Nov. 19, 1929. P. B. SADTLER 1,735,979

EVAPORATOR

Filed July 9, 1926

Fig. 1.

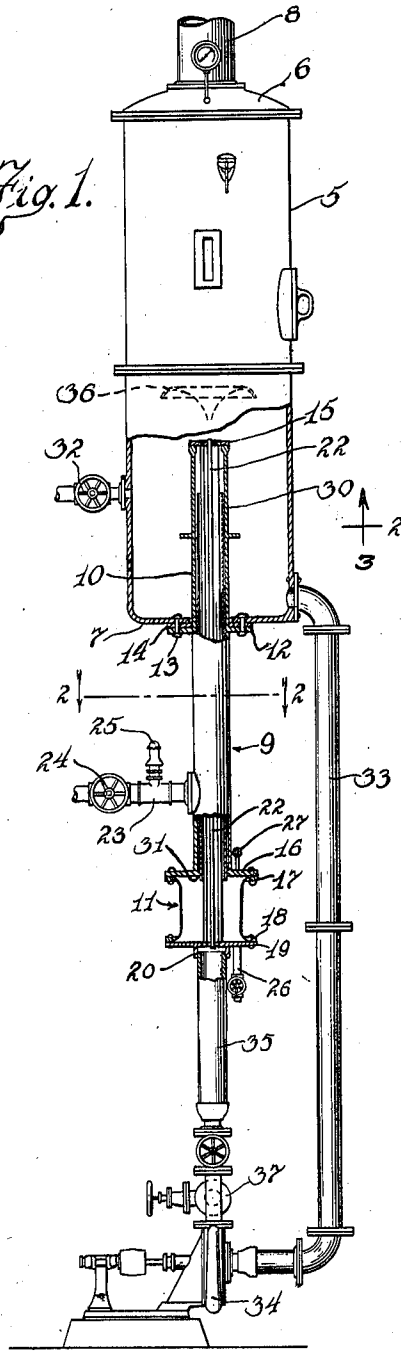


Fig. 2.

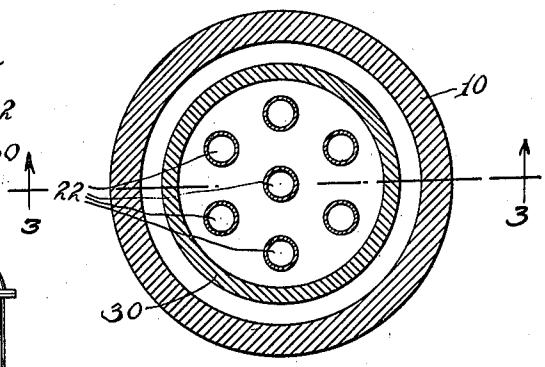
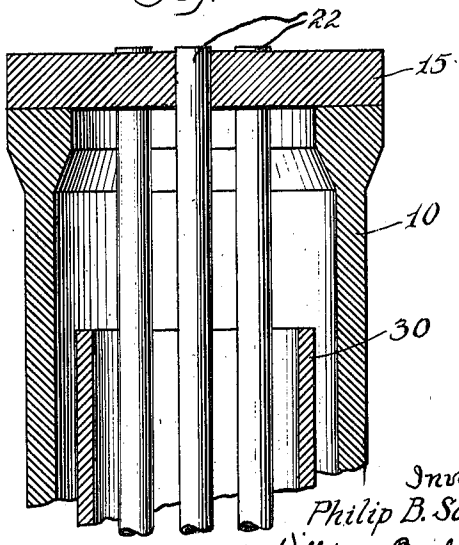


Fig. 3.



Inventor
Philip B. Sadtler
By Williams, Bradbury,
McCaleb & Hinkle.
Attorneys

Patented Nov. 19, 1929 1,735,979

UNITED STATES PATENT OFFICE

PHILIP B. SADTLER, OF CHICAGO, ILLINOIS, ASSIGNOR TO SWENSON EVAPORATOR COMPANY, OF HARVEY, ILLINOIS, A CORPORATION OF ILLINOIS

EVAPORATOR

Application filed July 9, 1926. Serial No. 121,452.

My invention relates to evaporators. It will be explained with particular reference to evaporators of the so-called "vertical tube" type wherein the liquid to be evaporated circulates upwardly through vertical tubes while the heating medium such as steam is applied to the outside of the tubes.

Heretofore it has been the common practice to provide tubes of relatively large diameter and short length or in coils or with bends and depend upon a relatively slow movement of the liquid into and through the same. Ordinarily natural circulation, that is, the circulation induced by the lifting effect of bubbles of vapor rising through the tubes has been depended upon to effect the heat transfer from the tubes to and through the liquid. Of course, the agitation and circulation of the liquid under such conditions is relatively sluggish, the transfer of heat is correspondingly slow and evaporation proceeds at a comparatively low rate.

The so-called "film" theory of heat transfer to and from metallic surfaces is now generally accepted. According to this theory the principal resistance to heat transfer from the steam on the outside of the evaporator tubes to the tubes and from the inside surfaces of the tubes to the liquid within them is due to relatively stagnant films of fluid lying against the outside and inside walls of the tubes. The film on the inside of the tubes is composed of the liquid being heated. The film on the outside of the tubes is composed of condensed steam and air and other non-condensable gases, and is usually called the steam film. These films produce most of the temperature drop between the heating fluid, for example, steam, and the liquid being evaporated. Thus, ignoring the effects of the metal walls of the tubes, and of scale which may be present, the overall rate of heat transfer from the steam on the outside of the tubes to the liquid on the inside of the tubes may be represented by the following formula, wherein U is the overall rate of heat transfer, K_1 is the steam film coefficient, and K_2 is the liquid film coefficient:

$$U=\frac{1}{1/K_1+1/K_2}$$

It has been recognized that increasing the velocity of the liquid flowing through the evaporator tubes would decrease the thickness of the stagnant liquid film and correspondingly raise the liquid film coefficient with the result that the rate of heat transfer is increased. Some attempts have been made to augment the velocity of the circulating liquid by indirect methods such as the provision of screw conveyors and paddle or propeller wheels and the introduction of buoyant agents such as air or other gases. Where viscous or easily scaling liquids have been treated, forced circulation has been provided by positive acting pumps. But with the adoption of all of these expedients to raise the liquid film coefficient, the practice has been to use large diameter short tubes or tubes offering such resistance to high velocity flow that only relatively low velocities and heat transfer has been attained.

It is generally accepted that the stagnant film on the outside or steam side of the evaporator tubes is composed of condensed steam and non-condensable gases, such as air, which are always present in or accompany the steam. Although, as will be apparent from the above formula, the steam film coefficient is a factor in the overall rate of heat transfer between the steam side and the liquid side of the tubes, yet under the common practice of employing large diameter tubes and slow circulation of liquid therethrough, the liquid film resistance has been so high that the steam film resistance was, or at least has been considered negligible in the ultimate result. However, by utilizing small diameter long tubes and high velocities such as I propose, the steam film resistance to heat transfer becomes a matter

of real importance. Where heating media of the character of flue gases have been used the heating medium film coefficient has been so high that the liquid film resistance was relatively unimportant. Consequently I not only increase the liquid film coefficient by providing high velocity circulation of the liquid through the tubes, but I raise the heating medium film coefficient by reducing the stagnant film of non-condensable gases and condensed vapor on the outside of the tubes.

Only apparatus whereby my improved process may be carried on is claimed herein; the method or process being separately claimed in my copending and divisional application, Serial No. 211,014, filed August 6, 1927.

One of the objects of my invention is to provide an improved evaporator.

Another object is the provision of apparatus for raising the liquid film coefficient and thereby increasing the overall rate of heat transfer to the liquid.

Another object is the provision of apparatus for raising the steam film coefficient and thereby further increasing the overall rate of heat transfer from the heating steam to the treated liquid.

Another object is to reduce the formation of foam during the evaporation of liquids subject to foaming.

Another object is to permit of a reduction of the heating area without decreasing but in fact raising the amount of evaporation.

Another object is to lessen the formation of scale on the inside walls of the evaporator tubes.

Other objects and advantages will hereinafter appear. In the accompanying drawing I have shown typical apparatus for practicing my improved method of operation. In the drawing,

Fig. 1 is an elevation and partial section of my improved evaporator;

Fig. 2 is an enlarged section on the line 2—2 of Fig. 1, and

Fig. 3 is an enlarged vertical section of the top portion of the vertical tube heater on the line 3—3 of Fig. 2.

According to my improved method of operating evaporators, the liquid to be treated is positively circulated at high velocity into and upwardly through an unobstructed high velocity zone composed of relatively long heating tubes of small diameter and is projected from the upper ends of the tubes into the vapor space of a collecting or evaporating chamber; the heating steam is caused to flow downwardly, that is, in a direction opposite to the liquid flow, so that the steam will remove from the tubes and carry along the condensed vapor and the non-condensable gases and thus reduce the film on the steam side of the tubes. Augmented by the effect of the steam generated during the passage of the liquid through the tubes, the velocity of the treated liquid becomes very high, the liquid film coefficient is raised and heat is imparted to the liquid at a rapid rate. The treated liquid is freely expelled or projected from the tubes into the evaporating or collecting chamber and, since the velocity increases as the liquid approaches the exit ends of the tubes, the liquid film coefficient and rate of heat transfer increase in the direction of expulsion. This increase of the liquid film coefficient in the direction of liquid and vapor travel is coordinated with the increase of the heating medium film coefficient so that they are higher in the same region.

The evaporator has a generally cylindrical metal body 5 which forms a collecting chamber in which separation of liquid and vapor takes place. This body has a cover 6 and a bottom 7. A vapor pipe 8 communicates with this chamber through cover 6. This vapor pipe, as is common in evaporator practice, is for the discharge of vapors driven off during the evaporating process and for the application of whatever vacuum may be desirable.

The treated liquid in the evaporator body is heated by a heating element 9. This heating element comprises, in general, a long tubular section or drum 10 and a relatively short enlarged cylindrical section 11. Tubular section 10 extends below body 5 and projects upwardly through bottom 7 some distance into the evaporating chamber. It is provided with an annular flange 12 by which the heater may be attached to the evaporator body by appropriate means such as bolts 13. A suitable packing ring 14 may be employed to insure a tight joint. Section 10 is tightly closed at its upper end by a tube sheet 15 joined thereto by suitable means such as welding or screws and the like. The lower end of drum section 10 is provided with an annular flange 16 to which the upper flange 17 of the enlarged section 11 is attached by bolts or other suitable means. The lower end of section 11 has a flange 18 to which a combined bottom plate and lower tube sheet 19 is secured by bolts or the like. This bottom tube sheet is provided with a downwardly extending annular flange 20 for the reception of a liquid inlet pipe to be hereinafter described.

A series of long and substantially straight tubes 22, which are open at both ends, extend through the steam drum and openings in the two tube sheets 15 and 19. The ends of these tubes are pressed, expanded or otherwise tightly secured to the tube sheets so that steam under pressure may be supplied to the drum outside of the tubes and cannot escape. In effect, the heater is like a water tube boiler in that the treated liquid is inside of the tubes and the heating medium is on the outside thereof.

Steam is supplied to the drum in the space

or chamber around the tubes through a steam inlet 23 controlled by a valve 24. Excessive pressures can be avoided by providing a steam relief valve 25. The enlarged section 11 provides a chamber for the collection and separation of the water of condensation and the non-condensable gases which usually accompany steam. The condensate may be removed by a valved drain 26 located at the bottom of the collecting chamber, while the gases may escape through a valved gas vent pipe 27 at the top thereof. The side wall of section 11 may be made of relatively thin sheet metal so that the additional function of an expansion joint may be performed by this section.

A steam deflector is located within the steam drum to direct the flow of steam downwardly along the tubes. This deflector is in the form of a tube 30 which lies in the steam chamber between the inner wall of drum section 10 and the group of tubes. Its lower end fits within the inwardly projecting rim 31 of flange 16 and, either by the tightness of the fit or otherwise, forms a closed-bottom steam passage around the tubes. The upper end of steam deflector tube 30 is open and is located somewhat near the upper tube sheet 15. Thus, the steam entering the heater through steam inlet 23 flows upwardly in the steam chamber out of contact with the tubes almost to their upper open ends, then flows downwardly in the steam chamber along and in contact with the tubes in a direction opposite to that of the flow of liquid therethrough and finally collects as condensate in section 11. The condensate may be removed through drain 26 and the gases liberated through vent 27. If desired, the lower end of deflector tube 30 may project below flange 16 in order to provide a gas trap in the top of section 11.

Liquid to be treated is supplied by a valved liquid supply pipe 32 in the evaporator body. The liquid is withdrawn from the body through a liquid outlet pipe 33 which leads to a pump 34, such as a centrifugal pump. A valved inlet pipe 35 extends from the discharge side of pump 34 and has its upper end tightly fitted within and connected to flange 20 of bottom plate 19 so that the pump directly and positively forces the withdrawn liquid upwardly into the lower ends of the heater tubes.

A somewhat cone-shaped baffle 36 is located above the open ends of tubes 22 in body 5, to disperse and diffuse the hot liquid which is projected from the tubes when the evaporator is in operation. The concentrated liquid, or other products resulting from evaporation, may be withdrawn through a valved outlet 37 in pipe 35.

The heating tubes are made relatively long and of small diameter, for example, for ordinary evaporating processes, these tubes may be in the neighborhood of 6 to 10 feet long and ¾ to 1 inch inside diameter. The length of the tubes does not excessively increase the height of the evaporator body because the tubes may be largely outside of the body.

In operating the evaporator according to my improved method, the liquid which is withdrawn from the evaporator body, is positively pumped directly upward at high velocity into and through the long slender tubes. At the same time, the steam is directed downwardly outside of the tubes, opposite to the direction of the liquid flow therethrough and in the same direction as the force of gravity acting upon the film of condensate and gases which tends to cling to the tubes. Because the steam is directed downwardly by the steam deflector, condensation creates a downward current or flow of the steam along the tubes at a relatively high velocity. The steam velocity is greatest near the upper ends of the heater tubes which is the region where the liquid velocity also is the greatest. Consequently, the steam film coefficient is highest in that region of the heater where the liquid film coefficient is the highest.

The entrance velocity of the pumped liquid at the bottom ends of the tubes may, for example, be raised to the neighborhood of 5 to 7 or more feet per second as compared to an entrance velocity probably must less than 1 to 2 feet per second where natural circulation is employed. With this initial high velocity augmented by the lifting effect of the steam created by the boiling the treated liquid, as steam is formed by evaporation while passing through the heating element, attains great speed and momentum as it flows upwardly through the tubes and is projected directly into the vapor space above the level of any liquid in the collecting chamber. The high velocity of the liquid flow upwardly through the tubes reduces the stagnant liquid film on the inside of the tubes and also tends to remove and prevent the deposit and collection of scale so that the liquid film coefficient is raised and the scale resistance to heat transfer is reduced. Consequently, the rate of heat transfer and evaporation are high and therefore high liquid velocities are entirely feasible, and excessive pump capacity and power consumption are not required.

The downwardly directed and high velocity flow of heating steam carries along the condensate and non-condensable gases which tend to cling as a relatively stagnant and heat transfer resistant film on the outside of the tubes, aiding the force of gravity to carry them to the common collecting and separating chamber at the bottom, where the condensate and gases are removed. Thus, the steam serves to sweep the film from the steam side of the tubes, resulting in a rise of the steam film coefficient and increased heat transfer. And this higher steam coefficient is par-

ticularly pronounced in the upper region of the tubes where the liquid film coefficient is likewise highest.

The increase in the rate of heat transfer permits the use of a smaller area of heating surface for the treatment of the same or even greater volumes of treated liquid so that more durable but more expensive metal may be employed for the tubes. Thus, nickel, which for many purposes is by far the most satisfactory metal because of its non-corrosive properties, may be used, although its cost ordinarily has been prohibitive with the prior processes and evaporators because of the relatively large heating surface required.

The extremely high velocity at which the treated liquid and vapors rise through the heating tubes prevents in a large measure the formation and retention of gas bubbles within the body of treated liquid. Further, if such bubbles are formed they are broken by the excessive velocity with which the mass of liquid and vapor, issuing from the tubes, strikes the deflector 36. It is the presence of these gas bubbles which constitutes the principal agent in the formation of foam. Consequently, my high velocity process reduces the tendency to foam, because it reduces or prevents the formation and retention of gas bubbles within the body of liquid, and breaks any foam that may be formed by the action of baffle 36.

By inserting the heating element as a unit from the outside of the body and having all of the connections therefor entirely outside of the evaporating chamber, the placement and removal of the heating element is a relatively easy matter and the number of openings and connections through the wall of the evaporator body is reduced while yet retaining the desirable feature of introducing the steam near the top of the heater. In the event that the heater becomes clogged, or for any other reason requires attention and repair, it may be removed from the evaporator body and a duplicate substituted therefor. Thus, continuous and efficient operation may be insured without duplicating the relatively great expense of providing additional evaporator bodies.

Having described my invention what I claim as new and desire to secure by Letters Patent of the United States is:

1. An evaporator comprising an evaporator body; and a heating element projecting into the body, said heating element comprising a series of tubes through which the liquid to be treated may pass into the body, a steam drum surrounding the tubes, and a steam deflector interposed between the tubes and the drum to direct the steam downwardly along the outside of the tubes.

2. In an evaporator, the combination of an evaporator body, a series of heating tubes extending into the body and through which liquid may pass to the body and be heated in its passage, a steam drum surrounding the tubes, a steam deflector within the drum to direct the flow of heating steam downwardly about the tubes, an outlet pipe for withdrawing liquid from the body, a liquid circulating pump connected to the outlet pipe, and an inlet pipe connecting the pump to the bottoms of the tubes so that the pump can force the withdrawn liquid back into the body through the tubes.

3. An evaporator having a body; and a heating element projecting into the body, said heating element comprising a steam drum attached to the body and extending below and projecting into the body, a series of tubes extending through the drum for the circulation of liquid therethrough in heat exchanging relation to steam in the drum, and a condensate and gas collecting and separating chamber at the lower end of the drum.

4. An evaporator having a body; and a heating element for heating and discharging liquid into the body, said heating element comprising a steam drum, tube sheets closing opposite ends of the drum to form a steam space, a series of tubes extending between the tube sheets so as to be in contact with steam in the drum and through which liquid may be discharged into the body, a condensate and gas collecting and separating chamber at the bottom of the drum and in communication with the steam space, and a steam deflector for directing the flow of steam to the chamber.

5. An evaporator having a body, a tube projecting into the body and through which treated liquid is passed to be heated for evaporation in the body, a chamber surrounding the tube and in which a condensible heating-fluid is brought into heat exchanging relation to the tube, a heating-fluid connection for the chamber outside of the body, and means for directing the flow of heating-fluid upwardly out of contact with the tube and then downwardly about the tube in the direction of the gravitational flow of the condensate from the fluid so as to reduce the stagnant film on the tube.

6. An evaporator having a body; a heating element projecting into the body, said heating element comprising a series of tubes through which the treated liquid is passed to the body and heated in its passage, and a steam chamber about the tubes and to which steam is admitted outside of the body and directed upwardly into the body and then downwardly along the tubes in the direction of the gravitational flow of the condensate from the steam; and a force-circulating system for withdrawing liquid from the body and forcing the same at high velocity through the tubes of the heating element back into the body.

7. An evaporator having a body forming a separating chamber for liquid and vapor; and a heating element for heating the liquid to be evaporated, said heating element being attached to and projecting vertically through the bottom of the body and comprising a plurality of substantially straight and relatively long and narrow tubes through which the liquid to be treated is passed at high velocity and directly discharged into the vapor space above the level of liquid in the body, a drum surrounding the tubes substantially throughout the length thereof to form a heating medium chamber about the tubes, a connection outside of the body for admitting a fluid heating medium to the chamber about the tubes, and a deflector for directing the heating medium into first contact with the tubes in the region of their upper discharge ends and then downwardly about the tubes in a direction reverse to the liquid flow therethrough.

8. An evaporator having a body forming a separating chamber for a liquid and vapor; a heating element for boiling the liquid to be evaporated, said heating element projecting vertically through the bottom of the body and comprising a plurality of substantially straight and relatively long and narrow tubes through which the liquid undergoing treatment can be passed, heated and discharged directly into the vapor space above the level of liquid in the body, and means for directing a fluid heating medium into first contact with the tubes in the region of their upper discharge ends and then downwardly about the tubes in a direction reverse to the flow of liquid therethrough; a pipe for circulating liquid from the body to the lower entrance ends of the tubes; and a pump whereby liquid flowing through said pipe may be supplied to the tubes at high entrance velocity.

In witness whereof, I hereunto subscribe my name this 2nd day of July, 1926.

PHILIP B. SADTLER.