July 5, 1932. A. J. NERAD 1,866,367

APPARATUS FOR HEAT REMOVAL BY MERCURY

Original Filed Oct. 14, 1927 2 Sheets-Sheet 1

Fig. 1.

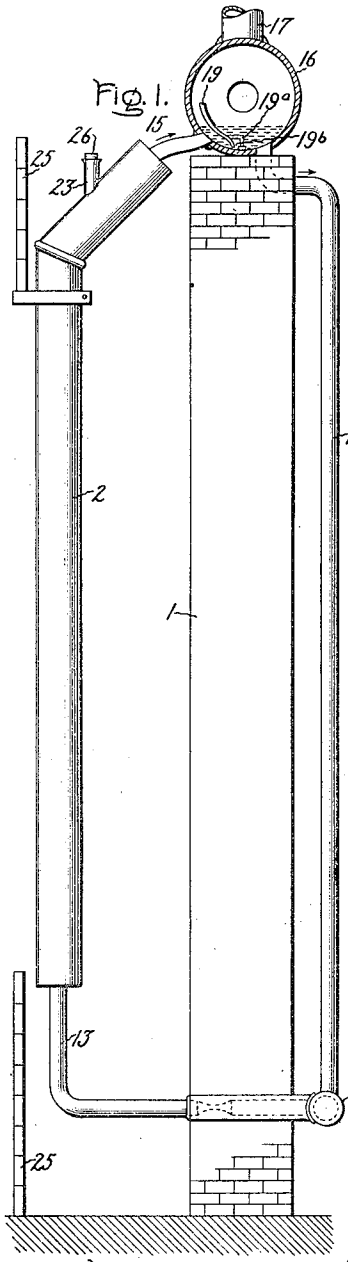


Fig. 2.

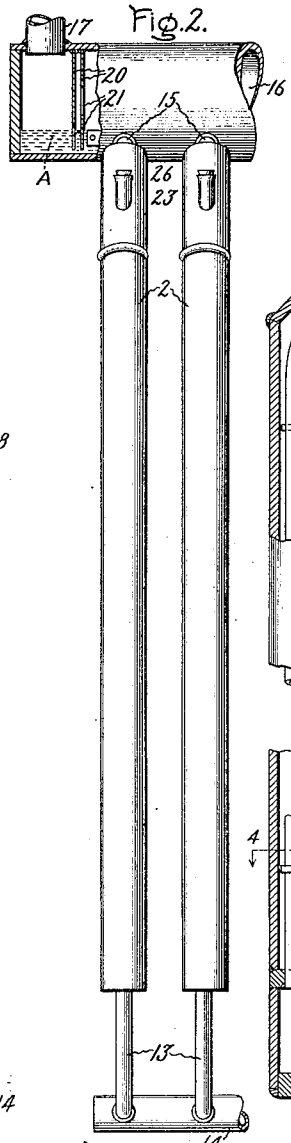


Fig. 3.

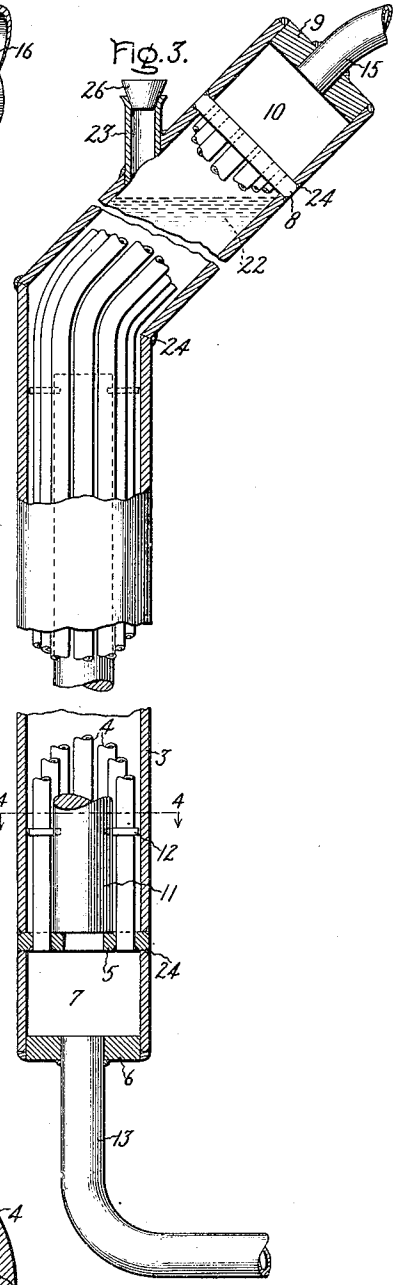


Fig. 4.

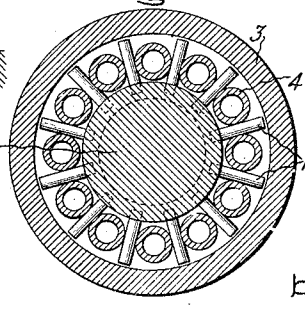
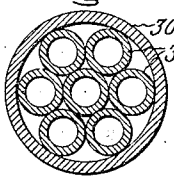


Fig. 5.



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Fig. 6.

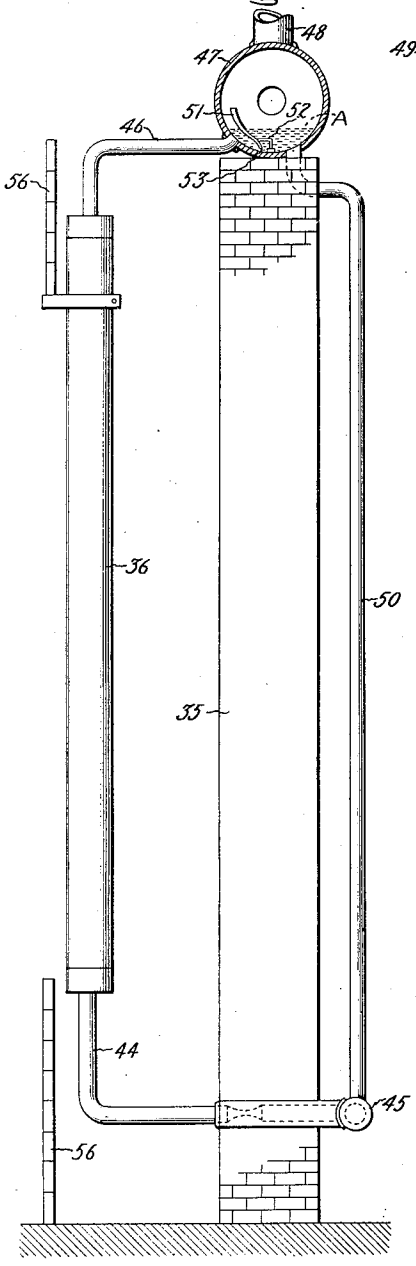


Fig. 7.

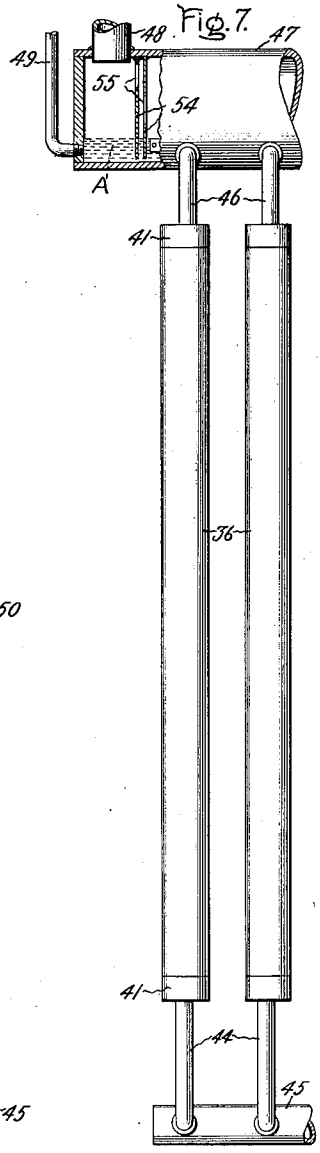


Fig. 8.

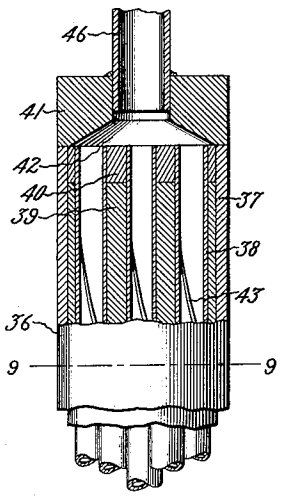


Fig. 9.

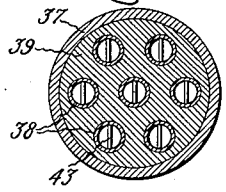


Fig. 10.



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Patented July 5, 1932 1,866,367

UNITED STATES PATENT OFFICE

ANTHONY J. NERAD, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK

APPARATUS FOR HEAT REMOVAL BY MERCURY

Continuation of applications Nos. 226,246, filed October 14, 1927, and 473,403, filed August 6, 1930. This application filed January 14, 1932. Serial No. 586,637.

This application is a continuation of my application Serial No. 226,246, filed October 14, 1927, and my application Serial No. 473,403, filed August 6, 1930, the latter case being a continuation in part of my application Serial No. 370,668, filed June 13, 1929.

In connection with apparatus, such as boilers, for vaporizing mercury, it is essential, for known reasons, to reduce to a minimum the amount of mercury required for operation. In this connection, the difficulty is met with that while mercury liquid is a fairly good agent for the removal of heat from a wall with which it is in contact, mercury vapor is a very poor heat-removing agent. As a result, therefore, the application of the high temperatures met with in furnaces, to boiler tubes containing mercury and exposed directly to the fire, offers difficulties in that if the circulation of the mercury is not maintained at a high rate so as to have present liquid mercury for carrying away the heat, the tubes may be burned and damaged.

The object of my invention is to provide an improved apparatus for heat-removal by mercury, and for a consideration of what I believe to be novel and my invention, attention is directed to the accompanying description and the claims appended thereto.

According to my invention, I provide a mercury vapor generating apparatus comprising a suitable number of boiler tube units, each boiler tube unit comprising a plurality of tubes arranged in spaced relation to each other through which the mercury circulates in parallel, the plurality of tubes being surrounded by and embedded in a substance which I term a secondary or heat-transferring substance. The embedded tubes, which may be termed "inner tubes", are of comparatively small diameter and considerable length so as to offer a relatively large surface for the mercury contained therein for the absorption of heat. The secondary or heat-transferring substance receives the heat at an intense rate, it being sufficient in quantity to absorb the heat readily from the fire without becoming overheated, and distributes it among the inner tubes, the area of the surfaces of the inner tubes being sufficient to absorb readily all the heat without being heated to too high a temperature.

The secondary or heat-transferring substance may be any suitable substance, either liquid or solid at the operating temperature, which meets the requirements.

A specific application of my invention is in connection with wall screens for furnaces and it is this application which I have chosen to illustrate and describe.

In the drawings, Fig. 1 is an end view of a furnace wall provided with a wall screen embodying my invention; Fig. 2 is a face view, partly in section, of the construction shown in Fig. 1; Fig. 3 is a side view, partly in section and partly broken away, of one of the boiler tube units, the same being shown on an enlarged scale; Fig. 4 is a sectional view taken on line 4—4, Fig. 3; Fig. 5 is a detail view of a modification; Figs. 6 and 7 are views similar to Figs. 1 and 2 of another construction embodying my invention; Fig. 8 is a side view, partly in section and partly broken away, of the upper end of one of the boiler tube units shown in Figs. 6 and 7; Fig. 9 is a sectional view taken on line 9—9, Fig. 8; and Fig. 10 is a detail view of the spiral strip located in the inner tubes.

Referring to Figs. 1 to 4 of the drawings, in which is illustrated an embodiment of my invention wherein the secondary or heat-transferring substance is liquid at the operating temperature, 1 indicates a furnace wall and 2 indicates generally a wall screen in front of it. The wall screen comprises a number of boiler tube units, each unit comprising an outer tube 3 in which are arranged a plurality of comparatively small diameter inner tubes 4. The lower ends of tubes 4 are fastened into a tube sheet 5 which is spaced from the lower end wall 6 of tube 3 and defines therewith a liquid space 7. The upper ends of tubes 4 are fastened into a tube sheet 8 which is spaced from the upper end wall 9 of tube 3 and defines therewith a vapor space 10. There may be several circular rows of tubes 4 or there may be only a single circular row as shown. At the center of tube 3 is a rod 11 which forms a filler and from which project at a suitable number of points

along its length a series of pins 12 which serve to space tubes 4.

Liquid spaces 7 at the lower ends of tubes 3 are connected by conduits 13 to a supply conduit 14. Vapor spaces 10 at the upper ends of tubes 3 are connected by conduits 15 to a vapor drum 16. Dotted line A indicates the liquid mercury level in drum 16, and as will be noted from Fig. 1, conduits 15 are connected with drum 16 below the level of the liquid therein. 17 indicates a conduit through which mercury vapor may be drawn off from drum 16. Circulation of liquid from drum 16 to supply conduit 14 is effected by a conduit 18 which connects the lower portion of drum 16 to conduit 14.

In drum 16 in front of the ends of conduits 15 is a curved baffle plate 19 supported by suitable brackets 19a. Baffle plate 19 stands in spaced relation to the wall of the drum and extends from a point adjacent to the bottom of the drum to a point above the liquid level A. There is thus provided beneath the lower edge of baffle plate 19 a passage 19b for the flow of mercury liquid. In drum 16 is a baffle 20 provided with openings 21 through which the vapor flows to conduit 17. The baffle serves to change the direction of flow of the vapor, thereby acting as a means for separating liquid particles from the vapor.

In connection with each tube unit, the space inside the tube 3 surrounding tubes 4 is filled with a suitable secondary heat-transferring fluid 22 which may be, for example, lead. At 23 is indicated a filling spout for the secondary fluid.

In the present instance, tubes 3 are shown as being formed in several sections welded together as is indicated at 24. The upper ends of the tube structures are bent at an angle. This allows differential expansion without excessive stress.

At 25 are indicated walls of refractory material which may be provided, if found desirable, for protecting the upper and lower portions of the boiler tube units from the direct heat of the fire. Walls 25 may be supported in any suitable manner such as from the tube structures themselves in the case of the upper wall and from the floor in the case of the lower wall as is indicated in the drawings.

It is desirable to provide some means for protecting the secondary fluid from oxidation, and for this purpose I may provide a suitable hermetic seal for the filling spouts 23, the air from the space above the secondary liquid being exhausted or not as found desirable. In the present instance, I have shown sealing means in the form of plugs 26 which fit in the ends of spouts 23.

In operation, the heat from the fire is absorbed by the secondary fluid and is conveyed by it to the mercury in tubes 4.

By reason of the arrangement of a number of small tubes within a larger tube, the tubes being in a vertical position or arranged with considerable slope, convection currents are formed in the secondary fluid whereby the heat is distributed rapidly throughout the secondary fluid. As a result, a low temperature gradient from the outer tubes to the inner tubes is obtained. It follows therefore that with this arrangement I am enabled to distribute the heat quite evenly to the inner tubes.

Also, by reason of this arrangement of the tubes, the tubes 4 being supplied with mercury at their lower ends by the vertical or sloping conduit 18, a natural circulation of the mercury is set up due to the fact that as the mercury in tubes 4 is heated, its density is decreased whereupon it is forced upward by the mercury of greater density in conduit 18. As a result, no external pumping means is required to effect circulation of the mercury through tubes 4. This serves to add reliability to the system.

The arrangement of a number of tubes in one outer tube, the inner tubes being connected in parallel as regards the flow of liquid, has the important advantage that it serves to increase the dependability of the boiler in operation since the impairment of circulation in one of the inner tubes of a unit would not result in complete failure of the unit from excessive overheat.

The tube unit arrangement has a further important advantage in that by reason of the arrangement, the resulting stresses on the tubes are low. That the stresses on the tubes be maintained at a low value is important since the tubes are used principally where the temperatures are high, which means that the strength of the materials is low. In the case of the inner tubes, the static pressure of the molten secondary fluid against the outer walls of the inner tubes reduces the effective pressure on them due to the mercury which they contain. On the other hand, the outer tube, which is subjected to the most intense heat, has only the static pressure of the secondary fluid to withstand, and being tubular and of relatively small cross section, the stress is quite low.

The construction of the tube units from an outer tube in which are arranged a number of smaller inner tubes, the tubes being substantially straight and with their axes substantially parallel, has important advantages from a mechanical standpoint in that it results in a construction which can be built at relatively low cost, being economical of both material and labor, and one wherein a tube can be readily repaired. Also in the case of a structure formed from a number of tube units, one of the units can be readily replaced.

Most materials suitable as secondary fluids

solidify when the units are allowed to cool. Solidification and melting result in contraction and expansion of the secondary fluid with great possibilities of excessive stresses being set up. With my improved construction, such stresses are minimized or eliminated because voids are formed throughout the tube unit when the fluid solidifies, such voids being formed because the cooling surfaces enclose but small cross sections of the solidifying fluid. Also, since, when starting up, circulation of the boiling fluid commences with the application of heat, the hot liquid rises so that the upper parts of the inner tubes reach melting temperatures of the secondary fluid before much of the lower regions of the tubes reach such temperatures. As a result, melting of the solidified secondary fluid proceeds approximately from the top downward, thus permitting free expansion of the secondary fluid as the melting proceeds. In this connection, the arrangement of quite straight tubes with substantially parallel axes is a helpful and important feature in that it insures even initial distribution of the heat to the solidified secondary fluid. Also, in this connection, the baffle plate 19 performs an important function in that as the hot liquid mercury begins to flow upon the application of heat in starting up, the baffle plate directs it downward to the admission ends of conduits 18 so there is obtained immediately circulation of the hot liquid. At this time the circulation of the liquid is at relatively low velocity. As the application of heat increases, the velocity of the flow in tubes 4 increases and as soon as the heating reaches a value such that vapor is formed, the velocity of flow from tubes 4 reaches a value such that the vapor is forced upward by baffle plate 19 to the space above the liquid in drum 16.

Under certain conditions of lesser heat absorption, it may be found advantageous for reasons of economy, to group the inner tubes in clase relation to each other and to the outer tube, and under these circumstances the convection of the secondary fluid would be reduced. However, the secondary fluid would serve still to provide a good heat transfer bond, although not as good as is obtained when the secondary fluid surrounds entirely the inner tubes. An arrangement of this character is shown in Fig. 5, wherein 30 indicates the outer tube and 31 the inner tubes, the inner tubes being arranged in contact with each other and with the outer tube. The spaces among the inner tubes are filled with the secondary fluid.

Referring now to Figs. 6 to 10, in which is illustrated an embodiment of my invention wherein the secondary or heat-transferring substance is a solid at the operating temperature, 35 indicates a furnace wall and 36 indicates generally a wall screen in front of it. The wall screen comprises a number of boiler tube units, each unit comprising an outer tube 37 in which are arranged a plurality of comparatively small diameter inner tubes 38. The inner tubes 38 are embedded in a heat-transferring substance 39 which is a solid at the intended operating temperature. As the heat-transferring substance, copper, which has a melting point of 1981° F. and a heat conductivity about nine times that of steel, may be utilized. Or I may utilize aluminum which has a melting point of 1216° F. and a heat conductivity about five times that of steel at room temperature but which increases with increase of temperature, reaching a value about equal to that of copper at high temperatures. At the present time I believe copper to be the best heat-transferring substance for use in my improved tube. At the ends of the tubes are tube sheets 40 provided with openings in which the ends of tubes 38 are fastened by suitable means such as welding, and which protect the substance 39 from direct contact with the mercury. Fastened over the ends of the tubes are caps 41 which may be welded to the outer tube 37 and which provide upper and lower spaces 42 with which the tubes 38 communicate at their upper and lower ends, as shown in Fig. 8.

Preferably I provide in each inner tube 38 a twisted strip 43 which serves to give a whirling motion to the mercury flowing upward through the tube, causing it to wash the surface of the tube.

The outer and inner tubes may be constructed from steel. For the outer tube I may use, with advantage, chrome nickel steel or low carbon steel, which has been calorized to protect it against oxidation at higher temperatures. The tubes may be constructed in any suitable way. In this connection, however, it is important to have a good bond between the tubes and the heat-transferring substance 39 so as to reduce to a minimum the resistance to the flow of heat between the tubes 37 and 38 and the substance 39. This is accomplished by uniting the tubes and the heat-conducting substance by fused metal whereby there is produced, in substance, a unitary metallic structure. By united by fused metal I mean united through the intermediary of metal which has been fused in the process of joining the metals and afterward permitted to harden whereby there is formed an intimate bond between the metals to be united. To this end, in the case of copper, the tubes may be arranged in correct spaced relation to each other and the copper in molten condition caused to flow around the tubes, after which it is permitted to harden. This results in a construction wherein the copper and the tubes are united by fused metal. In practice, I have found in a construction of this type that it is not possible

to again separate the tubes from the copper, the metals being fused together and united by an autogenous bond.

The spaces 42 at the lower ends of tubes 37 are connected by conduits 44 to a supply conduit 45. The spaces 42 at the upper ends of tubes 37 are connected by conduits 46 to a vapor drum 47. Dotted line A indicates the liquid mercury level in drum 47, and as will be noted from Fig. 6, conduits 46 are connected with drum 47 below the level of the liquid therein, although they need not be so arranged necessarily. 48 indicates a conduit through which mercury vapor may be drawn off from drum 47, and 49 indicates a supply conduit for liquid mercury. Circulation of liquid from drum 47 to supply conduit 45 is effected by a conduit 50 which connects the lower portion of drum 47 to conduit 45.

In drum 47 in front of the ends of conduits 46 is a curved baffle plate 51 supported by suitable brackets 52. Baffle plate 51 stands in spaced relation to the wall of the drum and extends from a point adjacent to the bottom of the drum to a point above the liquid level A. There is thus provided beneath the lower edge of baffle plate 51 a passage 53 for the flow of mercury liquid. In drum 47 is a baffle 54 provided with openings 55 through which the vapor flows to conduit 48.

At 56 are indicated walls of refractory material which may be provided, if found desirable, for protecting the upper and lower portions of the boiler tube units from the direct heat to the fire. Walls 56 may be supported in any suitable manner such as from the tube structures themselves in the case of the upper wall and from the floor in the case of the lower wall, as is indicated in the drawings.

In operation, the mercury flows from drum 47 down conduit 50 to supply conduit 45, from which it is fed to the boiler tubes in parallel, flowing upward through all the inner tubes 38 of each boiler tube. The heat from the fire is absorbed by the solid substance 39 and is conveyed by it to the mercury in the tubes, distributing the heat substantially equally among the tubes. The tubes 38 being supplied with mercury at their lower ends by the vertical or sloping conduit 44, a natural circulation of the mercury is set up due to the fact that as the mercury in tubes 38 is heated, its density is decreased, whereupon it is forced upward by the mercury of greater density in conduit 50. As a result, no external pumping means is required to effect circulation of the mercury through tubes 38. This eliminates the unreliability of external pumping.

The use of a substance which is always solid for heat transfer to the inner tubes is of advantage in that should a crack or hole occur in the outer tube the solid substance will not run out as would be the case were a liquid heat-transferring substance used. Also since the outer tube will be subjected to relatively low stresses, being in substance only a covering and protection from chemical attack for the heat-transferring solid, it may be made comparatively thin, or, if the substance in which the tubes are embedded is, in itself, sufficiently resistant to the heat of the furnace so it is not affected adversely thereby, then an outer tube or covering may be dispensed with. Also instead of providing an outer tube I may treat the outer surface of the heat-transferring solid in a manner to render it capable of operation at the temperatures to be met with without being affected adversely by the heat of the furnace.

Use of a substance always solid for heat transfer avoids passing through a change of phase (solidification or melting) and its attendant expansion problems which are met with where a liquid is used as the heat-transfer medium because most liquids suitable for such purpose solidify when the unit is allowed to cool. By using a substance which remains solid for heat transfer it is not necessary to provide enough mercury or boiling fluid so that in starting the boiler, circulation commences with the application of heat, for some initial heating without circulation will not be detrimental. The increase in volume of mercury due to boiling may thus be used advantageously with a solid heat-transfer medium.

A unit with a solid material as the heat-transfer medium is well adapted to the use of an amalgam as disclosed in my patent No. 1,759,133, dated May 20, 1930, in place of mercury in the boiler because partial solidification is likely to occur in the amalgam. This would mean that circulation would commence in the unit only after some considerable heat has been applied to the boiler.

The units may be operated in a horizontal position with vapor conduits vertical, an arrangement such as is found in some of the header and tube arrangements of steam boilers. Circulation in this case may commence with boiling and it may be arranged to have the liquid flow in one definite direction.

As stated above the tube unit arrangement has an important advantage in that by reason of the use of small tubes the resulting stresses are low. That the stresses on the tubes be maintained at a low value is important since the tubes are used principally where the temperatures are high, which means that the strength of the materials is low. In this connection I believe that the use of copper as the heat-transferring substance possesses especial utility in that it is capable of yielding or giving slightly, thereby relieving stresses set up in the inner tubes.

In accordance with the provision of the Patent Statutes, I have described the prin-

ciple of operation of my invention, together with apparatus which I now consider to represent the best embodiments thereof, but I desire to have it understood that the apparatus shown is only illustrative and that the invention may be carried out by other means.

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

1. A heating apparatus comprising a drum and a plurality of tube units, each tube unit comprising an outer tube, a plurality of inner tubes, and a secondary heat-conducting fluid in the outer tube for conveying heat from the outer tube to the inner tubes, conduits connecting the inner tubes of each tube unit to said drum, and conduit means for conveying fluid to said inner tubes.

2. A heating apparatus comprising a drum and a plurality of tube units, each tube unit comprising an outer tube, a plurality of inner tubes, a secondary heat-conducting fluid in the outer tube for conveying heat from the outer tube to the inner tubes, conduits connecting the upper ends of the inner tubes, of each tube unit to said drum, and conduits for conveying fluid from said drum to said inner tubes.

3. A heating apparatus comprising a drum and a plurality of tube units, each tube unit comprising an outer tube, a plurality of inner tubes, a secondary heat-conducting substance in the outer tube for conveying heat from the outer tube to the inner tubes, conduits connecting the upper ends of the inner tubes of each tube unit to said drum, conduit means for conveying fluid from said drum to said inner tubes, and means in said drum for directing fluid from said conduits to said conduit means.

4. A heating apparatus comprising a drum and a plurality of tube units, each tube unit comprising an outer tube, a plurality of inner tubes, a secondary heat-conducting substance in the outer tube for conveying heat from the outer tube to the inner tubes, conduits connecting the upper ends of the inner tubes of each tube unit to said drum, conduit means for conveying fluid from said drums to said inner tubes, and a baffle plate in said drum for directing fluid from said conduits to said conduit means.

5. A heating apparatus comprising a drum and a plurality of tube units, each tube unit comprising an outer tube, a plurality of inner tubes, and a heat-conducting substance in the outer tube for absorbing heat from the outer tube and conveying it to the inner tubes, conduit means connecting the inner tubes of each tube unit to said drum, and conduit means for conveying fluid to said inner tubes.

6. Apparatus for generating mercury vapor comprising a drum and a plurality of tube units connected to said drum in parallel, each tube unit comprising an outer tube, a plurality of inner tubes arranged therein, and a heat-conducting substance in the outer tube for absorbing heat from the outer tube and conveying it to the inner tubes, and a means for supplying mercury to the inner tubes.

7. Apparatus for generating mercury vapor comprising a drum and a plurality of tube units connected to said drum in parallel, each tube unit comprising a comparatively long outer tube, a plurality of inner tubes of comparatively small diameter arranged in the outer tube and extending throughout substantially the length of the outer tube, and a heat-conducting substance in the outer tube for absorbing heat from the outer tube and conveying it to the inner tubes, and means for supplying mercury to the inner tubes.

8. Apparatus for generating mercury vapor comprising a drum and a plurality of tube units connected to said drum in parallel, each tube unit comprising an outer tube, a plurality of inner tubes arranged therein, and a heat-conducting substance in the outer tube which is a solid at the intended operating temperature for absorbing heat from the outer tube and conveying it to the inner tubes, and means for supplying mercury to the inner tubes.

9. Apparatus for generating mercury vapor comprising a drum and a plurality of tube units connected to said drum in parallel, each tube unit comprising a plurality of tubes arranged in spaced relation to each other, and a heat-conducting substance which is a solid at the intended operating temperature in which said tubes are embedded for absorbing heat and conveying it to said tubes, and means for supplying mercury to said tubes.

In witness whereof, I have hereunto set my hand.

ANTHONY J. NERAD.