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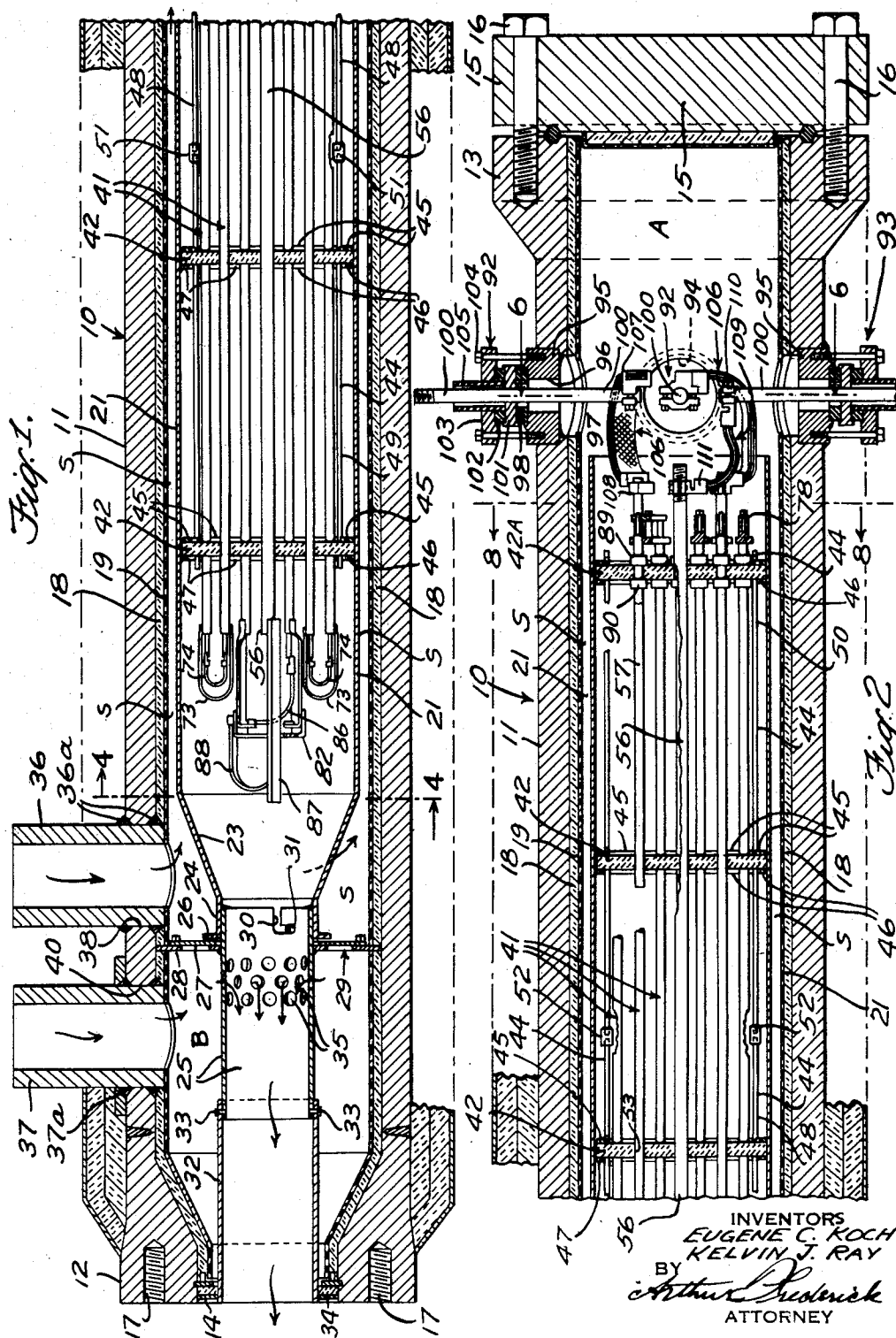
E. C. KOCH ET AL

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ELECTRIC FLUID HEATER

Filed June 12, 1957

7 Sheets-Sheet 1



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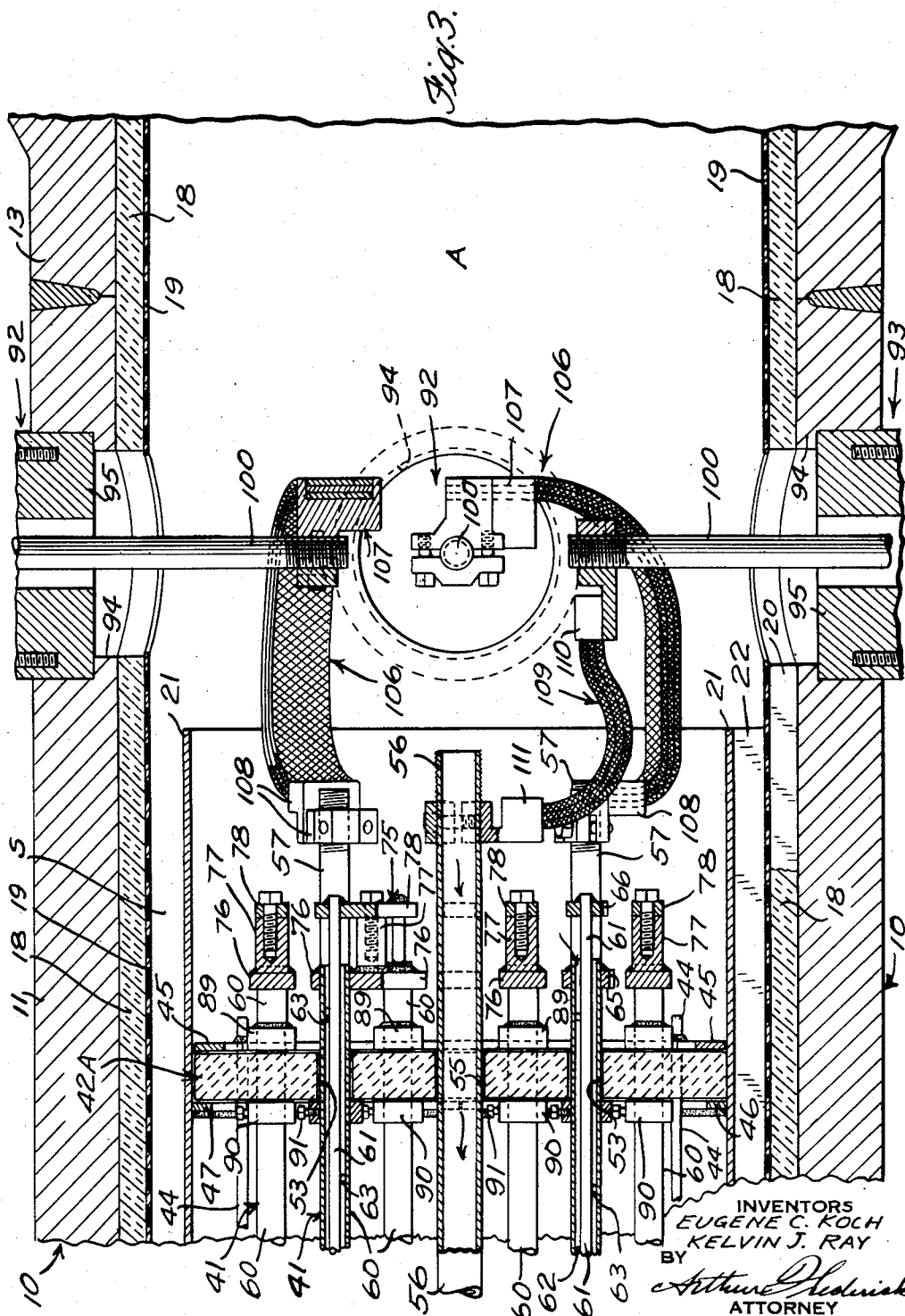
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ELECTRIC FLUID HEATER

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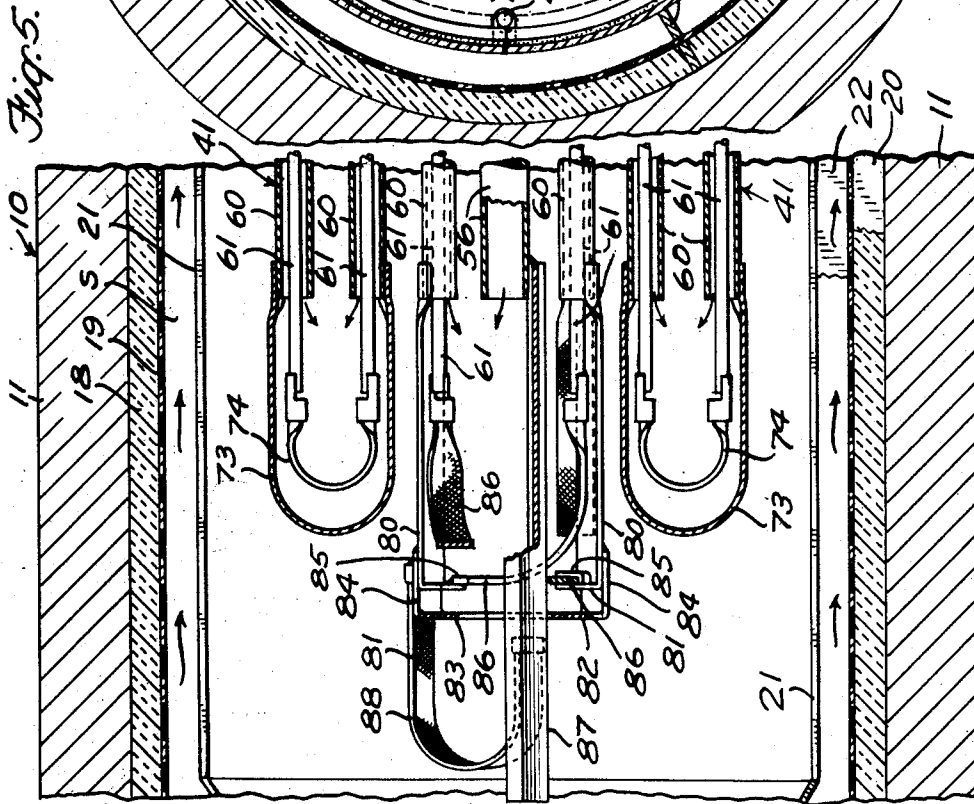
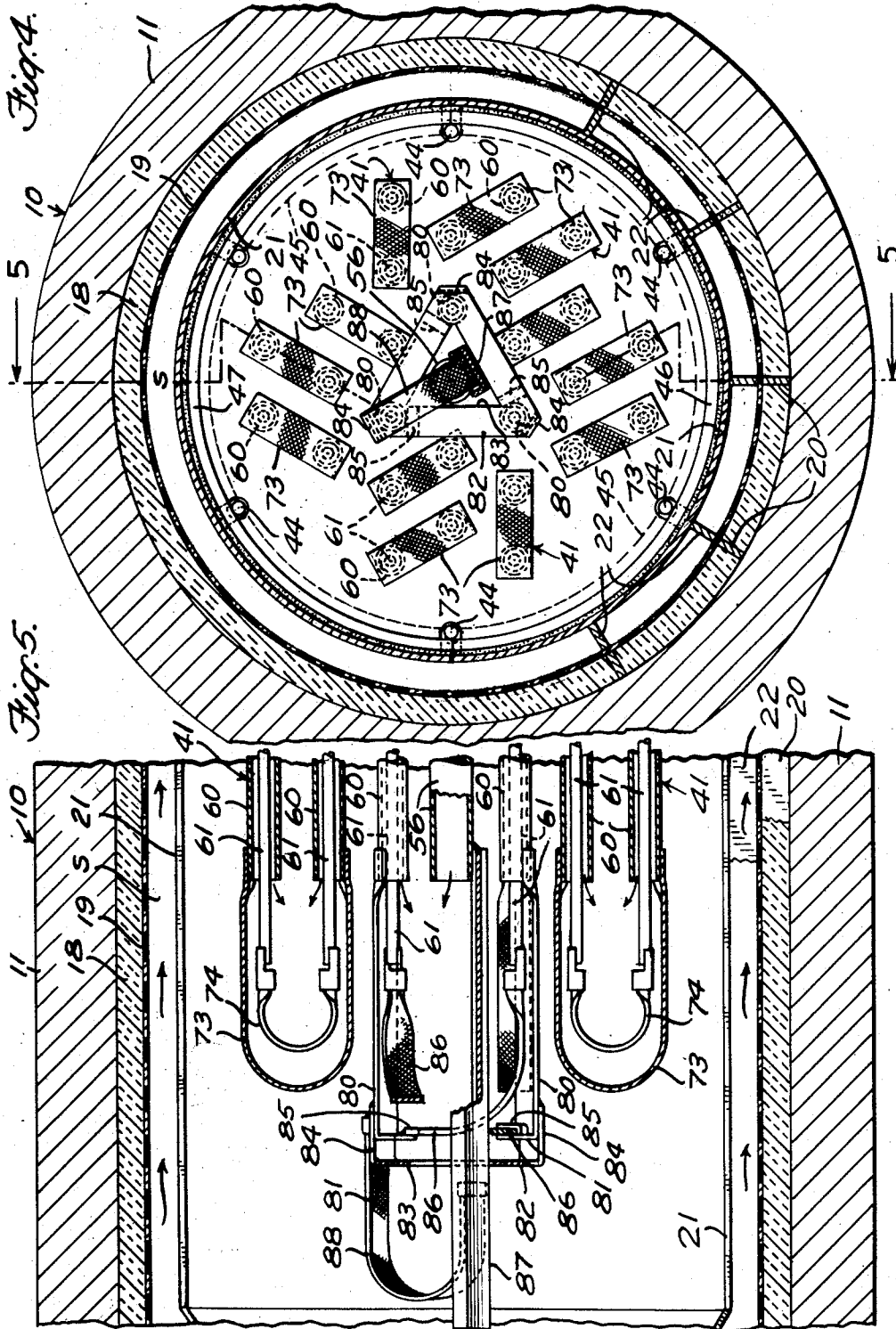
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Fig. 8.

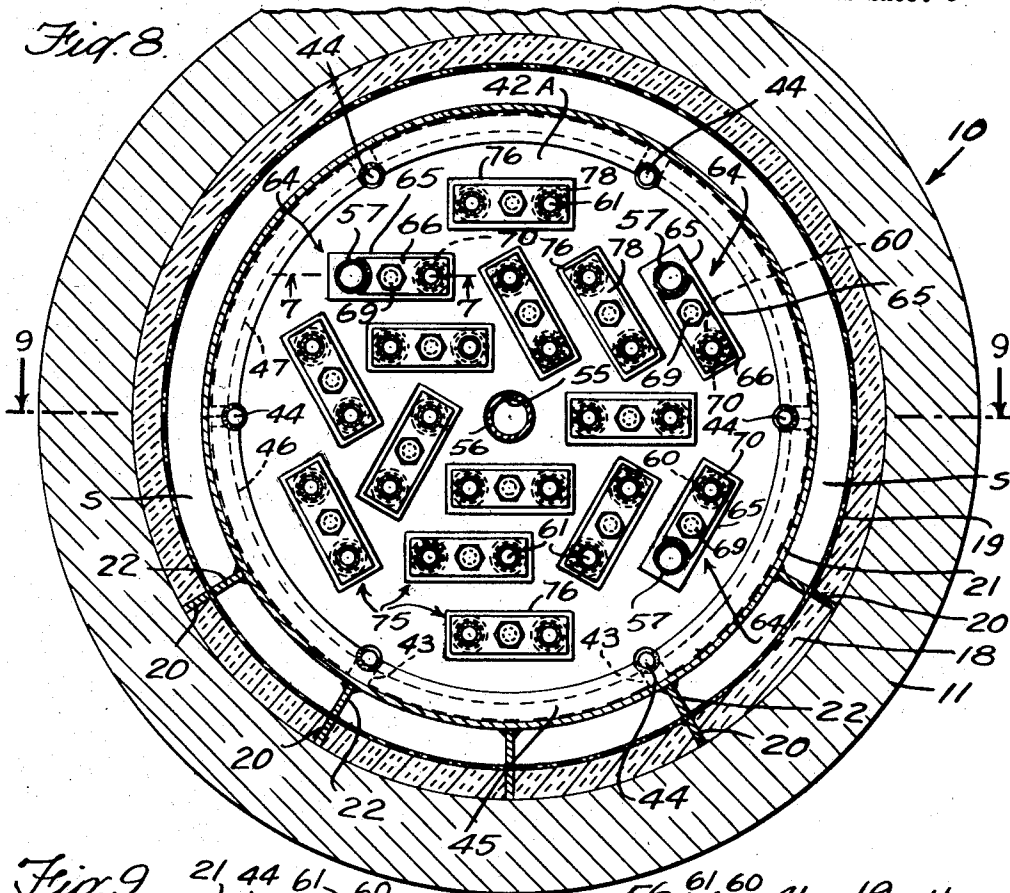
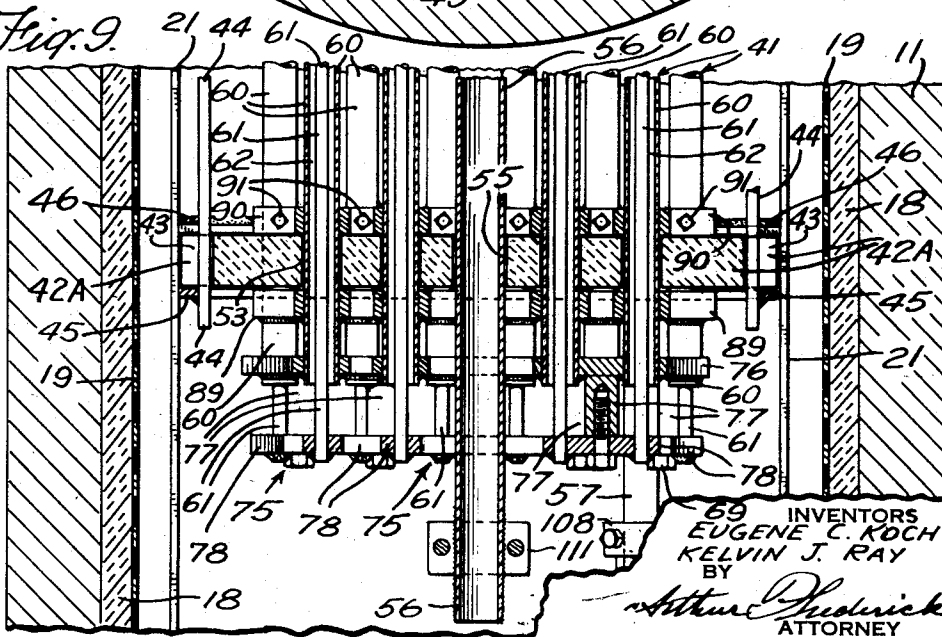


Fig. 9.



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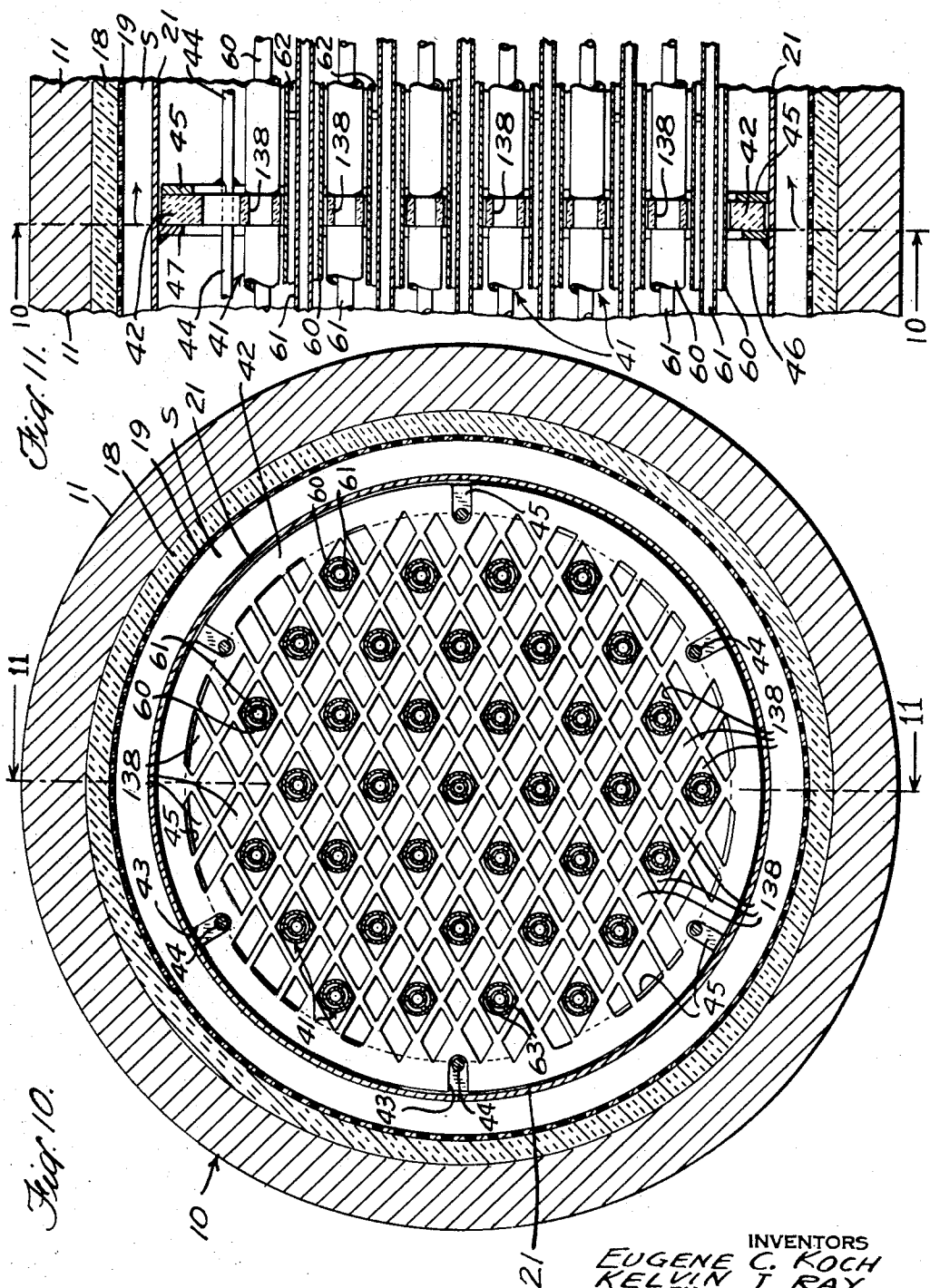
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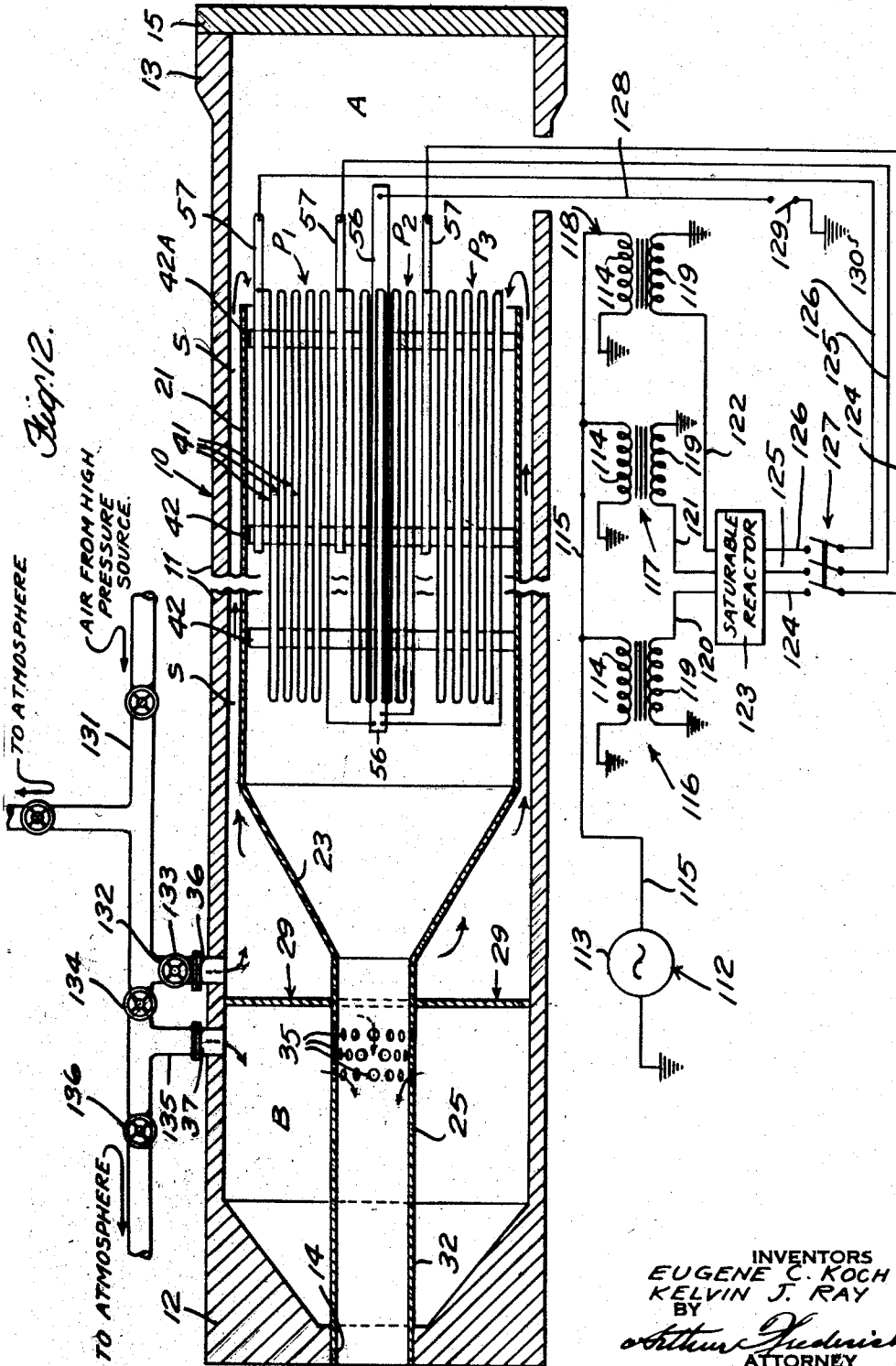
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ELECTRIC FLUID HEATER

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Application June 12, 1957, Serial No. 665,292

13 Claims. (Cl. 219—38)

This invention relates to heat exchangers and more particularly to fluid heaters wherein fluid is heated by means of electric heating elements.

In electrical fluid heaters of the type disclosed in United States Reissue Patent No. Re. 23,795, dated March 2, 1954, a plurality of tubular electrical resistance elements are supported in spaced parallel relationship to each other in the shell or housing of the fluid heater by a plurality of spaced metal tube sheets through which the electrical resistance elements pass. The electrical resistance elements are connected at one end to a source of electrical current through a bus and at the other end are grounded to the shell of the heater through another bus. The electrical resistance elements pass through bushings or collars of dielectric material at the tube sheets to electrically insulate the resistance elements from each other and the shell. Fluid to be heated enters the fluid heater through an inlet means in the shell and flows through the resistance elements, and is thereby heated. The heated fluid passes from the shell through an outlet means therein to a place of use. Control of outlet temperature of the fluid to be heated is effected by regulating electrical current flow through the resistance elements. It has been found that rapid and accurate control of outlet temperature cannot be achieved solely by control of electrical input to the resistance elements nor can a substantially constant outlet temperature be achieved. Another disadvantage of the aforesaid fluid heater is the difficulty in electrically testing the resistance elements, since the resistance elements are grounded to the shell. A further disadvantage is the relatively frequent short circuiting of the resistance elements through the tube sheets and shell by reason of the structural failure of the dielectric bushings which insulate each resistance element from the tube sheets.

Accordingly, one of the objects of this invention is to provide an electric fluid heater of substantially the same overall size as conventional electric fluid heaters, such as disclosed in the aforesaid reissue Patent No. Re. 23,795, but having greater heat transfer capacity.

Another object is to provide an electrical fluid heater capable of operating at very high temperatures and pressures.

A further object of the present invention is to provide an electrical fluid heater wherein fluid outlet temperature can be accurately maintained.

Another object of this invention is to provide an electric fluid heater in which electrical short-circuit of the heating elements is obviated.

A still further object of the present invention is to provide a fluid heater in which the heating elements can be quickly and easily electrically tested without the necessity of removing the heating elements.

The present invention contemplates a novel fluid heater having an outer shell or housing and fluid inlet means in the shell for passing fluid to be heated into the shell. The outer shell also is provided with a fluid outlet to pass heated fluid from the heater. A plurality of elec-

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trical resistance elements are supported and electrically insulated from each other within the shell by a plurality of tube sheets of dielectric material. Each of the electrical heating elements comprises two tubular members arranged in coaxial relationship to each other with the inner surface of the outer tubular member and the outer surface of the inner tubular member spaced from each other to provide an annular passageway. The electrical heating elements are electrically connected to provide a three phase electrical circuit, the heating elements of each phase being grounded outside of the shell. A baffle means is provided in the shell to provide flow of fluid to be heated from the fluid inlet means to the electrical heating elements. Fluid to be heated flows through the inner tubular members of the electrical heating elements and the annular passageway between the two tubular members of the heating elements and is thereby heated. A cylindrical member, defining a mixing chamber and having inlet means, is disposed in the shell in communication at one end with the heating elements to receive heated fluid from the latter and at the other end with the fluid outlet in the shell. A second fluid inlet means is provided in the shell for passing a regulated quantity of relatively cool fluid into the mixing chamber through the inlet means and into admixture with heated fluid.

In a second embodiment of the present invention, the dielectric tube sheets supporting the heating elements are each provided with apertures disposed between the apertures through which the electrical resistance elements pass to thereby provide for flow of fluid to be heated along the outer surface of the outer tubular members, as well as flow through the tubular members.

The invention will be more fully understood from the following detailed description thereof when considered in connection with the accompanying drawings wherein two embodiments of the invention are illustrated by way of example and in which:

Fig. 1 is a longitudinal sectional view of part of the fluid heater according to this invention;

Fig. 2 is a longitudinal sectional view of part of the fluid heater which is not shown in Fig. 1;

Fig. 3 is an enlarged fragmentary view of the fluid inlet end of the heating elements showing the means for electrically connecting the heating elements to the electrical input terminals;

Fig. 4 is a view in section taken along line 4—4 of Fig. 1, somewhat enlarged, showing the means for electrically connecting the heating elements together;

Fig. 5 is a view in section taken along line 5—5 of Fig. 4;

Fig. 6 is a view in section taken substantially along line 6—6 of Fig. 2, somewhat enlarged;

Fig. 7 is an enlarged sectional view of the means for electrically connecting terminal rods to first heating elements taken along line 7—7 of Fig. 8;

Fig. 8 is a sectional view taken along line 8—8 of Fig. 2, somewhat enlarged;

Fig. 9 is a view in section taken along line 9—9 of Fig. 8;

Fig. 10 is a transverse sectional view taken along line 10—10 of Fig. 11 adjacent a tube sheet of a fluid heater according to a second embodiment of the invention;

Fig. 11 is a sectional view taken along line 11—11 of Fig. 10; and,

Fig. 12 is a schematic drawing of the fluid heater according to this invention, showing the heating elements, the electric-circuit involved, and the means for introducing fluid into the heater.

Like reference characters in the several views refer to like parts.

Referring now to the drawings, and more particularly Figs. 1 and 2, 10 designates a hollow shell or housing

having a central body portion 11 and opposite end portions 12 and 13. End portions 12 and 13 are of larger external cross sectional dimensions than central portion 11 so that the external surface of end portions 12 and 13 project beyond the external surface of body portion 11. The internal cross sectional dimension of end portion 13 (Fig. 2) is the same as that of the central portion 11 so that the internal surface of end portion 13 is coextensive with the inner surface of central portion 11. The internal cross sectional dimension of end portion 12 (Fig. 1) is substantially less than that of central portion 11 to define an opening 14. The inner surface of end portion 12 tapers outwardly from the surface defining opening 14 to the inner surface of central portion 11. A high pressure cover plate 15 is secured to end portion 13 by a plurality of circumferentially spaced bolts 16 while end portion 12 is provided with a plurality of circumferentially spaced tapped holes 17 to receive bolts (not shown) to secure an adapter member (not shown) for connecting shell 10 to a duct or other apparatus which is to receive heated fluid.

The inner surface of shell 10 is lined with heat insulating material 18, such as glass wool. The insulating material is held in place against the inner surface of shell 10 by a perforated liner 19 having a configuration conforming to the inner surface of shell 10. Liner 19 is provided with perforations so that pressure is equalized on both sides of the liner, thus enabling the use of a liner of relatively thin gage material. Liner 19 is maintained in spaced relationship to the inner surface of shell 10 by a plurality of circumferentially spaced ribs 20 (shown in Figs. 3, 6 and 8) which extend radially from the liner 19 to shell 10 and substantially the entire length of body portion 11 and of end portion 13 of shell 10. As shown, ribs 20 are disposed along the lower circumference of liner 19 but if the fluid heater is intended to be used in a vertical position, ribs 20 would be disposed along the entire circumference of liner 19.

A tubular inner shell 21 of sheet metal, or the like, having smaller cross sectional external dimensions than liner 19 is disposed in shell 10 in coaxial relationship with the latter. One end of shell 21 terminates at a point short of end portion 13 of shell 10 to define between the end of shell 21 and end portion 13 a chamber portion A and at the opposite end terminates short of end portion 12 of shell 10. A plurality of circumferentially spaced ribs or fins 22 are secured to shell 21 and extend the length of shell 21 and radially therefrom to liner 19 in substantial alignment with ribs 20 of liner 19. As best shown in Figs. 4, 6 and 8, ribs 22 are spaced along the lower circumference of shell 21, but if the fluid heater is to be arranged vertically, ribs 22 would be disposed along the entire circumference of shell 21. Ribs 22 maintain shell 21 in spaced relationship with the inner surface of liner 19 to thereby provide an annular passageway S which communicates at one end with the space formed between shell 21 and end portion 12 and at the other end with chamber A. Inner shell 21 is open at one end (Fig. 2) to communicate with chamber A, and at the opposite end (Fig. 1) has a frusto-conical end member 23 which tapers inwardly to an open ended cylindrical end portion 24. A hollow mixing cylinder 25 is secured at one end, as hereinafter more fully described, within end portion 24 of inner shell 21. Cylindrical end portion 24 has a flanged end portion 26 which, when cylinder 25 and end member 23 of inner shell 21 are locked together, abuts an annular flange member 27. Flange member 27 is welded to cylinder 25 and is bolted, adjacent its outer periphery, to an annular ring 28 which is connected to the inner surface of shell 10 and extends therefrom to a point short of cylinder 25. Flange 27 and annular ring 28 form a partition 29 which seals off passageway S from the space B formed between the end of shell 21 and end portion 12 of shell 10.

Mixing cylinder 25 is provided at its end, adjacent to inner shell 21, with two spaced bayonet slots 30 (only

one of which is shown). End portion 24 of inner shell 21 is provided with spaced pins 31 (only one being shown in the drawings) which pins extend from the inner surface of end portion 24. Mixing cylinder 25 is secured within end portion 24 by inserting cylinder 25 axially within end portion 24 so that pins 31 fully enter slots 30. Thereafter, cylinder 25 is rotated clockwise, as viewed from end portion 12, to lock cylinder 25 to end portion 24. The end of cylinder 25, opposite from slots 30, fits within one end of a hollow cylindrical extension member 32, and is secured thereto by two pins 33 which are carried by extension member 32 and extend into two longitudinal slots in the end of cylinder 25 to allow for differential expansion and contraction between extension member 32 and cylinder 25. The opposite end of extension member 32 extends into opening 14 of end portion 12 of shell 10 and terminates flush with the outer end surface of end portion 12. Extension member 32 is suitably supported within opening 14 as by a ring 34 disposed transversely in said opening 14 and secured, as by welding, to end portion 12 and extension member 32. Mixing cylinder 25 is provided to the left of partition 29, as viewed in Fig. 1, with a plurality of spaced inlet openings 35 which communicate the interior of the mixing cylinder 25 with space B. The purpose and function of cylinder 25 and inlet openings 35 will be hereinafter fully described.

A fluid inlet nozzle 36 is secured to the right of partition 29, as viewed in Fig. 1, by welding or the like, at 36a within an opening 38 in shell 10 and liner 19 so that nozzle 36 communicates with passageway S. Another fluid inlet nozzle 37 is secured to the left of partition 29, as viewed in Fig. 1, by welding, or the like, at 37a within an opening 40 in shell 10 and liner 19. Inlet nozzle 36 is connected to a source of high pressure fluid to be heated, as for example air, or any other fluid having proper dielectric properties. Inlet nozzle 37 is connected to receive high pressure fluid, from the same source as nozzle 36 or from a different source of fluid.

A plurality of electrical tubular heating elements 41 are supported in spaced parallel relationship to each other within inner shell 21 by a plurality of tube sheets 42 transversely disposed in inner shell 21 and positioned at spaced points along the length of shell 21. The endmost tube sheet 42, adjacent end portion 13 of shell 10, will be hereinafter designated by the reference character 42A. Each tube sheet 42, including tube sheet 42A, is dimensioned so that it fits snugly but movably within shell 21. Preferably, each tube sheet 42 and tube sheet 42A is composed of a dielectric material having high resistance and strength at high temperatures and pressure, as for example, alumina or fused silica quartz. Each tube sheet 42 and tube sheet 42A is provided with a plurality of circumferentially spaced slots 43, as for example, six in number, as shown in Figs. 8 and 10, which extend inwardly from the peripheral edge of the tube sheet. Tie rods 44, corresponding in number to the number of slots 43 in each tube sheet, are disposed in slots 43, as shown in Figs. 4, 8, 9 and 10. To secure each tube sheet in position within inner shell 21, an annular ring 45 (Figs. 3, 4, 8 and 9) is disposed in close spaced relationship with one side of the tube sheet and is welded to tie rods 44. On the other side of each tube sheet, in close spaced relationship therewith, a semi-circular ring 46 is secured, as by welding to the lower half of shell 21 and a second semi-circular ring 47 is secured, as by welding, to the upper half of shell 21 in close spaced relationship to the tube sheet. Each tie rod 44, as shown in Figs. 1 and 2, comprises a center section 48 and end sections 49 and 50, which sections are joined together by two sleeves 51 (Fig. 1) and 52 (Fig. 2). Each tie rod section 49 is secured, as by welding, or the like, in one end of sleeve 51 while end tie rod section 50 is secured, as by welding, or the like, in one end of sleeve 52, the center tie rod section 48 being free to move longitudinally within the other end of

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sleeves 51 and 52. The tie rod sections thus joined together, allow for longitudinal differential expansion of the tie rods and inner shell 21.

Each tube sheet 42, including tube sheet 42A, is provided with a plurality of spaced openings 53 to receive therethrough tubular heating elements 41 and a centrally positioned opening 55 to receive a tubular ground member 56. Tubular ground member 56 is of electrical resistor material, as for example, nickel-chromium alloy or other suitable material. Tube sheet 42A and the next adjacent tube sheet 42, in addition to openings 53 and opening 55, are each provided with three spaced openings disposed near the peripheral edge of the tube sheets to receive three terminal rods 57 (see Figs. 3, 6, 8 and 12). Terminal rods 57 are only long enough to extend through tube sheet 42A and the next adjacent tube sheet 42, the terminal rods 57 being supported by the aforesaid tube sheets.

Each tubular heating element 41 comprises an outer tube 60 and an inner tube 61, each of which are of electrical resistor material, for example, nickel-chromium alloy or other equivalent electrical resistor material. Inner tube 61 is of smaller external diameter than the internal diameter of tube 60, and is arranged within outer tube 60 in coaxial relationship with outer tube 60 to define between the inner surface of the outer tube 60 and the outer surface of inner tube 61 a fluid passageway 62. To maintain inner tube 61 in coaxial and spaced relationship to outer tube 60, a plurality of radial spacer members or fins 63 are positioned at various points along the length of tube 61 and extend radially from the outer surface of tube 61 to abut against the inner surface of outer tube 60 (Fig. 3). Outer tubes 60 are of equal length and have their opposite ends extending to a point beyond tube sheet 42A and the opposite endmost tube sheet 42, while inner tubes 61 are of equal length and have their opposite ends extending to a point beyond the opposite ends of tubes 60. Tubular ground member 56 is of such a length that one end thereof extends from tube sheet 42A beyond the ends of tubes 61 and the opposite end terminates beyond the opposite endmost tube sheet 42 in the same plane as the ends of outer tubes 60.

As best shown in Fig. 12, heating elements 41 are arranged to form a three-phase electrical circuit. Each phase, hereinafter designated P₁, P₂ and P₃, comprises a plurality of heating elements 41, a terminal rod 57 and the tubular ground tube 56, which members in each phase are connected together in parallel or serially connected together as illustrated in the drawings and as hereinafter described. A first electrical heating element 41 of each phase is connected by an electrical connector means 64 to a terminal rod 57 in each phase.

Each electrical connector assembly 64, as best shown in Figs. 3 and 7, comprises two rectangular blocks 65 and 66 of electrical conducting material which are secured in spaced relationship to each other by a spacer member 67 which extends between blocks 65 and 66. Spacer member 67 is secured, as by welding, at one end to the center of block 65 and at the other end is provided with an axial hole 68 which is threaded to receive a bolt 69. Block 66 is provided with a hole to receive therethrough bolt 69 which is threaded into tapped hole 68 to thereby secure blocks 65 and 66 together. Block 65 is provided with two transverse holes 70 and 71 which are respectively adapted to receive therethrough the end of outer tube 60 of a first electrical heating element 41 and the end of terminal rod 57. Block 65 is secured, as by welding, around holes 70 and 71 to outer tube 60 of the first electrical heating element 41 and to the terminal rod 57, respectively. Block 66 is provided with a hole 72, adjacent one end thereof, which hole is adapted to receive therethrough the end of inner tube 61 of the first electrical heating element 41. Block 66 is secured, as by welding, around the periphery of hole 72 to the inner tube 61, while the opposite end of block 66 is provided with a

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concavity adapted to engage part of the peripheral surface of terminal rod 57, block 66 being secured along the concavity, as by welding, to the terminal rod.

The opposite end of each first electrical heating element 41 is electrically connected to the next adjacent electrical heating element 41 in each of the phases P₁, P₂ and P₃, by electrical connector members 73 and 74, as best shown in Figs. 4 and 5. Flexible connector members 73 comprise a flat strap of electrical conducting material, as for example, wire braided strap or nickel, which is "looped" and is suitably secured, as by welding, at one end to the outer tube 60 of the first electrical heating element and at the other end to outer tube 60 of the next adjacent electrical heating element 41. Connector member 74 is a flat strip of electrical conducting material, as for example, a low carbon nickel, which is "looped" and suitably secured at one end to the inner tube 61 of the first electrical heating element and at the other end to the inner tube 61 of the next adjacent electrical heating element 41.

As shown in Figs. 6, 8, and 9, the next adjacent heating element 41 is electrically connected at the opposite end (adjacent tube sheet 42A) to the next succeeding heating element 41 by a connector assembly 75. Connector assembly 75, similar in construction to connector assembly 64, comprises a block 76, similar to block 65, having two spaced holes adapted to receive therethrough the ends of outer tubes 60 of adjacent heating elements 41 which are to be connected together. Block 76 has a spacer member 77, similar to spacer member 67, secured thereto, as by welding, which spacer member is provided with an axially extending tapped hole. Another block 78, slightly smaller in dimensions than block 76, is secured to spacer member 77 by a bolt threaded into the tapped hole in spacer member 77. Block 78 is provided with two spaced holes which are adapted to receive therethrough the ends of the inner tubes 61 of adjacent heating elements 41 which are to be connected together. Block 76 is secured, as by welding, to outer tubes 60 of the adjacent heating elements around the periphery of the holes in block 76, while block 78 is secured, as by welding, to the inner tubes 61 of the adjacent heating elements around the periphery of the holes in block 78. The remaining heating elements 41 in each phase P₁, P₂ and P₃ are serially connected together as hereinbefore described by connector members 73 and 74 and connector assemblies 75.

As best shown in Figs. 4 and 5, a flat metal strip 80 of high electrical conductivity, as for example, nickel, is electrically connected, as by welding, to the end portion of each of outer tubes 60 of the last serially connected heating element 41 in each of the three phases. Each strip 80 is coextensive with the heating element to which it is secured and extends to a point beyond the ends of inner tubes 61. Strips 80 have end portions 81 bent to extend in a direction toward each other. Strips 80 are interconnected by a triangular-shaped plate 82 of electrical conducting material, as for example, nickel, having a triangular-shaped central opening 83. Plate 82 is provided with three projecting tabs 84 which extend normal to the plate. Plate 82 is dimensioned so that tabs 84 lie in surface contact with the outer surface of strips 80, tabs 84 being secured to strips 80, as by welding, to thereby electrically connect together outer tubes 60 of each of the last heating elements 41 in each phase. A flexible connector 86, such as a wire braided strap, is provided for each inner tube 61 of the last heating elements in each phase. Each connector 86 is electrically connected at one end, as by welding, to an inner tube 61 and at the other end at 85 to an end portion 81 of a strip 80. In this manner, each of the inner tubes 61 is electrically connected at 85, through end portions 81 of strips 80, to plate 82. To connect outer tubes 60 and inner tubes 61 of the last heating elements 41 in each phase to ground tube 56, a channel member 87, U-shaped in cross section, is secured at one end to the

end of ground tube 56 so as to extend coextensively with the latter, through opening 83 in plate 82. Channel 87 is of metal having high electrical conductivity, as for example, nickel. Channel 87 is electrically connected to plate 82 by means of a "looped" flexible connector 88, as for example, wire braided strap, which is secured at one end, as by welding, to one of the tabs 84 of plate 82 and at the other end to channel 87. The aforescribed means for electrically connecting the last heating elements 41 in each phase to ground tube 56 while effectively connecting the inner and outer tubes of each of the last heating elements 41 to ground tube 56, provides at the same time, means for allowing differential expansion between the outer tubes 60 and inner tubes 61 and between outer tubes 60 and ground tube 56. The differential expansion and contraction between the outer tubes 60 and inner tubes 61 are compensated for by flexible connectors 86 while relative contraction and expansion of ground tube 56 and outer tubes 60 is compensated for by flexible connector 88.

Electrical heating elements 41 are each secured within tube sheet 42A against longitudinal movement as best shown in Figs. 2 and 9, by a collar 89 which is passed over the end of outer tube 60 and is secured, as by welding, to the outer tube adjacent the outer surface of tube sheet 42A. A second collar 90 is positioned on tube 60 adjacent the inner surface of tube sheet 42A, and is secured to outer tube 60 by means of a set screw 91. Collars 89 and 90 secured to tubes 60 on either side of tube sheet 42A prevents endwise misalignment of tubes 60 relative to tube sheets 42 and tube sheet 42A. Since the inner tubes 61 are secured to outer tubes 60 by connector assemblies 64 and 75, inner tubes 61 are also held against endwise misalignment relative to tube sheets 42 and tube sheet 42A. Because outer tubes 60 and inner tubes 61 are fixed against linear movement with respect to tube sheet 42A, linear expansion and contraction of outer tubes 60 and inner tubes 61 will be in a direction toward the left as viewed in Figs. 1 and 5, and for this reason, differential expansion between outer tubes 60 and inner tubes 61 will be manifested at the tube end portions adjacent end portion 12 of shell 10. To allow for this differential expansion, outer tubes 60 and inner tubes 61 are separately connected together, connector members 73 connecting outer tubes 60, while inner tubes 61 are connected together by connector members 74. In addition, flexibility of connector members 73 allows for relative expansion and contraction between outer tubes 60 which are electrically connected together while the flexibility of connector members 74 allows for differential expansion and contraction of inner tubes 61 which are electrically connected together by connector members 74.

In shell 10, adjacent end portion 13, three electrical input terminals 92 and a ground terminal 93 are disposed in circumferential spaced relationship to each other and secured in openings 94 in shell 10. (see Figures 3 and 6). Input terminals 92 and ground terminal 93 are identical in construction, each comprising a base member 95 having a central opening 96 and a recessed outer surface to provide a shoulder 97. A disc 98 of insulating material, as for example, alumina, having a central opening 99 is inserted in the recess against a gasket 98A which lies against shoulder 97 of base member 95. A terminal post 100 is provided with a plate 101 which is secured to the post between its opposite ends. Terminal post 100 is inserted axially through openings 99 in disc 98 and opening 96 in base member 95 until plate 101 impinges another gasket 98B which is disposed against the outer surface of disc 98. Another insulating disc 102, similar to disc 98 and having a centrally disposed opening, is passed over the outer end of terminal post 100 and is held against plate 101 by a hold-down plate 103. Plate 103 is provided with a central opening adapted to receive therethrough terminal post 100. A plurality of bolts 104 extend through circumferentially spaced holes in

hold-down plate 103 and are threaded into tapped holes in base members 95. When bolts 104 are turned into tapped holes in base member 95, hold-down plate 103 and base member 95 are drawn together thereby causing insulating discs 98 and 102 to be respectively clamped between plate 101 and base member 95 and between plate 101 and hold-down plate 103. Tightening bolts 104 also squeezes gaskets 98A and 98B between base member 95, disc 98 and plate 101 to thus provide a pressure-tight assembly. An insulating sleeve 105 is passed over the outer end of terminal post 100 and into the openings in hold-down plate 103 and disc 102 to electrically insulate terminal post 100 from hold-down plate 103 and thereby prevent electrical arcing between the post and hold-down plate 103. The opposite end portions of terminal posts 100 are threaded to receive electrical connectors.

As best shown in Figs. 3 and 6, input terminals 92 are each electrically connected to a terminal rod 57 by means of a flexible connector 106, as for example, a multilayer braided strap, having secured at one end a split clamp 107 and at the other end a split clamp 108. Connector 106 is connected to terminal post 100 by tightening split electrical clamp 107 to the inner threaded end portion of the terminal post. At the other end, connector 106 is secured to terminal rod 57 by fastening split clamp 108 to the end portion of the terminal rod. Similarly, terminal post 100 of ground terminal 93 is connected to ground tube 56. A flexible connector 109, as for example, a multilayer braided strap, having secured at one end a split clamp 110 and at the other end a split clamp 111, electrically connects terminal post 100 of ground terminal 93 and ground tube 56 by tightening split clamp 110 to the threaded end portion of terminal rod 100 and securing split clamp 111 to the end portion of ground tube 56. The outer end portions of terminal posts 100 of input terminals 92 are connected to receive electrical power while terminal post 100 of ground terminal 93 is connected to the ground. Terminal posts 100 are connected to terminal rods 57 rather than directly to heating elements 41 so that a permanent electrical power connection to the heating elements is effected and free expansion and contraction of the tube bundle is allowed.

As shown in Fig. 11, electrical power is supplied from a source of electricity 112, such as an electric generator 113, to the primary coil 114 of three transformers 116, 117 and 118 by way of line 115. The secondary coils 119 of transformers 116, 117 and 118 are respectively connected by way of lines 120, 121, 122 to a saturable reactor 123 which controls voltage and current flow to each of the input terminals 100. Electrical current flows from saturable reactor 123 via lines 124, 125 and 126, through a 3-pole single throw switch 127 when closed, to input terminals 92. Ground terminal 93 is connected by way of line 128 to a ground disconnect switch 129, the switch 129 being grounded at 130.

All electrical heating elements are thus connected in a three-phase electrical circuit having a common ground and may be supplied from a common source of power 112, as described. Electrical current in each of the phases P₁, P₂ and P₃ flows from terminal posts 100 of input terminals 92 through flexible connector 106 to the terminal rods 57 in each phase (Fig. 3). Thereafter, current flows from the terminal rods 57 to outer tubes 60 and inner tubes 61 of the first electrical heating elements 41 of each phase by way of connector assembly 64 (Fig. 7) to thereby heat the tubes 60 and 61. The current flows from outer tubes 60 and inner tubes 61 of the first electrical heating elements 41 to the outer tubes 60 and inner tubes 61 of the next adjacent heating elements 41 of phases P₁, P₂ and P₃ by way of connector members 73 and 74 (Figs. 4 and 5). After flowing through the adjacent heating elements 41, the current flows to outer tubes 60 and inner tubes 61 of the next successive heating elements 41 through connector assemblies 75 (Figs.

3, 8 and 9). Thereafter, electric current continues to flow in series through the remaining heating elements in each phase to and through the last heating elements 41 in each phase. Current then flows from outer tubes 60 and inner tubes 61 of each of the last heating elements 41 in each phase, through strips 30, connectors 86, plate 82, connector 88 and channel 37 to ground tube 56 (Figs. 4 and 5). At the other end of ground tube 56, current flows therefrom by way of connector 109, terminal post 100 of ground terminal 93 and line 128 to ground 130.

Operation

Electrical heating elements 41 in each of the phases are heated by flow of electrical current therethrough as aforescribed. Fluid to be heated, as for example, air at 80° F., is introduced under high pressure, as for example 4,000 p. s. i. g., into shell 10 through valve line 131 (Fig. 12), line 132, valve 133 and inlet nozzle 36 (Figs. 1 and 12). From inlet nozzle 36, the fluid flows through annular passageway S between the inner shell 21 and liner 19 and is thereby preheated by heat radiating from inner shell 21. Outer shell 10 is insulated from the high temperatures by the cool fluid flowing through passageway S and heat insulating layer 18. From passageway S, the fluid flows into chamber A and into and through inner tubes 61, annular passageways 62, formed between outer tubes 60 and inner tubes 61 of heating elements 41, and ground tube 56. Fluid in passing through electrically heated inner tubes 61 absorbs heat therefrom by conduction and radiation from the inner surface of tubes 61 while fluid flowing through passageways 62 absorbs heat by conduction and radiation from the outer surface of tubes 61 and from the inner surface of tubes 60. Fluid in passing through ground tube 56 is heated by conduction and radiation of heat from the inner surface of the ground tube. Heated fluid passes from heating elements 41 and ground tube 56 into the frusto-conical end member 23 of inner shell 21, thence through cylindrical portion 24 into mixing cylinder 25.

A controlled amount of relatively cool fluid, such as air, under pressure and at a relatively low temperature, as for example, 80° F., is admitted through a valve 134 in line 131, a line 135 connected to line 131, and inlet nozzle 37 (Fig. 12) and thence into space B which is formed between partition 29 and end portion 12 of shell 10. Since space B communicates, through openings 35 in mixing cylinder 25, with the interior of cylinder 25, cool fluid flows from space B through openings 35 into cylinder 25 and into admixture with heated fluid flowing from heating elements 41. The use of a mixing cylinder 25 and the position of openings 35 with respect to heated fluid flow and nozzle 37 is for the purpose of providing sufficient turbulence within cylinder 25 to insure intimate mixing of the cool fluid and heated fluid. Intimate mixing of the two fluids provides a fluid mixture at the heater outlet which is of substantially uniform temperature throughout its flow area. The mixture of fluid passes from cylinder 25 into extension member 32 and passes out at the opposite end thereof at a relatively high temperature, as for example, 1600° F. into an adapter member (not shown) which in turn is connected to conduit means for passing the heated fluid to a place of use.

The fluid heater of this invention is operated to deliver a predetermined quantity of heated fluid, which quantity is less than the total desired quantity, to mixing cylinder 25 at a temperature above a desired outlet temperature. An amount of relatively cool fluid, equal to the difference between the amount of heated fluid delivered to mixing cylinder 25 and the total desired quantity, is introduced through nozzle 37 into admixture with the heated fluid within cylinder 25 to thereby provide the total desired quantity of heated fluid at the desired outlet temperature. Furthermore, should it be desired to quickly provide fluid at a lower outlet temperature, a greater amount of cool fluid may be admitted into mixing cylinder 25 through

line 131, valve 134 and nozzle 37 with a commensurate reduction in the quantity of fluid flowing through lines 131 and 132, valve 133, nozzle 36 and heating elements 41 by reducing flow of fluid through valve 133. Similarly, if it is desired to rapidly provide fluid at a higher outlet temperature, a greater quantity of fluid may be circulated through heating elements 41 by increasing flow of fluid through valve 133 with a lesser quantity of cool fluid being admitted through nozzle 37 by reducing the opening in valve 134. Under normal operating conditions, as aforescribed, valve 136 is closed. In addition, secondary control of outlet temperature may be effected by control of current flow through heating elements 41 by adjustment of saturable reactor 123.

Modification

Another embodiment of the present invention is shown in Figs. 9 and 10, which embodiment is similar to the fluid heater described and shown in Figs. 1 to 9, inclusive, and 12, except that tube sheets 42, including tube sheet 42A, are each provided with a plurality of diamond-shaped openings 138 to form a lattice-like structure. Heating elements 41 are supported in various openings 138, as shown, so that they extend in lateral spread relationship. Fluid to be heated, as for example air, flows through inner tubes 61 and passageways 62 which are formed between inner tubes 61 and outer tubes 60 of each of the heating elements 41, as well as through openings 138 in tube sheets 42 and tube sheet 42A. Fluid to be heated which is flowing through openings 138, flows between tubes 60 and absorbs heat by radiation and conduction from the outer surface of tubes 60. Since tube sheets 42 and tube sheet 42A according to this embodiment, permit passage of fluid to be heated between the heating elements 41 as well as through them, the pressure drop through the inner shell is greatly reduced and the heat transfer is increased by utilizing the outer surface of tubes 60 for heating fluid. Thus, a greater quantity of fluid may be heated than in the other embodiment of this invention.

It can readily be seen, from the foregoing description, that a fluid heater has been provided for heating a greater quantity of fluid without an appreciable increase in its overall size. This increased capacity is accomplished by novel electrical heating elements which have one tube within another and by arranging the electrical heating elements in a three phase electrical circuit. In addition, all of the electrical heating elements of the fluid heater may be electrically tested by merely inserting a megohmmeter in ground line 128 to test the insulation value and for change in resistance of the heating elements. This test may be made after each run or periodically, and in this manner, imminent breakdown can be anticipated and corrective measures undertaken before actual failure. Furthermore, the electrical heating elements of each phase may be separately tested for change in insulation value and change in resistance which would indicate imminent breakdown of one or more of the heating elements in the phase being tested.

The fluid heater of this invention has relatively long operative life, since short circuiting of the heating elements through the tube sheets is obviated by providing tube sheets of dielectric material.

Although two embodiments of the invention have been illustrated and described in detail, it is to be expressly understood that the invention is not limited thereto. Various changes can be made in the arrangement of parts without departing from the spirit and scope of scope of the invention, as the same will now be understood by those skilled in the art. As for example, inner shell 21 may be dimensioned so that it lies against liner 19, thus eliminating passageway S, and fluid inlet 36 may be disposed in the shell in direct communication with chamber A to deliver fluid to be heated directly to

heating elements 41 without departing from the spirit and scope of the present invention.

What is claimed is:

1. A fluid heater of the class described, comprising a shell, a plurality of electrical heating elements disposed in said shell, means for supporting said elements in spaced parallel relationship to each other and electrically insulating said elements from each other and from the shell, each of said elements comprising a first tube and a second tube of smaller diameter than said first tube, said second tube arranged in coaxial relationship with said first tube and spaced from the latter to provide an annular passage between the inner surface of said first tube and the outer surface of said second tube, an electrical input means connected to a source of electrical current and to a first of said heating elements for delivering electrical current to the latter, said heating elements being connected together to provide series flow of electric current, an electrical ground means in said shell connected to a last of said heating elements to complete the electric circuit through the resistance elements, said electrical input means and said ground means being electrically insulated from said shell, a fluid inlet means for passing fluid to be heated into said shell, baffle means for directing flow of fluid to be heated into one end of said second tube and into the annular passage formed between the first and second tubes of each of said heating elements, and fluid outlet means communicating with the other end of said second tube and said passage between the first and second tube of each of the heating elements to receive heated fluid from the latter.

2. A heat exchange apparatus of the class described, comprising a housing, a plurality of electrical heating elements, means for supporting said elements in spaced parallel relationship to each other in said housing, means for electrically insulating said heating elements from each other and the housing, said heating elements being arranged in a plurality of groups, an electrical terminal member disposed in said housing and insulated therefrom for each group of heating elements, an electrical ground terminal disposed in and insulated from said housing, each of said heating elements include a first tubular member and a second tubular member of smaller diameter than said first tubular member arranged within the other in coaxial relationship, means for electrically connecting said first and second tubular members of a first heating element of each group to the input electrical terminal associated with the group, means for connecting said first and second tubular members of each of the heating elements of each group for series flow of electrical current therethrough, another means for electrically connecting said first and second tubular members of a last heating element of each group to said electrical ground terminal, fluid inlet means in said housing in communication with said heating elements to deliver fluid to be heated to the latter, and fluid outlet means in said housing communicating with the heating elements to receive heated fluid from the latter.

3. A fluid heater of the class described, comprising a shell, a plurality of electrical heating elements disposed in said shell, each of said heating elements comprising two tubes arranged coaxially one within the other and with the outer surface of the inner tube spaced from the inner surface of the outer tube, means for supporting said heating elements in spaced relationship to each other and for electrically insulating said elements from each other and said shell, said heating elements being grouped in a plurality of electrical circuits, each electrical circuit group having a common ground, means for connecting a first heating element of each circuit to a source of electrical current, second means for electrically connecting each heating element of each circuit in series, third means for connecting a last heating element of each circuit to said common ground, a fluid inlet in said shell in communication with said heating elements for delivering fluid to

be heated to the latter, and a fluid outlet in said shell in communication with said heating elements for receiving heated fluid from the latter.

4. The apparatus of claim 3 wherein the second means for electrically connecting each heating element of each circuit in series comprises a first electrical conductor connected at one end to the outer tube of a heating element and at the other end to the outer tube of next adjacent heating element, and a second electrical conductor connected at one end to the inner tube of a heating element and at the other end to the inner tube of a next adjacent heating element.

5. A fluid heater of the class described, comprising a shell, a tube bundle disposed within said shell, said tube bundle comprising a plurality of first electrical heating elements, a plurality of second electrical heating elements, a plurality of third electrical heating elements, a ground tube, disposed adjacent said heating elements, each of said first, second and third electrical heating elements comprising two tubes disposed coaxially one within the other and with the outer surface of the inner tube spaced from the inner surface of the outer tube, a first electrical input terminal in said shell and insulated therefrom, said first input terminal being connected to a source of electrical current and to a first heating element of said plurality of first heating elements to respectively receive and deliver electrical current to the latter, a second electrical input terminal disposed in said shell and insulated therefrom, said second input terminal being connected to a source of electrical current and to a first heating element of said plurality of second heating elements to respectively receive and deliver electrical current to the latter, a third electrical input terminal disposed in said shell and insulated therefrom, said third input terminal being connected to a source of electrical current and to a first heating element of said plurality of third heating elements to respectively receive and deliver electrical current to the latter, said plurality of first heating elements being connected together in series, said plurality of second heating elements being connected together in series, said plurality of third heating elements being connected together in series, means for electrically connecting a last heating element of each of said plurality of first, second and third heating elements to said ground tube, a ground terminal disposed in said shell and insulated therefrom, said ground terminal being connected to receive electric current from said ground tube, fluid inlet means in said shell arranged to direct fluid to be heated to said first, second and third heating elements, and a fluid outlet means in said shell arranged to receive heated fluid from said first, second and third heating elements.

6. The apparatus of claim 5, wherein means for providing a fluid mixing chamber adjacent said outlet means and in communication with the latter and the first, second and third heating elements to receive heated fluid therefrom, and fluid inlet means in said shell in communication with said fluid mixing chamber to deliver relatively cool fluid to the latter into admixture with the heated fluid to provide heated fluid at a predetermined temperature.

7. A fluid heater of the class described, comprising a shell having inlet means for receiving fluid to be heated and outlet means for discharging heated fluid, a plurality of tubular electrical resistance elements disposed in said shell, a plurality of spaced tube sheets arranged in said shell to support said heating elements in spaced relationship to each other and said shell, said tube sheets being composed of dielectric material to electrically insulate said heating elements from each other and said shell, the heating elements being connected together and to a source of electrical current to conduct electrical current, said heating elements being arranged to receive fluid to be heated from said inlet means and to discharge heated fluid to said outlet means.

8. The apparatus of claim 7 wherein the tube sheets are composed of alumina.

9. The apparatus of claim 7 wherein the tube sheets are composed of fused silica.

10. The apparatus of claim 7 wherein the tube sheets are provided with a plurality of apertures therein to allow flow of fluid to be heated between the heating elements.

11. A heat exchange apparatus of the class described, comprising a shell having inlet means for receiving fluid to be heated and outlet means for discharging heated fluid, a plurality of spaced electrical heating elements disposed in said shell, each of said heating elements comprising two tubular electrical resistance members arranged coaxially one within the other and with the outer surface of the inner tube spaced from the inner surface of the outer tube to provide an annular passage between the tubular members, said tubular members of each heating element being connected to receive and conduct electrical current to be thereby heated, a plurality of spaced tube sheets disposed in said shell adapted to receive and support said plurality of electrical heating elements, each of said tube sheets being composed of dielectric material to electrically insulate said tubes from each other and the shell, each of said tube sheets being provided with apertures disposed therein between said heating elements to provide for passage of fluid to be heated in heat exchange relationship with the outer surface of the outer tubular member of each heating element, baffle means in said shell for directing fluid to be heated from said inlet means to one end of said heating elements and to the outlet means.

12. A fluid heater of the class described, comprising a shell, a plurality of electrical heating elements disposed in said shell, means for supporting said heating elements within said shell and including means for electrically insulating said heating elements from each other and said shell, each of said heating elements comprising two tubular electrical resistance members arranged coaxially one within the other and with the outer surface of the inner tubular member spaced from the inner surface of the outer tubular member, said tubular members of each heating element being connected to receive and conduct electrical current to be heated thereby, fluid inlet means in said shell in communication with one end of said heating elements to deliver fluid to be heated to the latter, and fluid outlet means in said shell communicating with the other end of said heating elements to receive heated fluid from the latter and to pass heated fluid from the fluid heater, second fluid

inlet means in said shell communicating with a source of relatively cool fluid, a member disposed in said shell and forming a mixing chamber, said member having an inlet end portion and an outlet end portion, said inlet end portion being connected to receive heated fluid from said heating elements and at the outlet end portion connected to the outlet means in said shell, and means communicating with said second inlet means and said member to pass relatively cool fluid from said second inlet means into the mixing chamber and into admixture with the heated fluid to provide heated fluid at a predetermined temperature.

13. A fluid heater of the class described, comprising an outer shell, an inner shell disposed within the outer shell and spaced therefrom to provide a passage for fluid to be heated, a fluid inlet means in said outer shell in communication with said passage, a second fluid inlet means in said outer shell connected to a source of relatively cool fluid, to receive cool fluid from the latter, a plurality of electrical heating elements disposed within said inner shell and in communication with said passage to receive fluid to be heated from the latter, means for supporting said heating elements in spaced relationship to each other and for electrically insulating said elements from each other and said inner shell, each of said heating elements comprising two electrical resistance tubes disposed coaxially one within the other and with the outer surface of the inner tube spaced from the inner surface of the outer tube, the two tubes of each heating element being connected to receive and conduct electrical current to be thereby heated, a fluid outlet means in said shell, a cylindrical member open at both ends and connected at one end to the inner shell to receive heated fluid and at the opposite end to said outlet means, said cylindrical member having a plurality of spaced openings which communicate with said second inlet means for passing relatively cool fluid into admixture with heated fluid in said cylindrical member to provide heated fluid at a predetermined temperature.

References Cited in the file of this patent

UNITED STATES PATENTS

45	Re. 23,795	Cartinhour	Mar. 2, 1954
	1,034,952	Ball	Aug. 6, 1912
	1,727,585	Carleton	Sept. 10, 1929