

March 5, 1935.

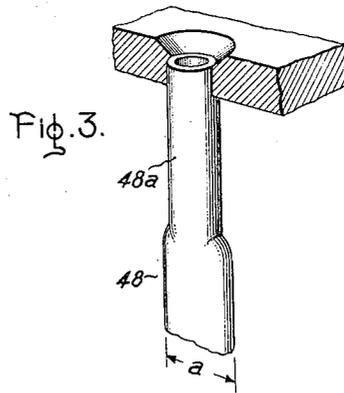
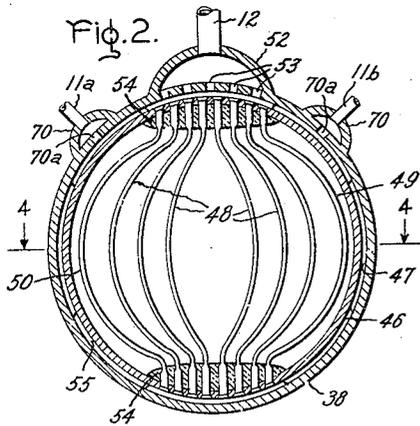
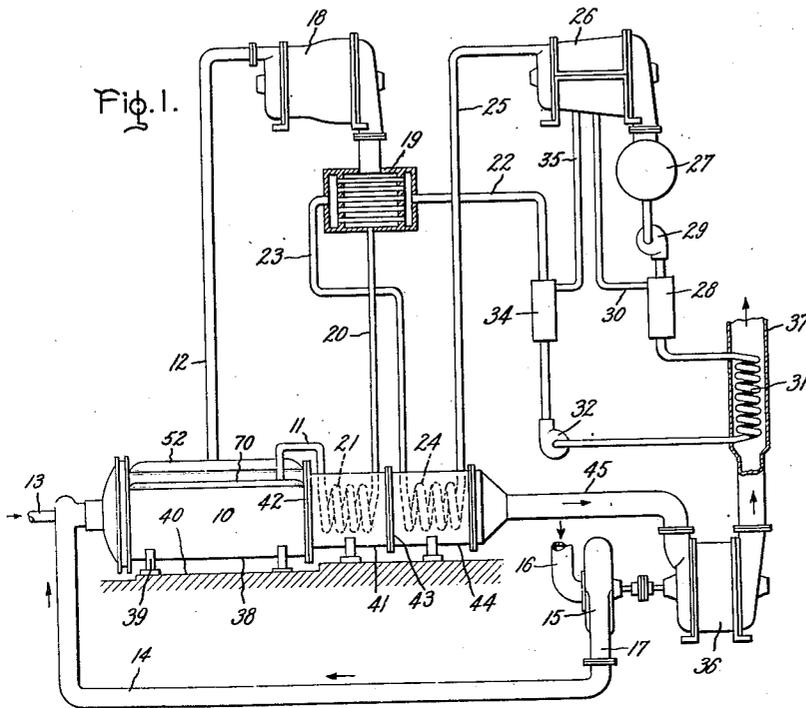
K. BAUMANN ET AL

1,993,585

MERCURY VAPOR GENERATING PLANT

Filed July 9, 1934

3 Sheets-Sheet 1



Inventors:
Karl Baumann,
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Their Attorney.

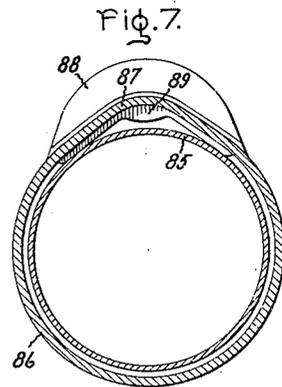
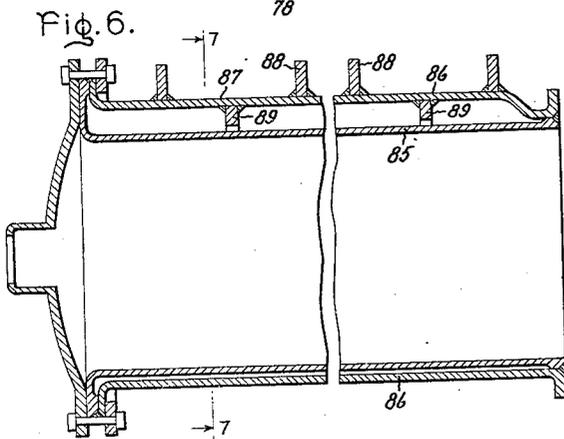
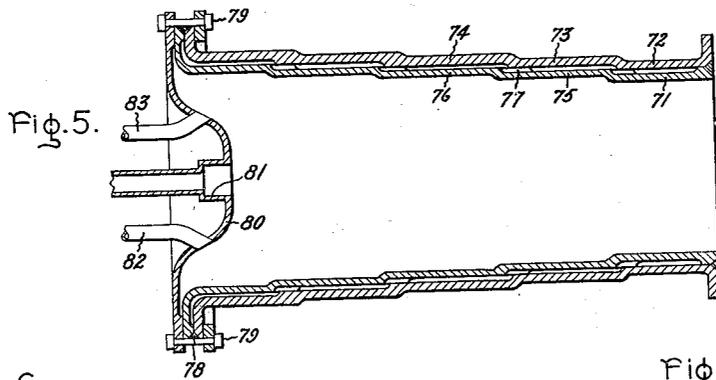
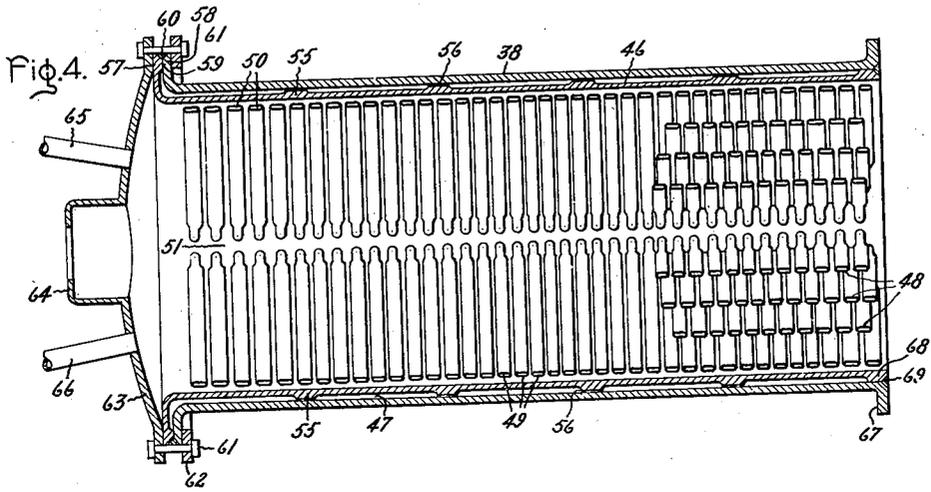
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3 Sheets-Sheet 3

Fig. 8.

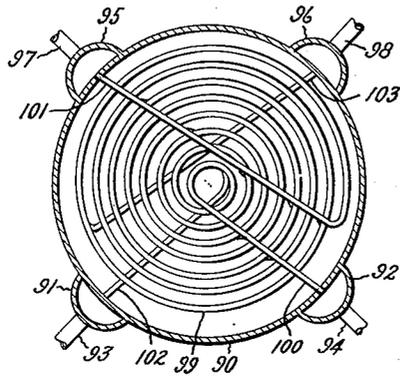
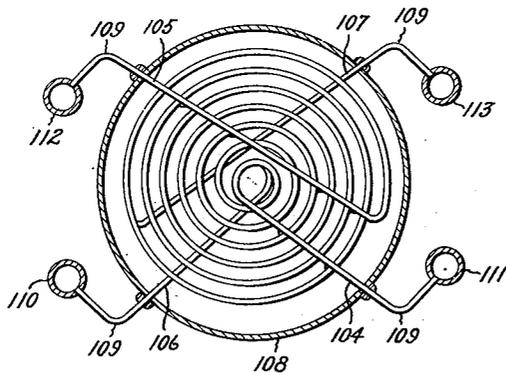


Fig. 9.



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UNITED STATES PATENT OFFICE

1,993,585

MERCURY VAPOR GENERATING PLANT

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Application July 9, 1934, Serial No. 734,386
In Great Britain July 6, 1933

12 Claims. (Cl. 122—145)

The present invention relates to mercury vapor generating plants, especially to the kind of plants which are operated on a binary fluid cycle to generate mercury vapor which after performing work in a turbine or other prime mover passes to a condenser where its latent heat of vaporization is transferred to water or another low boiling temperature medium circulated through the condenser as a cooling medium. The steam or other vapor thus produced may in turn be employed to perform work in a steam turbine or like apparatus.

One object of our invention is to provide an improved construction and arrangement of a binary fluid generating plant so that the quantity of mercury required for the plant is reduced to a minimum.

Another object of our invention is to provide an improved construction and arrangement of a mercury boiler. Still another object of the invention is to provide an improved arrangement of an economizer or heat exchanger or superheater.

For a consideration of what we believe to be novel and our invention, attention is directed to the following description and the claims appended thereto in connection with the accompanying drawings.

In the drawings, Fig. 1 is a diagrammatic view of a mercury power plant embodying our invention; Fig. 2 is a sectional view of a mercury boiler according to our invention; Fig. 3 is a detail view of Fig. 2; Fig. 4 is a sectional view along line 4—4 of Fig. 2; Fig. 5 shows a modification of a part of a mercury boiler according to our invention; Fig. 6 shows another modification of a boiler; Fig. 7 is a sectional view along lines 7—7 of Fig. 6; Fig. 8 is a sectional view of a preheater or economizer; and Fig. 9 is a modification of the preheater of Fig. 8.

The arrangement shown in Fig. 1 comprises a mercury boiler 10 connected to a conduit 11 for conducting liquid mercury to the boiler and to a conduit 12 for discharging generated mercury vapor. Combustible material is supplied to the boiler through a conduit 13 and air for maintaining the combustion is conducted to the combustion space of the boiler by a conduit 14.

In order to obtain a high heat transfer, we provide in accordance with our invention means for supplying air and fuel to the boiler at high pressure, more specifically at a pressure above atmospheric pressure. The air, as indicated in the present instance, is supplied to the boiler by a centrifugal compressor or blower 15 having

an inlet 16 communicating with the atmosphere and an outlet 17 connected to the conduit 14. The heating gases are forced along the heat transfer surfaces at high velocity, resulting in high heat transfer. This is particularly important in connection with mercury boilers in that it permits considerable reduction of the amount of mercury liquid per kilowatt output. The mercury vapor generated in the boiler 10 and discharged through the conduit 12 is conducted to a turbine 18, which latter exhausts into a condenser, more specifically a condenser boiler 19 which is of the surface type heat exchanger. The exhaust of the turbine is condensed in the condenser 19 and the condensate is conducted by a conduit 20 to a preheater or economizer 21, which latter is connected to the boiler inlet conduit 11.

The cooling medium for the condenser, in the present instance water, is supplied through an inlet conduit 22 to the condenser. The water as it passes through the condenser is evaporated and the steam thus produced is discharged and conducted by a conduit 23 to a superheater 24, whence the steam flows through a conduit 25 to a steam turbine 26. The latter exhausts into a condenser 27, the condensate being forced through a preheater 28 by means of a pump 29. The preheater 28 receives heating medium, in the present instance by an extraction conduit 30 connected to a lower stage of the turbine 26. The extraction steam supplied to the preheater 28 mixes with the condensate or water received from the condenser 27. The water thus heated in the preheater 28 flows through an economizer 31 heated by the exhaust gases of the boiler, whence the water is forced by means of a pump 32 through another preheater 34. The latter receives heating medium through an extraction conduit 35 connected to a higher stage of the turbine 27. The mixture of heated water and steam is discharged from the preheater 34 through the aforementioned conduit 22 into the condenser boiler.

The binary cycle just described forms two separate though dependent systems, a mercury system including the mercury boiler 10, the turbine 18, the condenser 19 and the economizer 21, and a steam system comprising the steam turbine, the condenser 27, the heaters 28, 31 and 34, the condenser boiler 19 and the superheater 24. The two systems, as will be clearly understood, are linked together, primarily by the condenser boiler 19 whereby the output of the steam sys-

tem depends upon the output of the mercury system.

As stated above, the heating gases are forced through the combustion space of the boiler 10 at high pressure and high velocity. In order to utilize the heat energy and the velocity energy contained in the exhaust gases of the boiler, we provide according to our invention the mercury preheater 21 and the steam superheater 24 in the path of these gases and conduct the gases through a gas turbine 36 whose exhaust is connected to a flue 37. The heat energy contained in the exhaust gases of the gas turbine 36 is utilized for heating the water passed through the economizer 31. Regarding the constructional arrangement, it is noted that the boiler 10 comprises an outer shell 38 which is horizontally disposed and connected at one end to the conduits 13 and 14 for supplying fuel and compressed air to the combustion space or chamber defined within said drum. The shell 38 is supported by brackets or cradles 39 on a foundation 40. The economizer or preheater 21 includes an outer shell 41 connected at one end to a flanged portion 42 of the shell 38 and at the other end to a flanged portion 43 of a shell 44, which latter forms a part of the superheater 24. Thus the combustion gases in the combustion chamber of the boiler 10 are passed in succession through the shell 41 of the mercury preheater 21 and the shell 44 of the steam superheater 24, whence the gases are conducted by a conduit 45 to the inlet of the gas turbine 36. The support of the preheater shell 41 and the superheater shell 44 on the foundation is similar to that of the outer shell 38 of the mercury boiler, the arrangement being such that the outer shells may freely expand horizontally in at least one direction.

Referring now more in detail to the construction of the mercury boiler 10, as shown in Figs. 2, 3 and 4, the boiler comprises the aforementioned outer shell 38 which surrounds an inner shell 46. The two shells 38 and 46 are horizontally disposed and concentrically spaced to define a mercury space 47 of comparatively small volume. The spacing between the two shells may be in the order of one-fourth of an inch. The space within the inner shell defines a combustion chamber 51. The mercury space 47 between the two shells serves primarily as a down-comer for the mercury during its circulation within the boiler. Lower and upper portions of the mercury space 47 are connected by a plurality of heating or circulation tubes 48 which are disposed within the inner shell. More specifically, two rows of outer tubes 49 and 50 are arranged to form a screen adjacent the inner surface of the inner shell 47 in order to reduce the radiant heat transfer from the combustion chamber towards said inner surface. A front portion of the space defined between the two rows of tubes 49 and 50 forms the combustion chamber 51 and a rear portion of said space is filled with circulation tubes 48 so as to provide sufficient passages for the combustion gases discharged from the combustion space. The tubes are constructed so as to present a large heating surface in relation to their cross-sectional area so that a maximum heating effect is obtained for a minimum quantity of mercury, but at the same time the cross-sectional areas of the tubes and also the space between the inner and outer shells of the boiler are maintained sufficiently

large to allow a substantially free natural circulation of the mercury.

Due to the use of pressure combustion, the heating surface of the boiler absorbs heat at a higher rate than it would with natural circulation and combustion at substantially atmospheric pressure. The tubes 48 are curved or bent longitudinally and arranged so as to extend substantially uniformly over the cross-sectional area of the inner shell. They are sprung into position within the inner shell and their ends are welded in openings of lower and upper portions of said inner shell. The welding is effected before the inner shell is inserted in the outer shell. As stated above, the tubes 49 and 50 are arranged within the heating space of the boiler close to the inner wall of the inner shell so that a complete wall of tubes passes along the entire length of the shell to screen the inner shell from the direct radiant heat of the furnace and the flue gases. The tubes constitute risers for the mercury. The mercury space defined between the inner shell and the external shell forms a down-comer for the mercury. Thus, from another viewpoint, our improved mercury boiler comprises two rows of tubes 49 and 50 defining a combustion chamber 51 and a conduction chamber which latter is uniformly filled with tubes 48. Upper and lower ends of the tubes are connected to upper and lower portions respectively of an inner shell, which latter is concentrically disposed within an outer shell to define a mercury space acting as a down-comer for mercury.

During operation, mercury liquid is heated and partly evaporated in the tubes 48, 49 and 50. The mixture of liquid and vapor flows up into the mercury space, whence the vapor is discharged and the mercury liquid recirculated. The vapor, as stated before, is discharged through a conduit 12 to a turbine 18. The conduit 12 is connected to a discharge dome 52 which extends substantially along the entire length of the upper portion of the outer shell and communicates with the mercury space through a plurality of openings 53 in an upper wall portion of the outer shell.

With the tube arrangement above described the part of the inner shell which is connected to the closely spaced upper and lower ends of the tubes will be effectively cooled owing to the relatively large amount of surface presented to the flue gases by the tubes in their substantially straight end portions. Thus, the heat-absorbing surface tends to be centered to the top and bottom of the heating chamber, the top and bottom of the internal shell where the tubes are fastened to the shell tending to remain relatively cool. If further cooling of the internal shell at these points is desired, refractory material 54 may be provided between the ends of the tubes.

In order to reduce the quantity of mercury required in the boiler tubes they are of relatively small cross-sectional area. This may be accomplished as shown in the present instance by flattening the tubes over the greater part of their length. Such flattening not only reduces the internal volume of the tubes but at the same time increases the flexibility of the tubes. Each tube is flattened so as to give maximum flexibility to its bend, that is, the major axis A (Fig. 3) of the cross section of the tube must be at right angles to the plane of the bent or curved tube so that the expansion stresses of the tubes when under operating conditions

may be taken up without difficulty. From another viewpoint, the tubes are bent in a direction to provide maximum areas for the passage of heating gases. The flattening also enables the tubes to be sprung more easily into position during assembly of the boiler. The walls of the flattened tubes must be sufficiently thick to secure the cross-sectional area being maintained under all operating conditions. Great thickness, however, is not necessary even at the high temperature at which the mercury boiler is operated owing to the comparatively low boiling pressure of mercury. Moreover, due to the utilization of pressure combustion in the boiler, the pressure tending to alter the cross section of the tubes, that is, the differential pressure between the pressure inside the tube and that outside the tube is comparatively low. This differential pressure is, for example, of the order of 80 pounds per square inch only when the pressure in the combustion space is 60 pounds per square inch and the pressure of the boiling mercury 140 pounds. During manufacture of the tube the entire tube is first flattened. Thereafter the end portions of the flattened tubes are rolled into circular shape as shown at 48^a in Fig. 3, and finally the intermediate portion of the tube is bent into arcuate form. By rolling the mercury circulating tubes round at the ends where they are welded to the internal shell, the entry and exit of the mercury into and out of the tubes is facilitated. This passage of the mercury can be further facilitated by the provision of an increased clearance between the inner and outer shells over the area where the inner shell is connected to the ends of the tubes.

Although the inner shell is subjected to more severe pressure than the external shell and is also subjected to the tube thrusts, it is less affected by the pressure of the working fluid owing to the high pressure maintained in the combustion space. The outer surface of the inner shell and the inner surface of the outer shell are preferably machined to provide for a substantially uniform thickness of the mercury space. The machining of the shells incurs somewhat greater expense in the manufacture of the boiler but this expense is compensated for by the economy in the quantity of mercury required.

At least one of the adjacent surfaces of the two shells is provided with spacers. In the present example (Figs. 2 and 4) the inner shell is provided with a plurality of spacers 55. Several sets of axially spaced apart spacers are provided and each set comprises a plurality of circumferentially spaced apart projections on the inner shell. During cold condition the outer surfaces of the spacers are slightly spaced from the inner surface of the outer shell, thus defining clearances 56 to avoid excessive thrust onto the outer shell during starting. The inner shell has a comparatively thin wall whereby during operation the inner shell expands relatively more than the outer shell and causing the projections or spacers 55 to engage the inner surface of said outer shell. Thus the spacers represent means for supporting the inner shell on the outer shell during operating condition. The end portions of the inner shell are rigidly united with the outer shell. In the present instance (Fig. 4) the left-hand ends of the two shells are provided with flanges 57 and 58. The flange 57 has an annular portion 59 bearing against the face of the flange 58 and being inte-

grally united therewith by an annular weld 60. The flanges 57 and 58 in addition are held together by means of bolts 61 and a ring 62 engaging the outer surface of the flange 58. The bolts 61 also serve to fasten an end plate 63 to the shells. The end plate 63 has a central dome 64 for accommodating a burner and is connected to tubes 65 and 66 for conducting secondary compressed air to the combustion space. The right-hand end of the outer shell has a flange 67 and the right-hand of the inner shell has an annular projection 68 engaging the inner surface of the outer shell and being united therewith by an annular weld 69. Mercury liquid is conducted to the mercury space by the conduit 11^a (Fig. 1). The latter has two branches 11^a and 11^b (Fig. 2). Each branch is connected to a liquid supply dome 70 provided on opposite sides of the vapor discharge dome 52 and below the level of the latter. The domes 70 extend along the entire length of the outer shell and communicate with the mercury space through openings 70^a in the outer shell.

The alternative form of the construction of the boiler shells, shown in Fig. 5, comprises two shells 71 and 72. Both the inner shell 71 and the outer shell 72 are forged in a stepped form to define successive lengths 73, 74 and 75, 76 respectively, increasing in diameter by an amount equal to twice the thickness of the space to be left between the shells. The stepped portions are arranged so that when the two shells are assembled, a short length 77 at the end of each stepped portion on the external side of the inner shell registers with a corresponding short portion on the internal side of the outer shell. Thus, the outer surface of the short length 77 which actually forms a part of the section 76 engages a corresponding short length of the section 73 of the outer shell. The short lengths or portions 77 are recessed at several points along their circumference to permit communication between the spaces defined by the different sections of the two shells. The left-hand ends of the shells are flanged and united by an annular weld 78 and bolts 79. The latter also serve to fasten an end plate 80 corresponding to the end plate 63 in Fig. 4 to the shells. The end plate 80, in the present instance, is dished inwardly whereas in the arrangement shown in Fig. 4 the end plate 63 is dished outwardly. The central portion of the plate 80 is provided with a dome 81 for accommodating a gas or other suitable burner. Conduits 82 and 83 are connected to openings in the end plate for conducting secondary air to the combustion space. The conduits 82, 83 are arranged so as to distribute the combustion air uniformly over the combustion chamber and thus tend to keep the whole of the combustion head cool.

The modification shown in Figs. 6 and 7 comprises an inner shell 85 and an outer shell 86. An upper portion of the outer shell is forged to form a dome 87 extending substantially along the entire length of the shell and over an area covering substantially the outlet ends of the heating tubes. The latter are not indicated. The dome portion 87 is strengthened by stiffeners or ribs 88 welded to the outer surface of the dome 86 and by internal ribs 89 welded to the inside of the dome 87. Instead of providing both internal and external ribs, only one kind of ribs may be provided. Internal ribs cause less stress of the shell because such internal ribs are heated to the same extent as the outer shell.

The internal ribs 89 cover only a portion of the area defined between the inner shell and the dome to permit free flow of mercury between the different sections defined by said ribs. The end portions of the two shells are united in similar manner as shown and described in connection with Fig. 4.

Fig. 8 shows diagrammatically in cross section the mercury preheater or economizer which is constructed so that the capacity of the heater for mercury is relatively small and the capacity for the heating fluid or medium relatively great. It comprises a cylindrical shell 90 corresponding to the shell 41 in Fig. 1 and a plurality of spirally wound tubes connected to inlet and outlet headers. In the present instance we have shown two inlet headers or domes 91 and 92 receiving mercury through conduits 93 and 94 respectively corresponding to the conduit 20 in Fig. 1. Heated mercury is discharged through outlet headers or domes 95 and 96 into outlet conduits 97 and 98 respectively corresponding to the conduit 11 in Fig. 1. A spirally wound tube 99 has an inlet portion 100 connected to the inlet header 92 and an outlet portion 101 connected to the outlet header 95. Another spirally wound tube has an inlet portion 102 connected to the inlet header 91 and an outlet portion 103 connected to the outlet header 96. During operation mercury is conducted through the inlet headers 91 and 92 whence it flows through the spirally wound tubes and is discharged through the outlet headers 95, 96 to the boiler as described in connection with Fig. 1.

The economizer or mercury heater shell is conveniently constructed from a steel plate rolled into cylindrical form of substantially the same inner diameter as that of the inner boiler shell. As described in connection with Fig. 1, the ends of the economizer shell are preferably provided with flanged portions secured in fluid-tight manner to corresponding flanges of the boiler and the steam superheater respectively.

As shown in Fig. 8, the end portion 101 of the spiral extends substantially diametrically across the plane of the spirally wound tube, whereas the inlet portion 100 extends from a central portion of the spirally wound tube radially outward. These end portions 100 and 101 are preferably welded to different portions of the tube to act as spacers for such portions. The heating of the mercury passing through the tubes is effected by the exhaust gases of the combustion chamber. Preferably the upper headers 95 and 96 are arranged in alignment with the inlet headers 70 (Fig. 2) of the mercury boiler and are welded thereto at their adjacent ends. This minimizes the number of joints and thereby reduces the possibility of leakage of mercury.

In another form of construction of the economizer or mercury preheater, as shown in Fig. 9, the preheater comprises a plurality of layers of spirally wound tubes, one layer having end portions 104 and 105 corresponding to portions 100 and 101 of Fig. 8, and another layer having end portions 106 and 107 corresponding to end portions 102 and 103 of Fig. 8. In this arrangement the ends of said end portions project through openings in an outer shell 108 corresponding to the shell 90 of Fig. 8 and are provided with bent or curved portions 109 welded to annular headers 110, 111, 112 and 113 corresponding to the headers or domes 91, 94, 95 and 96 respectively of Fig. 8. The headers 110

to 113 are spaced somewhat from the outer surface of the shell 108 to permit relative expansion between the shell and the headers. This relative expansion is also facilitated by the bent portions 109 of the ends of the spirally wound tubes. The economizer tubes may be circular in section, in which case they are preferably relatively small in diameter to keep the quantity of mercury at a minimum, or they may be flattened out in the same manner as is described above in connection with the mercury boiler tubes.

The steam superheater 24, 44 in Fig. 1 may be of substantially similar construction to the economizer just described in connection with Figs. 8 and 9. In the superheater, however, it is not necessary to flatten out the spiral tubes, as no consideration of economy in the quantity of the working medium is called for. As stated above, the mercury boiler 10, the mercury preheater or economizer and the steam superheater are arranged to form a single unit horizontally disposed on supports or cradles to permit axial expansion during operation.

What we claim as new and desire to secure by Letters Patent of the United States, is:

1. In a mercury boiler, the combination of two horizontally disposed concentrically arranged shells defining a mercury space between them and a combustion space within the inner shell, and means comprising a plurality of heating tubes disposed adjacent the inner surface of the inner shell in the combustion space for reducing the radiant heat transfer from the combustion space to the inner surface of the inner shell, each tube having a lower end communicating with a lower portion of said mercury space and an upper end communicating with an upper portion of said space, means for conducting combustible material into the combustion space for heating and evaporating mercury liquid in said tubes, means for discharging vapor from an upper portion of the mercury space, and means for conducting liquid to a lower portion of the mercury space.

2. In a mercury boiler, the combination of two horizontally disposed concentrically arranged shells defining a mercury space between them, two rows of tubes lining the inner surface of the inner shell and being connected between upper and lower portions of the mercury space, a combustion space defined by said tubes, means for supplying combustible material into the combustion space to heat and evaporate mercury liquid in said tubes, a vapor discharge conduit connected to an upper portion of the outer shell, and a mercury liquid supply conduit connected to the outer shell at a level below the connection of the outer shell with the vapor discharge conduit.

3. In a mercury boiler, the combination of a horizontally disposed inner shell, an outer shell surrounding the inner shell and defining a mercury space therewith, a vapor discharge dome secured to a top portion of the outer shell and communicating with the mercury space through a plurality of openings in the outer shell, a combustion space and a combustion gas conduction space defined within the inner shell, means for conducting fuel to the combustion space, means comprising a plurality of tubes disposed adjacent the inner surface of the inner wall and connected between upper and lower portions of the mercury space for reducing radiant heat transfer from the combustion space to the inner

surface of the inner shell, and heating tubes disposed within the inner shell in the conduction space and connected between lower and upper portions of the mercury space.

4. In a mercury boiler, horizontally disposed inner and outer shells defining a mercury space between them, the inner shell defining a combustion space, means for conducting fuel and air to said space to maintain a combustion pressure above that of the atmosphere, a plurality of heating tubes located in the combustion chamber and connected between lower and upper portions of the mercury space and arranged to intercept the transfer of radiant heat from the combustion space to the inner surface of the inner shell, each tube having a rounded end portion and a flattened curved intermediate portion, the flattened portions being disposed so as to provide for maximum passages for the combustion gases intermediate adjacent tubes.

5. In a mercury boiler, the combination of two horizontally disposed concentrically spaced shells defining a mercury space between them, each shell comprising a plurality of sections of successively decreased diameters, the reduction of the diameters of successive sections being equal to twice the thickness of the mercury space, one end of each section of the outer shell engaging a portion of the inner shell, and means integrally uniting the ends of the shells.

6. In a mercury boiler, two horizontally disposed concentrically spaced shells defining a mercury space between them, the inner shell defining a combustion space and a combustion gas conduction space, means comprising a plurality of heating tubes positioned adjacent the inner surface of the inner shell in the combustion space and connected between lower and upper portions of the mercury space for reducing radiant heat transfer from the combustion space to the inner surface of the inner shell, heating tubes disposed in the combustion gas conduction space, means for discharging mercury vapor comprising a dome secured to an upper portion of the outer shell and extending substantially along the entire length of said shell, and means for conducting mercury liquid to the mercury space comprising at least one dome secured to the outer shell below the level of the discharge dome and communicating with the mercury space through a plurality of openings in the outer shell.

7. In a mercury boiler the combination of a horizontally disposed inner shell, an outer shell surrounding the inner shell and defining a mercury space therewith, means communicating with said mercury space for discharging vapor therefrom, a combustion space and a combustion gas conduction space defined within the inner shell, means for conducting fuel to the combustion space, means comprising a plurality of curved tubes positioned adjacent the inner surface of the inner shell and connected between lower and upper portions of the mercury space for reducing radiant heat transfer from the combustion space to the inner surface of the inner shell, and heating tubes disposed within the inner shell in the combustion gas conduction space and connected between lower and upper portions of the mercury space.

8. A mercury boiler including the combination of a horizontally disposed inner shell, an outer shell surrounding the inner shell and defining a mercury space therewith, a combustion space defined within the inner shell, and means comprising a plurality of tubes connected to the inner shell and having curved portions positioned adjacent the inner surface of the inner shell for reducing radiant heat transfer from the combustion space to the inner surface of the inner shell.

9. A mercury boiler including the combination of a horizontally disposed inner shell, an outer shell surrounding the inner shell and defining a mercury space therewith, a combustion space defined within the inner shell, and means comprising a plurality of tubes having curved portions positioned adjacent the inner surface of the inner shell and being connected between the upper and lower portions of the mercury space for reducing radiant heat transfer from the combustion space to the inner surface of the inner shell.

10. A mercury boiler including the combination of a horizontally disposed inner shell, an outer shell surrounding the inner shell and defining a mercury space therewith, means for injecting fuel and air under pressure into the combustion space, and means comprising a plurality of tubes having flattened portions positioned adjacent the inner surface of the inner shell and being connected between upper and lower portions of the mercury space for reducing radiant heat transfer from the combustion space to the inner surface of the inner shell.

11. In a mercury boiler, the combination of a horizontally disposed inner shell, an outer shell surrounding the inner shell and defining a mercury space therewith, means for conducting fuel and air to said space to maintain a combustion pressure above that of atmosphere, a plurality of heating tubes positioned in the combustion space adjacent the inner surface of the inner shell and connected between upper and lower portions of the mercury space for reducing radiant heat transfer from the combustion space to the inner surface of the inner shell, and cooling means located adjacent the end connections of the heating tubes for maintaining the end connections at a temperature lower than that of the central portions of the tubes.

12. A mercury boiler comprising a horizontally disposed outer shell having a flange at one end extending at right angles to the horizontal axis of said boiler, an inner shell disposed within the outer shell having a flange resting against the flange of said outer shell and fabricated thereto at its outer edge, a combustion space defined by the inner shell, a dished end plate, means for securing said end plate to said flange and for strengthening the fabricated connection between the flanges, means connected to said end plate for conducting fuel and air under pressure to said combustion space, and a plurality of sets of axially displaced spacers integrally connected to said inner shell, each set extending around the outer surface of the inner shell.

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