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H. E. MEANS

3,134,432

HEAT EXCHANGER

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FIG. 1

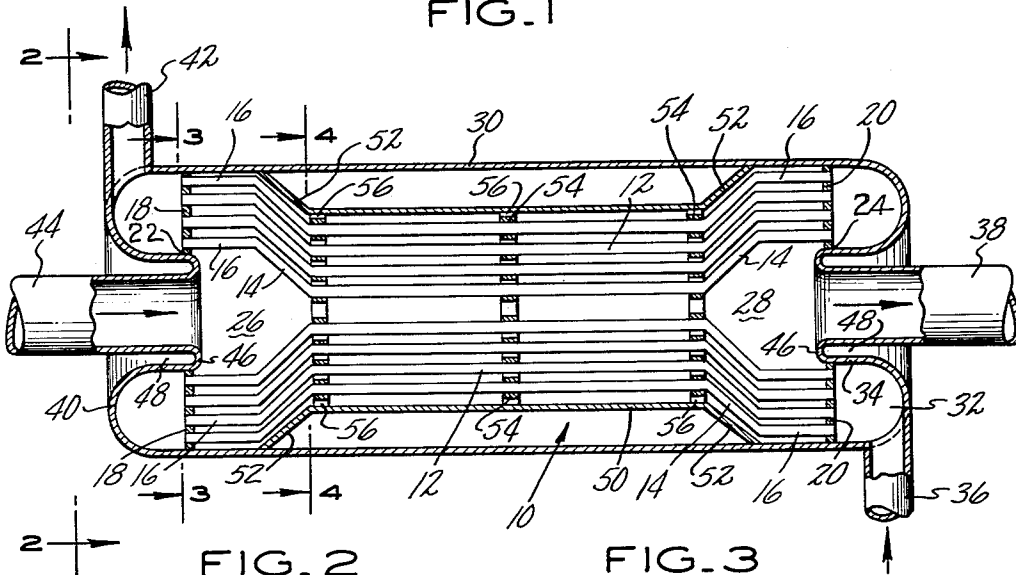


FIG. 2

FIG. 3

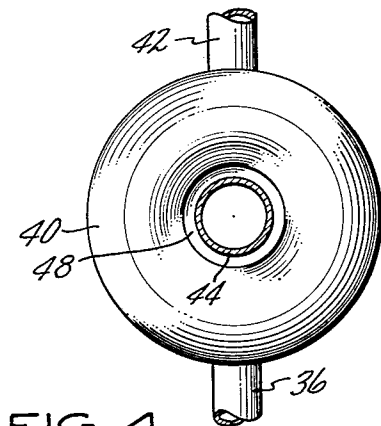


FIG. 4

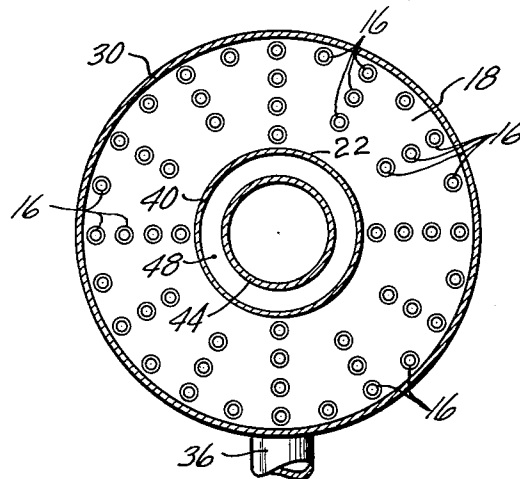
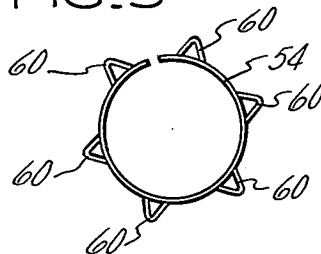
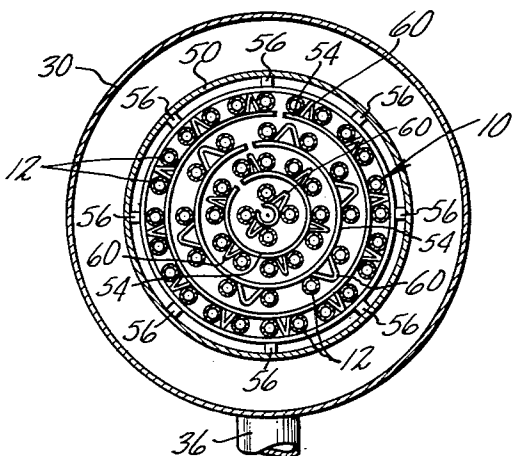


FIG. 5



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3,134,432

HEAT EXCHANGER

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This invention relates to heat exchangers and more specifically to heat exchangers of counter-fluid-flow configuration suitable for high-temperature liquid-metal applications.

Among the objects of this invention are to provide a heat exchanger of this type in which the wall-to-wall spacing of the tubes in the center portion of the tube matrix can be optimized independently of structural limitations in the tube sheet; in which the unit is essentially symmetrical about both the axial and the mid-plane center lines; in which the tubes in the tube matrix are all the same length and the same shape; in which a one-piece cylindrical shell can be assembled over the tube bundle, thereby eliminating longitudinal closure welds in the outer casing following assembly; in which the distribution of shell-side fluid is very good due to tube symmetry and due to tube fanning in the two end regions; in which no part of the main heat-exchanger structure, other than the tubes, has hot liquid on one side and cold liquid on the other side; and in which the annular tube sheets can be reinforced and supported at their center, thereby minimizing the tube sheet thickness.

A further object of this invention is to provide a heat exchanger especially adapted for use with liquid metals which, when properly installed, will completely fill without trapping gas and completely drain without liquid residue.

A still further object is generally to improve counter-fluid-flow heat exchangers for high-temperature liquid-metal applications.

These and other objects and advantages of the invention will be evident or will be specifically pointed out in connection with the following detailed description of one embodiment of the invention shown in the accompanying drawing. In the drawing:

FIG. 1 is a longitudinal sectional view of a preferred embodiment of the invention;

FIG. 2 is a sectional view on line 2-2 of FIG. 1;

FIG. 3 is an enlarged sectional view on line 3-3 of FIG. 1;

FIG. 4 is an enlarged sectional view on line 4-4 of FIG. 1; and

FIG. 5 is a detail of a tube supporting ring.

As herein shown, the heat exchanger includes an axial tube bundle 10 which is generally cylindrical. As shown most clearly in FIG. 1, the tube bundle includes a cylindrical, intermediate portion 12 in which straight tubes are relatively closely spaced one from another. The straight tubes of the intermediate portion 12 have their ends fanned at 14 into short, straight, cylindrical end portions 16. Tubes in end portions 16, due to the larger diameter of these end portions, are more widely spaced one from another than the tubes in the intermediate portion 12 which allows variation of the wall-to-wall tube spacing in portion 12 by variation of the spacing in end portions 16.

The tube bundle includes two tube sheets 18 and 20, one at each end, having apertures into which the ends of the tubes project. The spacing of the tube apertures in the tube sheets and the amount of fanning determines the spacing of the tubes in the tube bundle. The tube sheets 18 and 20 have axial apertures 22 and 24, respectively, which communicate with reentrant axial

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chambers 26 and 28 formed at the ends of the tube bundle by reason of the fanned tube portions 14. It will be evident that by fanning the tubes so that the tubes in the cylindrical end portions 16 can be more widely spaced where they enter the tube sheets, it is possible to provide any desired spacing of the tubes in the intermediate portion 12 to obtain the optimum axial flow characteristics through the long, straight, intermediate tube portion 12 of the tube bundle.

It will be apparent that the tube bundle is generally cylindrical and is symmetrical about both its longitudinal axis and its mid-plane center line. Also, the tubes are identical in length and shape. Because of the cylindrical shape of the tube bundle, a one-piece cylindrical shell, or casing, 30 can be assembled axially over the tube bundle, thus avoiding undesirable longitudinal closure welds in the outer casing following assembly.

A somewhat torus-shaped inlet header 32 is welded at its outer periphery to one end of casing 30 and forms a closure for the casing at this end except for the central axial wall 34 of the header which is a close fit in the aperture 24 of the tube sheet and is welded thereto. A radial inlet pipe 36 is provided for the tube side fluid flow. An axial outlet tube 38 is welded to the inner end of wall 34 of the inlet header adjacent the aperture 24 in the tube sheet which provides an outlet passage for the shell side fluid flow.

A similar outlet header 40 is provided at the other end of the shell 30 having a radial outlet pipe 42 for the tube side fluid and an axial inlet pipe 44 for the shell side fluid. As shown in FIG. 1, the inlet pipe 44 and the outlet pipe 38 for the shell side fluid flow are each provided with an annular flange 46 of semicircular cross section which is welded at the junction of the headers and the tube sheets to provide a small spacing 48 between these pipes and their respective headers.

A flow directing liner 50 is provided in order to insure that the fluid entering through pipe 44 into chamber 26 will flow along the straight, closely spaced, intermediate portion of the tubes. This liner is cylindrical over the straight tube portion 12 and has oblique flanges 52 at its ends which engage the inner wall of the outer shell 30 adjacent end portions 16 of the tubes.

As shown, the straight intermediate portion of the tubes in the tube bundle are supported at spaced points by a series of split hoops, or C-rings, 54. The outermost hoop has external lugs 56 welded thereto which engage the straight-cylindrical, intermediate portion of the flow liner. The rest of the hoops 54 are provided with tube supports 60 which are welded thereto and are located between each pair of tubes about the hoop. There are three sets of hoops shown and the supports 60 are staggered in the sets relative to adjacent tubes so as to provide adequate support for all of the tubes. One set of hoops is shown in detail in FIG. 4.

The heat exchanger has been shown with its longitudinal axis in a horizontal position to facilitate illustration and it may in some applications be installed in this horizontal position. One of the advantages of the heat exchanger of the present invention, however, is realized only if it is installed with its longitudinal axis vertical. It will be noted that the inlet pipe 36 and the outlet pipe 42 for the tube-side flow are tangential to the semi-circular wall of the headers as these are viewed in cross-section in FIG. 1. As a result, when vertically installed it is possible to completely fill the heat exchanger without trapping gas and to completely drain it without liquid residue. This is of particular importance when one or both of the fluids employed are high temperature liquid metals, such as sodium, NaK lithium, etc.

It will be evident that as a result of the above con-

struction a heat exchanger of the counter-fluid-flow type has been provided which is extremely simple to construct and which avoids many of the difficulties encountered in previous heat exchangers. For example, the elimination of longitudinal welds in the outer casing, or shell, following assembly enables the tube matrix to be accurately fitted into the casing without subsequently distorting the shell due to the weld or setting up stresses in the structure. Also, the arrangement by which the tubes are fanned adjacent their ends into a larger diameter section at the tube sheet locations enables the wall-to-wall spacing in the center of the matrix to be determined independently of structural limitations in the spacing of the tubes at the tube sheets.

It will also be evident that the unit is symmetrical in every way and that the tubes themselves are all identical as to length and shape. This has a definite bearing on the cost of making the tube matrix and also on the characteristics of the fluid flow through the tubes. Further, the distribution of the shell side fluid is clearly improved due to the symmetry of the matrix and due to the fanning of the tubes at the end regions.

It will also be noted in this connection that no part of the main structure of the heat exchanger, other than the tubes, has hot liquid on one side and cold on the other, thus minimizing stresses in the structure.

Making the tube bundle so that it can be slipped axially into a closely fitted outer shell without the necessity of longitudinal welds in the latter following the assembly removed some of the most troublesome problems in the construction of heat exchangers for very high-temperature fluids. If the longitudinal weld in the outer shell is made after assembly, the shrinkage in the metal causes a longitudinal depression, or trough, along the weld which destroys the cylindrical geometry of the shell and frequently results in burning of one or more tubes in the interior matrix during welding. Also avoiding longitudinal shell welds eliminates long welds which are incapable of inspection and long loop welds.

Another advantage of the present construction is the support provided for the tube sheets. These washer-shaped members are welded to the outer casing and to the header at their outer periphery and to both the header and the axial flow tube at their inner periphery, resulting in a much lighter weight tube sheet than would otherwise be possible.

While only one embodiment of the invention has been shown, it will be understood that various changes in the construction and arrangement of the parts may be made without departing from the invention as defined in the following claims.

I claim:

1. In a heat exchanger of counter-fluid-flow configuration, a generally cylindrical tube bundle, the tubes in said bundle being identical as regards length and shape and comprising intermediate straight closely spaced tubes which extend throughout the major length of the bundle and straight outwardly offset connected tubes at each end which are parallel with said intermediate tubes and are more widely spaced, the offset tubes providing an annular axial chamber reentrant into the bundle at each end of the tube bundle, an annular tube sheet at each end of said bundle through which the offset ends of the tubes extend, each of said tube sheets having a central aperture axially aligned with the adjacent reentrant chamber at its respective end of the tube bundle, an annular tube-side header enclosing the outer side of each tube sheet having a central aperture axially aligned with the aperture in the adjacent tube sheet, one of said headers comprising an inlet header and having a radial inlet pipe for a first fluid, the other comprising an outlet header and having a radial outlet pipe for said first fluid, an inlet pipe for a second fluid extended axially through the central aperture in said outlet header and through the aligned aperture in said adjacent tube sheet, an outlet

pipe for said second fluid extended axially through the central aperture in said inlet header and through the aligned aperture in the adjacent tube sheet, and a cylindrical outer casing enclosing said tube bundle and said tube sheets and secured at its opposite ends to said respective headers.

2. A heat exchanger as defined in claim 1 in which a cylindrical flow-directing liner closely surrounds the intermediate tubes of the bundle and has outwardly directed annular end flanges which engage the outer casing adjacent the offset cylindrical tubes.

3. In a heat exchanger, an axial cylindrical tube bundle having an intermediate cylindrical waist portion made up of straight closely spaced tubes and having the tubes outwardly offset at their ends to form cylindrical end portions of larger diameter, an annular tube sheet at each end of said tube bundle through which the ends of the tubes extend, said tube sheets having a large central aperture, an annular tube side header enclosing the outer side of each tube sheet having an axial opening aligned with the central aperture in said tube sheets, a fluid inlet for a first fluid communicating with one of said headers, a fluid outlet for said first fluid communicating with the other of said headers, a cylindrical shell surrounding said tube bundle having a diameter adapted to closely receive the large diameter end portions of said bundle, a cylindrical flow-directing liner closely surrounding the intermediate portion of said tube bundle and flared at its ends into engagement with said shell adjacent the offset end portions of said tubes, and axial inlet and outlet pipes extended into said axial openings in said respective headers and the central apertures of said tube sheets and forming the inlet and outlet for a second fluid.

4. In a heat exchanger of the counter-fluid-flow type, a generally cylindrical tube bundle, said bundle having an intermediate straight cylindrical waist portion in which a plurality of straight tubes are closely spaced and from which the tubes are outwardly fanned and merge into cylindrical end portions of larger diameter in which straight tubes parallel with said intermediate tubes are more widely spaced, an annular tube sheet at each end of said bundle through which the ends of said tubes extend and by which the spacing of said tubes is determined, said tube sheets having a central aperture, an annular tube-side header enclosing the outer side of each tube sheet, each of said headers having an axial opening, inlet and outlet connections for a first fluid secured in said openings about the central aperture in said tube sheets, a radial outlet connection for the header which has said axial inlet connection and a radial inlet connection for the header which has said axial outlet connection, a cylindrical shell surrounding said tube bundle having a diameter adapted to receive closely the larger diameter end portions of said tube bundle, and a cylindrical flow-directing liner closely surrounding the intermediate portion of said tube bundle, said liner having its ends flared and engaging the inner annular surface of said shell.

5. In a heat exchanger, a straight tubular casing open at both ends, a tube matrix in said casing coextensive with the length of said casing, said matrix at its opposite ends having its tubes fanned into an annulus bounded by the tubular casing and forming an axial reentrant core passage, said tube matrix having an extensive waist portion intermediate the annuli at its ends in which the tubes are more closely spaced one from another and in which said matrix is spaced from said outer casing by a substantial distance, washer-shaped tube sheets at the ends of said matrix having tube apertures through which the tubes in said annuli extend, inlet and outlet headers secured to the opposite ends of said casing enclosing said tube sheets and forming a closure for the ends of said casing except for axial flow passages communicating through said headers with said axial core passages in the annuli of said matrix, inlet and outlet pipes for a first fluid flow connected to said inlet and outlet headers re-

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spectively, an axial inlet connection secured in a fluid-tight manner to the inner periphery of said outlet header for a second fluid flow, an axial outlet connection secured in a fluid-tight manner to the inner periphery of said inlet header for said second fluid flow, and a flow-directing liner in said casing surrounding the waist portion of said matrix for directing the path of said second fluid flow through said waist portion of said tube matrix.

6. In a heat exchanger, a tubular enclosing casing open at both ends, a tube matrix in said casing comprising a bundle of longitudinally extending tubes having their ends terminating at the ends of said casing, the several tubes in said bundle all being of the same length and the same shape, said tubes being straight and closely spaced from one another throughout a major intermediate portion of the length of said casing so that said tube matrix throughout said intermediate portion occupies an axial position in said casing well spaced from the casing side wall, the tubes in said straight portion of said tube matrix being flared at both ends into short axially extended portions which form an annulus bounded by the outer casing and by a central annular reentrant passage, the tubes in said annuli being straight and parallel with the tubes in said intermediate portion, a washer-shaped tube sheet at each end of said matrix having tube apertures through which said tubes extend, a torus-shaped inlet header for a first fluid flow at one end of said casing enclosing one of said tube sheets having an axial opening aligned with said central annular passage at said end of said matrix, an outlet pipe for a second fluid flow secured in said aligned axial opening of said inlet header, a similar torus-shaped outlet header for said first fluid flow at the other end of said casing enclosing the other tube sheet, an inlet pipe for said second fluid flow secured in the axial opening of said outlet header, and inlet and outlet connections for said first fluid in said inlet and outlet headers respectively.

7. A heat exchanger as defined in claim 6 in which a cylindrical flow-directing liner closely surrounds the intermediate portion of said tube matrix and has its ends fanned out along the flared tube ends into engagement with the inside surface of said outer casing, whereby the second fluid flow is directed axially along the intermediate straight portion of said tubes.

8. A heat exchanger as defined in claim 7 in which the

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tubes in the intermediate portion of the tube matrix are supported by at least one tube support assembly consisting of a plurality of annular concentric hoops each of which engages the inner surface of a circular array of tubes.

9. A heat exchanger as defined in claim 7 in which the tubes in the intermediate portion of the tube matrix are supported by at least one tube support assembly consisting of an outer hoop having peripherally spaced lugs which engage the inner surface of the flow liner and a plurality of concentric split hoops each engaging a circular row of a plurality of concentric rows of tubes, said split hoops each having a plurality of circumferentially spaced radially extending tube supports which are secured thereto and extend between adjacent tubes in the row which it supports.

10. A heat exchanger having a straight cylindrical outer shell, a cylindrical tube bundle receivable axially in said shell, said bundle having a straight cylindrical intermediate portion of considerably less diameter than the inner wall of said shell and cylindrical end portions which are a close fit in said shell, the tubes in said bundle all being of the same length and the same shape and each comprising a long, straight intermediate portion and straight outwardly offset end portions parallel with said intermediate portion which are connected by oblique portions with said intermediate portion, washer-shaped tube sheets at the ends of said cylindrical end portions of said bundle having apertures through which the offset ends of said tubes extend, inlet and outlet headers at opposite ends of said casing each enclosing one of the remote sides of said tube sheets and having inlet and outlet pipes respectively for the tube-side fluid, and axial inlet and outlet pipes for the shell-side fluid extended through said headers and through said tube sheets into said shell.

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