

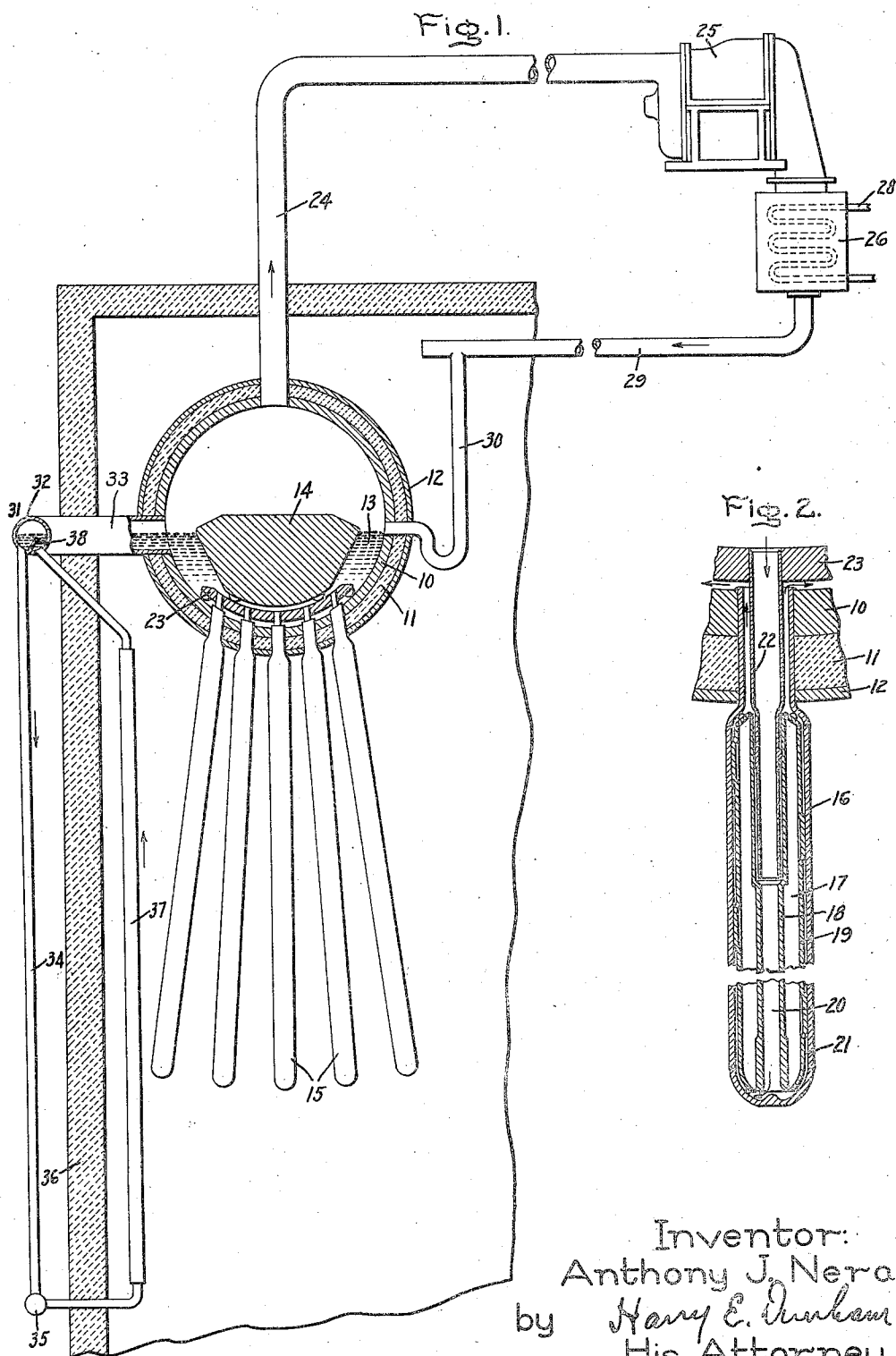
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MERCURY VAPOR GENERATOR AND THE LIKE

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MERCURY VAPOR GENERATOR AND THE
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The present invention relates to mercury vapor generators and the like in which mercury liquid is evaporated. More specifically, the invention relates to a method of operating and an arrangement for mercury boilers and like apparatus in which mercury liquid is in contact or associated with ferrous metal such as iron, steel or the like, at high temperature.

A mercury boiler as heretofore used comprises one or a plurality of drums with a plurality of tubes connected to the bottom portion of each drum. Each tube comprises two concentrically spaced tubular members, the inner member of which serves to conduct mercury liquid into the tube. The liquid flows down the inner tubular member to the space or passage defined between the inner and the outer tubular members and thence upward through such space. In flowing upward through such space, the mercury is heated, partly evaporated and returned to the drum. A mercury boiler of this type is more fully disclosed in the copending application of Emmet and Coulson, Serial No. 306,486, filed September 17, 1928.

In the actual operation of such mercury boilers, it was found that the upper portions of the narrow passages defined between the inner and the outer members of such tubes became gradually clogged during operation. The clogging took place relatively slowly in mercury boilers operated at relatively low temperatures; however, it was found to be a serious matter. With the advent of high operating temperatures, for example, operating temperatures of the order of 1000 degrees F., the clogging of the upper ends of the passages became an obstacle of such a serious character as to threaten the possibility of building mercury boilers for operation at such temperatures.

It was found from inspection of boiler tubes that the substance clogging the tubes comprised iron or like ferrous metal of which the boiler walls were made, the substance appearing to be in the nature of a crystalline deposit. The reasons for such deposits were not apparent.

After extensive investigations, I discovered that mercury liquid at high temperatures is capable of dissolving a minute amount of ferrous metal, the amount depending upon the temperature, and that the clogging was due to the fact that at the points of higher temperature in the boiler, the mercury dissolved ferrous metal and deposited it at points of lower temperature in the boiler. This I found to be due because of the following conditions.

During operation not all parts of a mercury boiler are at the same temperature. The various tubes in the furnace, for instance, have a somewhat higher temperature than the drum and the fluid therein, partly owing to the fact that the tubes are closer to the source of heat. These differences occur also with respect to each individual part. For instance, the lower portions of the tubes have a somewhat higher temperature than the upper portions because these lower portions are closer to the source of heat and, furthermore, owing to the fact that the liquid contained in the lower portions of the tubes has a higher boiling point than the liquid contained in the upper portions thereof. The boiling point of a liquid particle contained in a boiler depends not only upon the vapor pressure in the boiler but also upon the static pressure produced by the column of liquid resting on the particle. For example, a liquid particle at a depth of ten feet below the liquid level in a boiler drum has a higher boiling point than a liquid particle at a depth of six feet below the liquid level because it is subjected to an additional pressure produced by a column of liquid of four feet. This means that the liquid contained in the lower portions of the tubes has normally a somewhat higher boiling point than the liquid contained in the upper portions thereof.

Mercury can hold in solution at one time only a very minute amount of ferrous metal. For instance, only twenty parts of ferrous metal by weight can be held in solution in one hundred million parts of mercury at a temperature of 932° F. which is near the operating temperature of present day mercury boilers. The amount of ferrous metal held in solution in mercury liquid decreases with decreasing temperature. If, for example, in the above mentioned case the temperature of the mercury were reduced 35° F. then 15% of the ferrous metal or three parts of ferrous metal in one hundred million parts of liquid would have to drop out of solution to bring the mercury to normal saturation. From another viewpoint, if we have a completely saturated solution of ferrous metal and mercury at a temperature of 932° F., 15% of the dissolved ferrous metal will crystallize or drop out if said temperature is lowered by 35° F. The fact that mercury dissolves different amounts of ferrous metal at different temperatures means that mercury which is completely saturated with ferrous metal will have to drop out a part of its ferrous metal content if the temperature is decreased, that is, if said liquid of higher temperature is

conducted from a region of higher temperature to a region of lower temperature. I have discovered that this process takes place in a mercury boiler. As explained above, the different portions of the boiler have different temperatures. The mercury contained in portions of the boiler having higher temperatures dissolves ferrous metal until it is completely saturated and, as pointed out above, deposits a part of the ferrous metal content as it is conducted to portions of the boiler having lower temperatures. Such changes in temperature take place when the mercury is conducted from a lower portion of a tube to an upper portion.

In the operation of a mercury boiler a large amount of mercury is circulated especially through the tubes in order to absorb the heat from the tubes. A relatively small portion only of such liquid is vaporized during a single circulation. Thus a particle of liquid may be circulated thirty to forty times from the drum through the inner tubular member and back through the space defined between the inner and the outer tubular members into the drum before it is evaporated. During these circulations a cyclic change in temperature of a particle takes place. Each time a particle moves from the lower portion of a tube towards the upper portion thereof, a decrease in pressure followed by a slight decrease in temperature takes place. These different circulations or cycles cause a steady dissolving and depositing of ferrous metal of which the boiler is made. The mercury liquid dissolves or picks up a certain amount of ferrous metal from the lower wall portions of the tubes and deposits a part thereof on the walls defining the upper part of the space between the inner and outer tubular members. This is true also of other heating elements, for instance, wall screen elements through which mercury liquid is being circulated, as hereinafter referred to.

To fully appreciate the serious effect of this cyclic dissolving and depositing of iron owing to the temperature changes of the liquid, attention is directed to the fact that in a modern mercury boiler all the mercury therein makes an average of more than two million cycles per year; that is, all the mercury liquid is circulated more than two million times through the heating tubes and units of the boiler under normal operating conditions within one year. It has been estimated that under such conditions about two thousand pounds of ferrous metal would be dissolved and deposited in a mercury vapor generator producing vapor for operating a 20,000 kw. mercury-steam power plant.

As stated above, the detrimental effect, particularly the clogging of the narrow vapor passages of the boiler tubes due to this cyclic dissolving and depositing of ferrous metal, increases rapidly as the operating temperature of the boiler is increased and the effects therefrom tend to impose a serious limitation upon the operation of mercury boilers at higher temperatures.

The attack of ferrous metal by mercury in a mercury boiler has two serious consequences. The one, as above stated, is that the ferrous metal crystallizes out of solution from the mercury in the upper portions of the tubes, thereby clogging small passages. This considerably affects the circulation of mercury through the tubes and accordingly the efficiency of the boiler, and may cause the burning out of tubes. The second serious consequence is that ferrous metal is removed from certain parts of the boiler at a

rate great enough to limit the life of these parts to a considerable extent. This injurious effect is great with respect to the porcupine tubes connected to the bottom portion of a drum. The injurious effect is even greater in boilers comprising a wall screen in which mercury is heated and evaporated because a wall screen has vertically arranged tubes which are usually much longer than the tubes connected to the bottom portion of the drums, so that the lower ends of the wall screen tubes are subjected to higher temperatures than the ends of the porcupine tubes.

As a result of extensive studies and tests, I have discovered that the dissolving action of mercury on ferrous metal such as iron, steel, or the like, at high temperatures can be considerably reduced or eliminated by adding to or dissolving in the mercury a substance which functions to render the mercury not capable of dissolving ferrous metal; in other words, by adding to the mercury an inhibitor which serves to prevent or at least substantially prevent, mercury from dissolving ferrous metal. One such inhibitor is aluminum. Other inhibitors are nickel, chromium, magnesium and calcium. Preferably I utilize aluminum, which I have found to be entirely satisfactory. Only a small amount of such inhibitors is necessary to produce the desired result. For example, in the case of aluminum, I have found one-hundredth of one per cent by weight of aluminum added to the mercury is sufficient to minimize considerably or entirely prevent the dissolving action of mercury on ferrous metal at normal operating temperature of about 930° F. A somewhat greater amount of aluminum may be used if found desirable. For example, I have found up to twenty-five hundredths of one per cent by weight of aluminum effective. An amount of aluminum greater than this is ordinarily not desirable as it tends to form a thick crust of aluminum or aluminum and iron on the steel surfaces of the tubes which may be injurious to the operation of the boiler.

In the case of chromium, a somewhat greater amount is required than in the case of aluminum, for example an amount by weight of the order of one-tenth of one per cent to one per cent. In the case of magnesium and calcium an amount by weight of the order of one-quarter of one per cent has been found to be effective. In the case of nickel, an amount by weight of the order of one per cent has been found to be effective.

The above mentioned substances, particularly aluminum, when added to mercury, have another advantage in that they aid in establishing wetting of the ferrous metal walls by the mercury liquid. The wetting of the ferrous metal walls by the mercury liquid is important as it improves the heat transfer and accordingly the efficiency of the boiler. Thus, by my present invention I not only minimize or eliminate the dissolving action of mercury on ferrous metal but at the same time I improve the wetting action of the ferrous metal by the mercury.

In the accompanying drawing I have shown in Fig. 1 a mercury boiler arranged and operated in accordance with my invention, and in Fig. 2 a part of said boiler to an enlarged scale.

The arrangement comprises a drum 10 of ferrous metal covered by lagging or like heat insulating material 11 held in place by a cover 12. The drum is partly filled with mercury liquid 13 to which has been added an inhibitor as hereinbefore described. A filler block is provided in the

liquid space of the drum for displacing a portion of the liquid to minimize the amount of liquid necessary for operating the boiler. Fastened to the lower portion of the drum 10 are a plurality of heating tubes 15 made from ferrous metal. Each heating tube (Fig. 2) comprises an outer tubular member 16 fastened to the wall 10 of the drum, and a core or inner tubular member 17 having an inner wall 18 and an outer wall 19 welded together to define a hermetically closed space. The inner wall 18 defines a passage 20 communicating at its lower end with a passage 21 defined between the outer wall 19 and the outer tube 16. A sleeve 22 is fastened at its upper end to a baffle plate 23 provided in the drum 10 and extends into the passage 20 defined by the inner wall of the core. During operation, mercury liquid is conducted from the space above a baffle plate 23 in the drum 10 through the sleeve 22 into the passage 20, whence it is further conducted to the passage 21 defined between the outer tube 16 and the outer wall 19. Heat is conducted to the tubes and the drums by radiation and conduction. The liquid contained in the outer passage 21 is partly evaporated and conducted to the drum. The provision of a double-walled core in the tube minimizes the direct heat transfer from the outer passage 21, which may be termed the vapor passage, into the inner passage 20 which may be termed the liquid passage. This results in a differential pressure between the fluids conducted through the two passages, to the effect that a steady flow or circulation of fluid through said passages takes place. This arrangement is more fully described in application, Serial No. 306,467 previously referred to. The vapor produced in the boiler is conducted through a conduit 24 to a turbine 25, whence the exhaust is received by a condenser 26 having cooling means 28. The condensate is returned to the drum by means of a conduit 29 connected to the condenser 26 and a pipe 30 between the conduit 29 and the drum 10. A preferred arrangement of these conduits is more fully disclosed in the co-pending application of Coulson, Serial No. 649,350, filed December 29, 1932.

Besides the drums 10 and the heating tubes connected thereto, other heating units may be provided. In the present instance I have shown a heating unit 31 having a header 32 communicating with the liquid in the drum through a conduit 33. The heating unit 31 comprises a down-tube 34 connecting the header 32 to a lower header 35, located external a wall 36 of the furnace. The lower header 35 is connected to the lower ends of up-tubes 37 located inside the wall 36 of the furnace and having their upper ends projecting through the furnace wall and connected to the upper header 32. Tubes 37 form a wall screen for the furnace wall 36.

During operation, mercury liquid contained in the tubes 37 is heated to form vapor. The fluid in these tubes rises and flows into the upper header 32. The vapor thus formed is conducted through the conduit 33 to the drum and the liquid is recirculated through down-tubes 34 and up-tubes 37. To prevent the up-stream from tubes 37 from interfering with the liquid flowing into tubes 34, a baffle plate 38 is provided in the upper header 32.

While I have described my invention particularly in connection with mercury boilers, it is not limited thereto necessarily but may be utilized wherever conditions are met with which make it desirable to overcome the tendency for mercury

to dissolve ferrous metal at high temperatures.

In accordance with the provisions of the patent statutes, I have described the principle of operation of my invention, together with a particular method and apparatus which I now consider to represent the best embodiment thereof, but I desire to have it understood that the particular method and apparatus disclosed are only illustrative, and that the invention may be carried out with such modifications as come within the scope of the appended claims.

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

1. A mercury vapor generator having ferrous metal tubes through which mercury circulates from a region of higher temperature to a region of lower temperature, said generator being charged with mercury to which has been added an inhibitor to prevent the mercury from dissolving ferrous metal at a region of higher temperature and depositing it at a region of lower temperature.

2. A mercury vapor generator having ferrous metal tubes through which mercury circulates from a region of higher temperature to a region of lower temperature, said generator being charged with mercury to which has been added a metal which functions as an inhibitor to prevent the mercury from dissolving ferrous metal at a region of higher temperature and depositing it at a region of lower temperature.

3. A mercury vapor generator having ferrous metal tubes through which mercury circulates from a region of higher temperature to a region of lower temperature, said generator being charged with mercury to which has been added aluminum which functions as an inhibitor to prevent the mercury from dissolving ferrous metal at a region of higher temperature and depositing it at a region of lower temperature.

4. A mercury vapor generator having ferrous metal tubes through which mercury circulates from a region of higher temperature to a region of lower temperature, said generator being charged with mercury to which has been added one of the metals of the group aluminum, nickel, magnesium, calcium, and chromium, to prevent the mercury from dissolving ferrous metal at a region of higher temperature and depositing it at a region of lower temperature.

5. The method of heating mercury in the presence of ferrous metal including the step of treating the mercury to prevent it from dissolving ferrous metal at high temperature which comprises adding to the mercury prior to the heating thereof a metal which serves as an inhibitor.

6. The method of heating mercury in the presence of ferrous metal including the step of treating the mercury to prevent it from dissolving ferrous metal at high temperature which comprises adding to the mercury prior to the heating thereof a relatively small amount of aluminum.

7. The method of heating mercury in the presence of ferrous metal including the step of treating the mercury to prevent it from dissolving ferrous metal at high temperature which comprises adding to the mercury prior to the heating thereof a relatively small amount of one of the metals of the group, aluminum, nickel, magnesium, calcium, and chromium.

8. In a mercury vapor generator, the combination of ferrous metal tubes which are subjected to high temperature, mercury which circulates through said tubes, and means for preventing the mercury from dissolving ferrous metal of the

tubes comprising an inhibitor added to the mercury.

9. In a mercury vapor generator, the combination of ferrous metal tubes which are subjected to high temperature, mercury which circulates through said tubes, and means for preventing the mercury from dissolving ferrous metal of the tubes comprising aluminum added to the mercury.

10. In a mercury vapor generator, the combination of ferrous metal tubes which are subjected to high temperature, mercury which circulates through said tubes, and means for preventing the mercury from dissolving ferrous metal of the tubes comprising aluminum of the order of one-hundredth of one per cent by weight added to the mercury.

11. In a mercury boiler comprising a container made of ferrous metal, mercury liquid to be heated in the container, and a substance added to the

liquid for reducing the dissolving effect of mercury on ferrous metal.

12. An actuating fluid for boilers having ferrous metal walls comprising mercury and an inhibitor associated with said mercury which prevents dissolving of ferrous metal by said mercury at high temperature.

13. A composition for operating boilers having ferrous metal walls comprising substantially entirely mercury and a small amount of an inhibitor preventing mercury from dissolving ferrous metal at the operating temperature of the boiler.

14. A composition to be subjected to high temperatures of the order of one thousand degrees Fahrenheit in the presence of ferrous metal, said composition comprising mercury approximately ninety-nine per cent. by weight and the remainder an agent which minimizes the dissolving of ferrous metal by the mercury at such high temperatures.

ANTHONY J. NERAD.

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