2 are of the specific design shown in Figure 3.

In addition to tubes **5** being held in place by tube-sheets **4**, the relative positions of tubes **5** are further maintained by baffles **6** and **7** which are formed with openings **8** positioned in alignment with the holes in the tube sheets. Considerable rigidity is thus added to the tube bundle.

The individual plates and the successive baffles within the exchanger shell **1** are bound together in their proper spatial relationship and into a unitary construction by longitudinal strips **9**. These strips **9**, passing through the plates at slots **10**, also serve an additional purpose in that they are positioned to pass through the plates at peripheral areas that are not of sufficient size to accommodate tubes and, by placing them with their broad dimensions across the direction of flow of the shell fluid, they serve to obstruct any tendency of the fluid to channel through these ineffective zones. The shell fluid is given a helical motion by the baffle construction here disclosed and claimed, and these strips **9**, positioned as stated, block any tendency of the shell fluid to preferentially seek a path along the shell wall.

Referring to Figure 3, a single baffle plate is shown as 6. This plate is a segment of an ellipse, and the major axis *a—a* and the minor axis *b—b* thereof are indicated. It will be seen that plate **6** is a segment of an ellipse consisting of an entire semi-ellipse together with an extension or step *c, d, e, f, c*. Two of these plates, 6 and 7, are fitted together, as shown in Figure 2, to form a baffle, and they are there shown positioned in the tube shell with their planes at an angle of approximately 45° to the longtiudinal axis of the shell and at an angle of approximately 90° to each other. An angle lying approximately within the range of from 75° to 15° between the planes of the individual plates and the longitudinal axis of the shell will ordinarily be found most effective, the precise angle in any particular case being controlled by considerations such as shell-fluid velocity, heat exchange factor, quantity of shell fluid available, maximum or minimum permissible temperature change, permissible pressure drop, etc. The width of the semi-elliptic part of plate **6** is one-half of the internal diameter of shell **1**, or very slightly less, and the two plates constituting a baffle are positioned alongside of one another with their minor axes in longitudinal alignment, with their respective planes at an angle to one another, and with the extension of each plate extending across its companion plate.

Shell **1** is a cylindrical shell and it will be necessary, because the plates are positioned at an angle other than 90° to the longitudinal axis of the shell that they have greater length than the diameter of the shell. The individual plates will be segments of ellipses, the minor axes of which ellipses will equal the internal diameter of the shell **1**, and the major axes of which will be such that the plates will abut the inside of the shell at all points along their curved edge. For instance, if the angle of the plates to the axis of the shell is a 45° angle, the major axis of the elliptic plate will be 1.414 times the internal diameter of the cylindrical shell **1**. For any angle at which it is desired to position the plates, the length will be arrived at by multiplying the internal diameter of the shell by the cosecant of the proposed angle between the individual plates and the longitudinal axis of shell **1**. Each plate **6** is pierced with holes **8** to permit the insertion therethrough of the tubes **5** of the heat exchanger. The plate is also provided with slots **10** to receive supporting strips **9**.

It would be possible to make baffles from two plates which were exact semi-ellipses, cut along the major axis of the ellipse, but that would permit a certain amount of shell fluid to short-circuit and by-pass many of the tubes. For that reason the plates **6** carry extension areas *c, d, e, f, c* to direct the shell fluid over the maximum number of tubes and prevent its snaking along the length of the heat exchanger close to the axis thereof. This provision of plates with extensions *c, d, e, f, c* is a fundamental feature of this invention. Another embodiment of this feature will be described in connection with Figure 5. As respects plates **6**, **7** and **25**, the extensions on the plates protrude beyond the major axis of the ellipse by a substantially uniform dimension throughout their length, this dimension being not substantially less than one-twentieth or more than one-third of the length of the minor axis of the ellipse.

Figure 4, which is a sectional view on line I—I of Figure 1, shows the overlapping of the extensions of the two plates which constitute a baffle.

Figure 5 shows an embodiment of my invention which differs somewhat from that shown in Figure 3. It involves the use of plates **25** instead of plates **6**. In Figure 5 the individual plates of the baffles are again segments of an ellipse, but they differ from plate 6 shown in Figure 3 in that they have two extensions, *c', d, e, f, c'* and *c'', g, h, k, c''*, instead of one such extension as shown in Figure 3. Plate **25** having two extensions, must have a notch therebetween to permit the companion plates of a baffle to fit together. This notch *d, c', c'', g* is of a width to permit interlocking of companion plates and it extends inwardly from the outside edge of the extension to the major axis of the ellipse. Plate **25** further reduces the tendency of the shell fluid to seek a path down the axis of the shell. It also permits strong interlocking of the two companion paltes of a baffle.

Figures 6 and 7 show two related embodiments of my invention in which the segments of the ellipse include a semi-ellipse lying altogether on one side of the major axis together with an extension beyond the major axis on either one side or both sides of the minor axis. The embodiments shown in these two figures have extensions which are cut along radii of the ellipses, the form shown in Figure 6 having an extension along one-half its length, and the form shown in Figure 7 having an extension along each half of its length. In the embodiment of my invention shown in Figure 6, the plate **28** is a segment on an ellipse. The major axis *a—a* is indicated on the drawing, and so also the minor axis *b—b*, the intersection of the two axes being indicated at *c*. Plate **28** is cut along the major axis *a—a* from *c* to *k*, thence around the periphery of the ellipse for a full 180° and further by distance *f—e*, and in a straight line from *e* to *c*.

The form of baffle plate **29** shown in Figure 7 carries an extension beyond the major axis *a—a* on each side of intersection *c*.

In this case the baffle plate **29** is a segment of an ellipse, and the major axis is indicated at *a—a*, the minor axis at *b—b*, and the intersection of these two axes is indicated at *c*. Plate **29** is cut in a straight line along line *c—h*, from *h* along an elliptic periphery across major axis *a—a*, 180° therebeyond to major axis *a—a* again, and then through the extension width *f—e*, and thence in a straight line *e—c*. The extension *c—k—h—c* may or may not be equal in dimension to extension *c—f—e—c*.

In both plates **28** and **29**, the individual extensions may have an area up to as much as approximately 80 per cent of the area of a quadrant of the ellipse. This same proportion holds, in fact, for the extension of the plates shown in Figures 3, 5, 6, 7, 8 and 9.

Figures 8 and 9 show two related embodiments of my invention in which the segments of the ellipse include a semi-ellipse, lying altogether on one side of the major axis, together with an extension beyond the major axis on either one side or both sides of the minor axis. The embodiments shown in these two figures have extensions which are cut in a straight line from the intersections of the major axis with the elliptic periphery to a point on the minor axis which is somewhat removed from the major axis. In the embodiments of my invention shown in Figures 8 and 9, the plates **30** and **31** are segments of an ellipse. In each case the major axis *a—a* is indicated on the drawing, and so also the minor axis *b—b*. Plate **30**, shown in Figure 8 is cut in a straight line from each of the two intersections of the elliptic periphery with major axis *a—a* to a point on the minor axis out beyond the major axis, to produce somewhat more than a semi-ellipse, and a slot *d, c, c'', g* is then cut back along the minor axis to the major axis in order that two such plates, when used together to form a baffle, will abut at the intersections of their respective major and minor axes. Figure 9 shows plate **31**, with an extension *c, k, d, c* extending out beyond the major axis only on one side of the minor axis. The triangular extensions depicted in Figures 8 and 9 are especially effective in preventing the shell fluid from preferentially channeling along the longitudinal axis of the cylindric heat exchange device in which the baffles are used.

The various shapes of plates depicted in Figures 3, 5, 6, 7, 8 and 9 all have particular advantages according to the specific situation in which they are used, the disposition of the shell fluid to preferentially channel through some minor portion of the cross section of the heat-exchange device, the permissible pressure drop, etc.

The function of a tubular heat exchanger is to transfer heat between two fluids, one of which passes through the tubes and the other of which passes outside of the tubes and within the walls of the exchanger shell. Such an apparatus permits interchange of heat between the two fluids while preventing any direct contact or mixture of the two fluids. This invention is not directed to the handling of the fluid passing through the tubes: it concerns the handling of the shell fluid, i. e., the fluid which passes outside of the tubes and within the exchanger shell.

In this invention shell fluid is introduced through flanged inlet **2** in such manner as to pass through the shell **1** and to effect during such passage the maximum amount of heat transfer for the heat transfer area available.

The helical path of the shell fluid in its passage through the heat exchanger shell results from the interrelation, spatially, of successive baffles from the inlet end of the exchanger to the outlet end of the exchanger. As shown in Figures 1 and 2, my invention involves the use of a series of baffles, each baffle comprising two plates **6** and **7**, each baffle in a series is positioned closely adjacent to the baffle that precedes it in the series and to the baffle that follows it in the series; the baffles in a series are positioned with no substantial angular rotation between successive baffles, whereby the planes of corresponding plates in successive baffles assume parallel position and, with their companion plates, form two continuous channels of somewhat helical form from one end of the heat exchanger shell to the other end thereof. As will be obvious from Figures 1 and 2, the opposed planes of the two plates of the first baffle divide the stream of shell fluid into two separate streams which pass along successive baffles from end to end of the exchanger as parallel streams. Instead of plates **6** and **7**, as shown in Figures 1 and 2, the plates may be of the conformation shown in Figures 5, 6, 7, 8 and 9.

Referring to Figure 1 the stream of shell fluid entering a heat exchanger fitted with my system of baffling will be directed, in substantially equal parts, across the nearer end of each of the two plates **6** and **7** constituting the first baffle, then in a somewhat circular or helical course along the plate, this curving course being centered around the longitudinal axis of the exchanger shell. When the stream passes off of the first plate it passes in a channel formed by the under side of the adjacent plate of the first baffle and the top side of a plate of the second baffle. Specifically, the stream indicated by a dotted line and identified by numeral **11** will pass over plate **6** and then into a channel between plates **7** and **15** and on into a channel between plates **14** and **20**. The course of the second stream, indicated by a dotted line and identified by numeral **12** will be parallel to the course of stream **11** and always on the diametrically opposite side of the exchanger shell. The operation is the same, of course, when using baffles with plates such as shown in Figures 5, 6, 7, 8 and 9.

Various considerations may cause differences in the the rate of flow in the two parallel streams. These differences may result from the longitudinal strips **9**, from differences in the relative ararngement of the tubes in different portions of the cross section of the exchanger, and from the precipitation of fouling material.

My invention is designed to provide for these differences of resistance to flow in the two channels and the provision which has been made is both simple and adequate, and is a highly important element of my invention. My invention provides for the continual balancing of these differences, at a succession of points throughout the length of the exchanger, by providing a substantial area of contact **13** between the two streams at each baffle. Intermixing of the two streams occurs at the unpartitioned area **13** between the two streams and at every similar point through the length of the exchanger. This area of contact simultaneously effects a balancing of the streams and a certain intermixing of the streams that equalizes the temperatures of the two. This invention enables me to secure as much as 15 per cent more heat transfer per square foot of tube surface than is obtained in conventional types of heat exhangers and consequently permits an important reduction in the size, tube surface, and cost of heat exchange equipment.

The baffle structure herein described has particular application to heat exchangers of the shell and tube type and is adapted to a wide application in the field, including such specific apparatus as condensers, reboilers, etc. as well as that large class of devices known simply as heat exchangers. In addition, while shell and tube heat exchangers are frequently limited to use in systems wherein shell fluid and tube fluid are liquid only, no such restriction in use is contemplated in this apparatus since the disclosed apparatus will function efficiently whether the heat exchanging media are liquids, gases, or any combination of liquid and gas. The term gas is here used, of course, to embrace all vapors.

In this specification and in the appended claims I speak of the various individual plates **6**, **7**, **25**, **28**, **29**, **30** and **31** as being in the form of "a segment of an ellipse." When I use the expression "a segment of an ellipse" I mean thereby any portion of an ellipse less than a full ellipse, regardless of whether the non-elliptic portion of its periphery be a radius of the ellipse, a chord of the ellipse, or have some other configuration.

In this specification and in the appended claims, when I use the term "plate," I use it in its ordinary sense and mean thereby a flat piece of material.

What I claim is:

1. In a cylindric heat exchanger of the parallel tube type, a baffle system which comprises a plurality of baffles, each baffle comprising two plates; each plate being in the form of a segment of an ellipse, the said segment being a semi-ellipse, including all of the major axis of said ellipse, and an extension beyond said major axis along at least a portion of the length thereof, each plate being pierced to permit the passage therethrough of a plurality of tubes; with the minor axes of the two plates of each baffle in longitudinal alignment, with the planes of the two plates at an angle to each other and at an angle to the longitudinal axis of the cylindric heat exchanger, and with the extensions of the two plates interlocking.

2. In a cylindric heat exchanger of the parallel tube type, a baffle system which comprises a plurality of baffles, each baffle comprising two plates; each plate being in the form of a segment of an ellipse, the said segment being a semi-ellipse, including all of the major axis of said ellipse and an extension of uniform width beyond said major axis through at least a portion of the length thereof, each plate being pierced to receive a plurality of tubes, the two plates abutting at the intersection of their major and minor axes, with the minor axes of the two plates of each baffle in longitudinal alignment, with the planes of the two plates at an angle to each other and at an angle to the longitudinal axis of the cylindric heat exchanger and with the extensions of the two plates interlocking.

3. In a cylindric heat exchanger of the parallel tube type, a baffle system which comprises a plurality of baffles, each baffle comprising two plates, each plate being in the form of a segment of an ellipse cut along the major axis thereof for one-half the length of such axis and carrying an extension therebeyond along the remainder of said major axis, each plate being pierced to receive a plurality of tubes; the two plates of each baffle being positioned at an angle to each other and abutting at the intersection of the major and minor axes, with the minor axes of the two plates of each baffle in longitudinal alignment, with the minor axes of the plates in successive baffles lying in a single plane, with the planes of the two plates at an angle to the longitudinal axis of the cylindric heat exchanger, with extensions of the two plates interlocking, and with a plurality of longitudinal strips positioned in the curved periphery of the baffles.

4. In a cylindric heat exchanger of the parallel tube type, a baffle system which comprises a plurality of baffles, each baffle comprising two plates, each plate being in the form of a segment of an ellipse cut along the major axis thereof for one-half of the length of said axis and carrying an extension of substantially uniform width along the remainder of said major axis, each plate being pierced to receive a plurality of tubes; the two plates of each baffle being positioned at an angle to each other and abutting one another at a point located substantially midway on the major axes of said plates, with the minor axes of the two plates of each baffle in longitudinal alignment, with the minor axes of the plates in successive baffles lying in a single plane, with the planes of the two plates at an angle to the longitudinal axis of the cylindric heat exchanger and with the extensions of the two plates of the baffle interlocking.

5. In a cylindric heat exchanger of the parallel tube type, a baffle system which comprises a plurality of baffles, each baffle comprising two plates, each plate being in the form of a segment of an ellipse cut along the major axis thereof for one-half the length of said axis and carrying an extension of substantially uniform width along the remainder of said major axis, each plate being pierced to receive a plurality of tubes; the two plates of each baffle being positioned at an angle to each other and abutting one another at a point located substantially midway on the major axes of said plates, with the minor axes of the two plates of each baffle in longitudinal alignment, with the minor axes of the plates of successive baffles lying in a single plane, with the planes of the two plates at an angle to each other and at an angle to the longitudinal axis of the cylindric heat exchanger and with the extensions of the two plates overlapping in interlock.

6. In a cylindric heat exchanger of the parallel tube type, a baffle system which comprises a plurality of baffles, each baffle comprising two plates, each plate being in the form of a segment of an ellipse, somewhat more than a semi-ellipse, and with its straight side cut parallel to the major axis thereof, with a notch cut along the minor axis from the straight cut side of the segment of the ellipse to the intersection of the major and minor axes thereof; with the two plates of a baffle positioned at an angle to each other and abutting at the intersection of their major and minor axes, with their minor axes in longitudinal alignment, the minor axes of the plates of successive baffles lying in a single plane, with the planes of the plates at an angle to the longitudinal axis of the cylindric heat exchanger, each plate being pierced to receive a plurality of tubes.

7. In a cylindric heat exchanger of the parallel tube type, a baffle system which comprises a plurality of baffles, each baffle comprising two plates, each plate being in the form of a segment of an ellipse, somewhat more than a semi-ellipse, and with its straight side cut parallel to the major axis thereof, with a notch cut along the minor axis from the straight cut side of the segment of the ellipse to the intersection of the major and minor

axes thereof; with the two plates of a baffle positioned at an angle to each other and abutting at the intersection of their major and minor axes, with their minor axes in longitudinal alignment, the minor axes of the plates of successive baffles lying in a single plane, with the planes of the plates at an angle to the longitudinal axis of the cylindric heat exchanger, each plate being pierced to receive a plurality of tubes, and a plurality of longitudinal strips positioned about the curved periphery of the baffles.

8. A heat exchange apparatus of the shell and tube type which comprises two circular tube-sheets positioned substantially parallel to one another and apart from one another, each tube-sheet pierced with a plurality of holes adapted to receive tubes; a plurality of tubes extending in parallel from one tube-sheet to the other tube-sheet and fastened thereinto with fluid-tight joints; a header over each tube-sheet and a conduit connection to each header; a cylindric shell extending from one tube-sheet to the other tube-sheet, surrounding the plurality of tubes and made fluid-tight to said tube-sheets; a conduit connection adjacent to each end of the cylindric shell; a plurality of baffles within the shell extending in series from one end of the shell to the other end thereof, each baffle comprising two plates; each of the two plates of a baffle being in the form of a segment of an ellipse, cut along the major axis thereof for one-half the length of such axis and carrying an extension of substantially uniform width along the remainder of the major axis; each plate being pierced to permit the passage therethrough of the said plurality of tubes which extend from one tube-sheet to the other tube-sheet; the two plates of each baffle being positioned alongside of each other with their curved peripheries abutting the interior wall of the shell, with the minor axes of the two plates in longitudinal alignment, with the planes of the two plates at an angle to each other and at an angle to the longitudinal axis of the shell, and with the said extensions of the two plates interlocking.

9. A heat exchange appartus of the shell and tube type which comprises two circular tube-sheets positioned substantially parallel to one another and apart from one another, each tube-sheet pierced with a plurality of holes adapted to receive tubes; a plurality of tubes extending in parallel from one tube-sheet to the other tube-sheet and fastened thereinto with fluid-tight joints; a header over each tube-sheet and a conduit connection to each header; a cylindric shell extending from one tube-sheet to the other tube-sheet, surrounding the plurality of tubes and made fluid-tight to said tube-sheets; a conduit connection adjacent to each end of the cylindric shell; a plurality of baffles within the shell extending in series from one end of the shell to the other end thereof, each baffle comprising two plates; each of the two plates of a baffle being in the form of a segment of an ellipse, cut along the major axis thereof for one-half the length of such axis and carrying an extension of substantially uniform width along the remainder of the major axis; each plate being pierced to permit the passage therethrough of the said plurality of tubes which extend from one tube-sheet to the other tube-sheet; the two plates of each baffle being positioned alongside of each other with their curved peripheries abutting the interior wall of the shell, with the minor axes of the two plates in longitudinal alignment, with the planes of the two plates at an angle to each other and at an angle to the longitudinal axis of the shell, and with the said extensions of the two plates interlocking; and longitudinal strips extending from the first baffle in the series to the last baffle in the series and affixed to each baffle to maintain them in spatial relationship with each other, these longitudinal strips being positioned close to the exchanger shell.

10. A heat exchange apparatus of the shell and tube type which comprises two circular tube-sheets positioned substantially parallel to one another and apart from one another, each tube-sheet pierced with a plurality of holes adapted to receive tubes; a plurality of tubes extending in parallel from one tube-sheet to the other tube-sheet and fastened thereinto with fluid-tight joints; a header over each tube-sheet and a conduit connection to each header; a cylindric shell extending from one tube-sheet to the other tube-sheet, surrounding the plurality of tubes and made fluid-tight to said tube-sheets; a conduit connection adjacent to each end of the cylindric shell; a plurality of baffles within the shell extending in series from one end of the shell to the other end thereof, each baffle comprising two plates; each of the two plates of a baffle being in the form of a segment of an ellipse, cut along the major axis thereof for one-half the length of such axis and carrying an extension of substantially uniform width along the remainder of the major axis; each plate being pierced to permit the passage therethrough of the said plurality of tubes which extend from one tube-sheet to the other tube-sheet; the two plates of each baffle being positioned alongside of each other with their curved peripheries abutting the interior wall of the shell, with the minor axes of the two plates in longitudinal alignment, with the planes of the two plates at an angle to each other and at an angle to the longitudinal axis of the shell, and with the said extensions of the two plates interlocking; and longitudinal elements extending from the first baffle in the series to the last baffle in the series and affixed to each baffle to maintain them in spatial relationship with each other.

11. A heat exchange apparatus of the shell and tube type which comprises two circular tube-sheets positioned substantially parallel to one another and apart from one another, each tube-sheet pierced with a plurality of holes adapted to receive tubes; a plurality of tubes extending in parallel from one tube-sheet to the other tube-sheet and fastened thereinto with fluid-tight joints; a header over each tube-sheet and a conduit connection to each header; a cylindric shell extending from one tube-sheet to the other tube-sheet, surrounding the plurality of tubes and made fluid-tight to said tube-sheets; a conduit connection adjacent to each end of the cylindric shell; a plurality of baffles positioned within the shell between the two ends thereof, each such baffle comprising two plates; each of the two plates of a baffle being in the form of a segment of an ellipse cut along the major axis thereof for one-half the length of such axis and carrying an extension of substantially uniform width along the remainder of the major axis, each plate being pierced to permit the passage therethrough of the said plurality of tubes which extend from one tube-sheet to the other tube-sheet; two plates of each baffle being positioned alongside of each other with their curved peripheries abutting the interior wall of the shell, with the minor axes of the two plates in longitudinal alignment, with the planes of the two plates at an angle to each other, each plate of the pair being at approximately the same angle to the longitudinal axis of the shell, and with the said extensions of each plate overlapping the companion plate and interlocking.

12. A heat exchange apparatus of the shell and tube type which comprises two circular tube-sheets positioned substantially parallel to one another and apart from one another, each tube-sheet pierced with a plurality of holes adapted to receive tubes; a plurality of tubes extending in parallel from one tube-sheet to the other tube-sheet and fastened thereinto with fluid-tight joints; a header over each tube-sheet and a conduit connection to each header; a cylindric shell extending from one tube-sheet to the other tube-sheet, surrounding the plurality of tubes and made fluid-tight to said tube-sheets; a conduit connection adjacent to each end of the cylindric shell; a plurality of baffles within the shell extending in series from one end of the shell to the other end thereof, each baffle comprising two plates, each of the two plates of a baffle being in the form of a segment of an ellipse, cut along the major axis thereof and carrying two extensions of substantially uniform width along the major axis, each plate being pierced to permit passage therethrough of the said plurality of tubes which extend from one tube-sheet to the other tube-sheet, the two plates of each baffle being positioned adjacent each other with their curved peripheries abutting the interior shell wall with the minor axes of the two plates in longitudinal alignment with the planes of the two plates at an angle to each other and at an angle to the longitudinal axis of the shell, and with the said extensions of the two plates interlocking.

13. A heat exchange apparatus of the shell and tube type which comprises two circular tube-sheets positioned substantially parallel to one another and apart from one another, each tube-sheet pierced with a plurality of holes adapted to receive tubes; a plurality of tubes extending in parallel from one tube-sheet to the other tube-sheet and fastened thereinto with fluid-tight joints; a header over each tube-sheet and a conduit con-

nection to each header; a cylindric shell extending from one tube-sheet to the other tube-sheet, surrounding the plurality of tubes and made fluid-tight to said tube sheets; a conduit connection adjacent to each end of the cylindric shell; a plurality of baffles within the shell extending in series from one end of the shell to the other end thereof, each baffle comprising two plates; each of the two plates of a baffle being in the form of a segment of an ellipse, cut along the major axis thereof for one-half the length of such axis and carrying an extension of substantially uniform width along the remainder of the major axis; each plate being pierced to permit the passage therethrough of the said plurality of tubes which extend from one tube-sheet to the other tube-sheet; the two plates of each baffle being positioned alongside of each other with their curved peripheries abutting the interior wall of the shell, with the minor axes of the two plates in longitudinal alignment, with the planes of the two plates at an angle to each other and at an angle to the longitudinal axis of the shell and with the said extensions of the two plates interlocking.

14. In a cylindric heat exchanger of the parallel tube type, a baffle system which comprises a series of baffles, each baffle comprising two plates, each plate being in the form of a segment of an ellipse and including not less than 180° of the ellipse, measured from the major axis thereof, each plate being pierced to permit the passage therethrough of a plurality of tubes; the two plates of each baffle being positioned at an angle to each other and abutting at the intersection of their major and minor axes, with the minor axes of the two plates of each baffle in longitudinal alignment, with the minor axes of the plates in successive baffles lying in a single plane, and with the planes of the two plates at an angle to the longitudinal axis of the cylindric heat exchanger; the series of baffles creating two similar and diametrically adjacent passageways of generally helical shape from the first baffle of the series to the last baffle of the series, and the said passageways being in open communication with each other.

15. In a cylindric heat exchanger of the parallel tube type, a baffle system which comprises a series of baffles, each baffle comprising two plates, each plate being in the form of a segment of an ellipse, including a semi-ellipse lying altogether on one side of the major axis, each plate being pierced to permit the passage therethrough of a plurality of tubes; the two plates of each baffle being positioned at an angle to each other and abutting at the intersection of their major and minor axes, with the minor axes of the two plates of each baffle in longitudinal alignment, with the minor axes of the plates in successive baffles lying in a single plane, and with the planes of the two plates at an angle to the longitudinal axis of the cylindric heat exchanger; the series of baffles creating two similar and diametrically adjacent passageways of generally helical shape from the first baffle of the series to the last baffle of the series, and the said passageways being in open communication with each other.

16. In a cylindric heat exchanger of the parallel tube type, a baffle system which comprises a series of baffles, each baffle comprising two plates, each plate being in the form of a segment of an ellipse and including not less than 180° of the ellipse, measured from the major axis thereof; with the two plates of a baffle positioned at an angle to each other and abutting at the intersection of their major and minor axes, with their minor axes in longitudinal alignment, the minor axes of the plates of successive baffles lying in a single plane, with the planes of the plates at an angle to the longitudinal axis of the cylindric heat exchanger, each plate being pierced to permit the passage therethrough of a plurality of tubes; the series of baffles creating two similar and diametrically adjacent passageways of generally helical shape from the first baffle of the series to the last baffle of the series, and the said passageways being in open communication with each other.

17. In a cylindric heat exchanger of the multiple tube type, a baffle system which comprises a plurality of baffles, each baffle comprising two similar plates; each plate being in the form of a segment of an ellipse, the said segment comprising a semi-ellipse, including all of the said ellipse lying on one side of the major axis thereof, and at least one extension beyond said major axis, the said extension being bounded by a radius of the ellipse and the periphery of said ellipse and having an area not exceeding twenty per cent of the area of the full ellipse, a plurality of holes through each plate to permit the passage therethrough of the heat-exchange tube; the two plates of each baffle abutting at the intersection of their major and minor axes, with the minor axes of the two plates of each baffle in longitudinal alignment, with the planes of the two plates at an angle to each other and to the longitudinal axis of the cylindric heat exchanger, and with the minor axes of the plates in successive baffles lying in a single plane.

18. In a cylindric heat exchanger of the multiple tube type, a baffle system which comprises a plurality of baffles, each baffle comprising two similar plates; each plate being in the form of a segment of an ellipse, the said segment comprising a semi-ellipse, including all of the said ellipse lying on one side of the major axis thereof, and at least one extension beyond said major axis, the said extension being bounded by a line extending from the intersection of the major axis with the periphery of the ellipse to a point on the minor axis outside the semi-ellipse, and back along the minor axis to the major axis, and having an area not exceeding twenty per cent of the area of the full ellipse; a plurality of holes through each plate to permit the passage therethrough of the heat-exchange tubes; the two plates of each baffle abutting at the intersection of their major and minor axes, with the minor axes of the two plates of each baffle in longitudinal alignment, with the planes of the two plates at an angle to each other and to the longitudinal axis of the cylindric heat exchanger, and with the minor axes of the plates in successive baffles lying in a single plane.

19. In a cylindric heat exchanger of the parallel tube type, a baffle system which comprises a plurality of baffles, each baffle comprising two plates; each plate being in the form of a segment of an ellipse, the said segment being a semi-ellipse, including all of the major axis of said ellipse, and an extension in the same plane beyond said major axis along at least a portion of the length thereof, each plate being pierced to permit the passage therethrough of a plurality of tubes; with the minor axes of the two plates of each baffle in longitudinal alignment, with the planes of the two plates at an angle to each other and at an angle to the longitudinal axis of the cylindric heat exchanger; the said baffle system defining two similar and diametrically adjacent helical paths, in open communication with one another from the line of the minor axes of the plates of one baffle to the line of the minor axes of the plates of the next baffle.

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