Feb. 4, 1958 J. L. PORTER 2,822,157

PROCESS AND APPARATUS FOR TREATING LIQUIDS

Filed July 22, 1954 2 Sheets-Sheet 1

Fig. 1

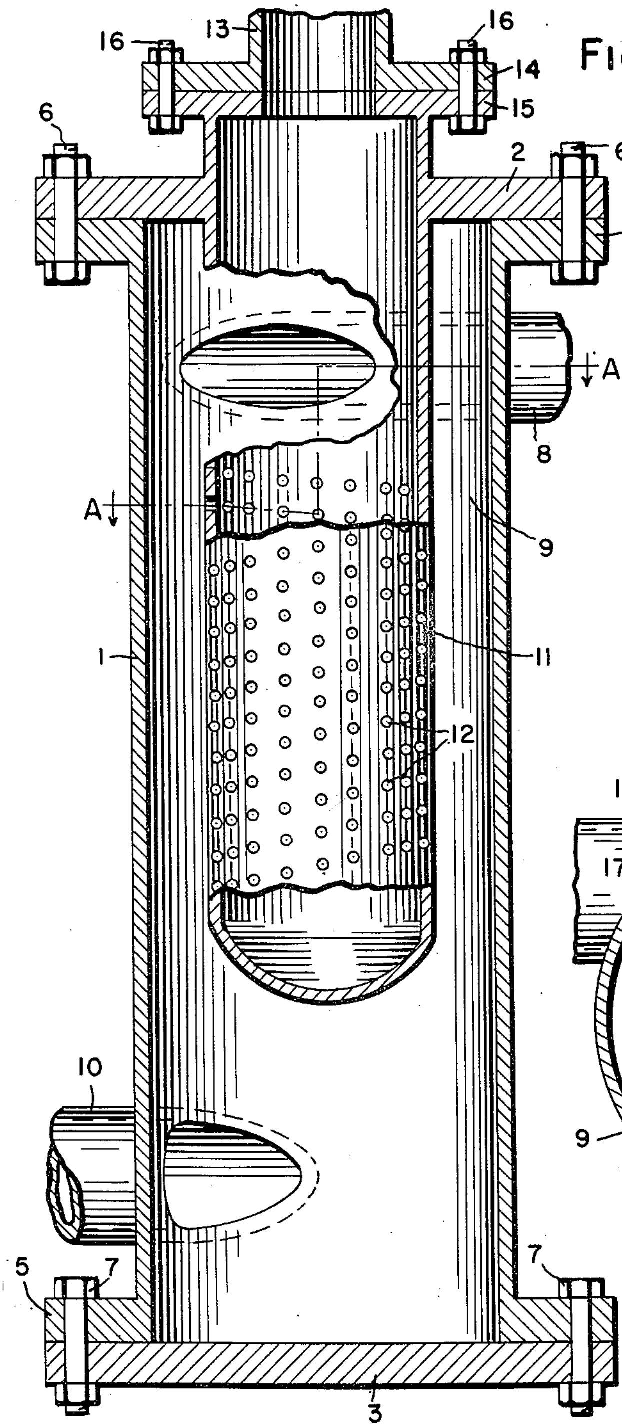

Fig. 2

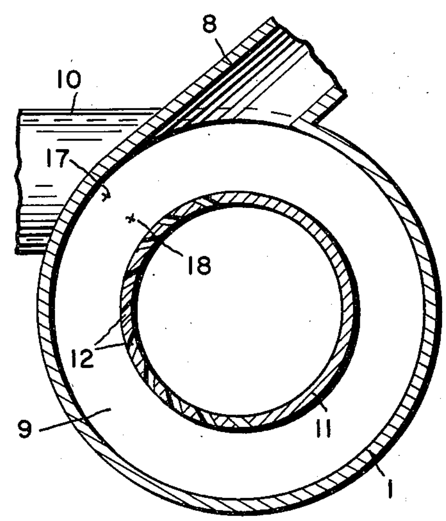

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Fig. 3

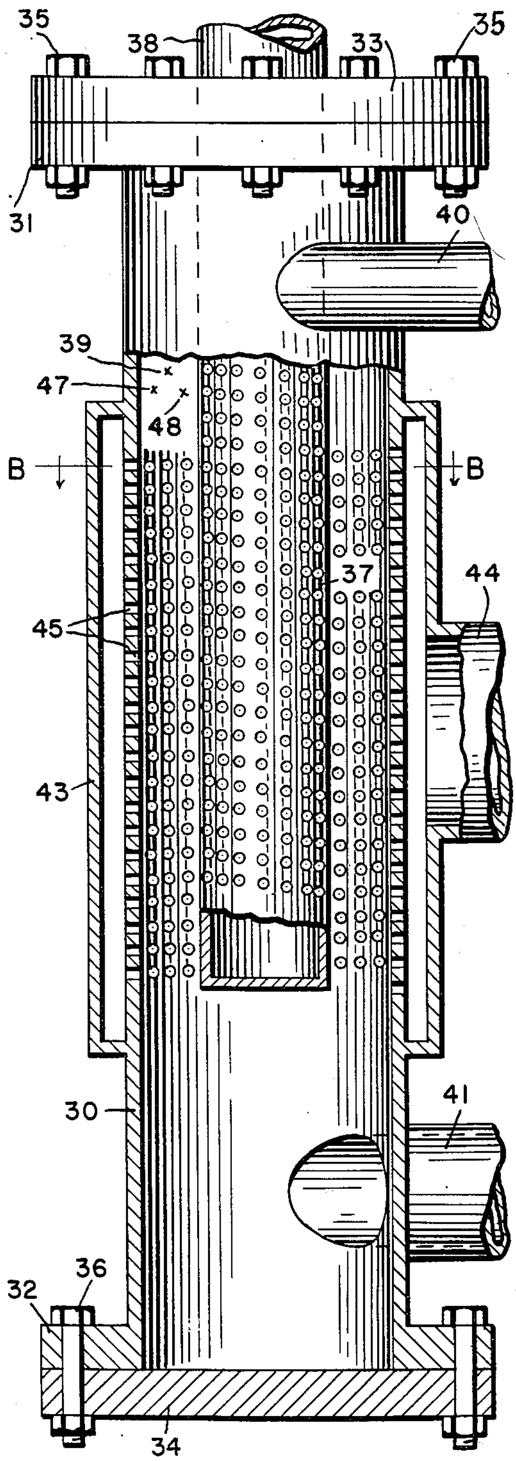
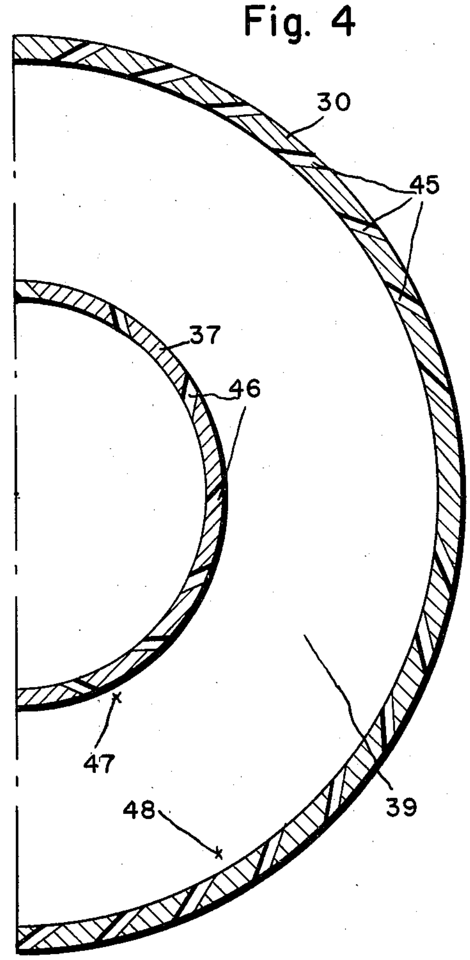


Fig. 4



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PROCESS AND APPARATUS FOR TREATING LIQUIDS

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12 Claims. (Cl. 261—124)

The herein described invention relates to a method for heating liquids and/or slurries by the injection of steam or other high temperature gaseous media therein. The invention also relates to apparatus which may be employed for heating liquids and/or slurries by the injection of steam therein.

There are many difficulties which attend the heating of liquids and/or slurries by the direct injection of steam, many of the difficulties being as yet unsolved. For example, apparatus heretofore designed and employed for heating liquids and/or slurries by the direct injection of steam are usually restricted to close ranges of operation in order to avoid the annoying and dangerous vibrations commonly termed "steam" or "water hammer." In general, the "steam" or "water hammer," which hereafter will be referred to as "water hammer," is caused by the rapid collapse of the steam and is aggravated by high temperature differentials between the steam and the liquid undergoing a temperature rise. If excessive water hammer is evidenced in a steam injection system, it can usually be reduced by decreasing the temperature rise, such as, by reducing the amount of steam consumed per unit of liquid being heated. Another method for decreasing the temperature rise is to recycle the heated liquid such that the temperature of the liquid feed to the heater is increased. This method also serves to reduce the difference between the liquid vapor pressure and the steam pressure, a relationship which materially affects the presence or absence of a water hammer. These methods for reducing or minimizing the water hammer under extreme operating conditions, of course, decrease the capacity of any live steam injection unit employed and naturally are to be avoided for greatest steam injection efficiency. It is apparent to those skilled in the art that the problems and difficulties associated with direct injection of steam into liquids are aggravated, furthermore, as the viscosity of a particular liquid or slurry undergoing heating increases. However, the differences in temperature between the liquid undergoing heating and the steam employed therefore afford the major sources for the difficulties resident in the heating operations. Consequently, there is a demand for a method of employing the direct injection of live steam which will accomplish the heat transfer from the steam to the liquid or slurry over a wide range of varying operating conditions without the accompaniment of the dangerous shocks attributed to the collapse of the steam during the process of heating.

According to the invention herein described, the above difficulties necessarily attending live steam injection may be substantially overcome by conveying the liquid to be heated to a heating zone in such a manner that a rapid rotation of the liquid is accomplished about the axis of the heating zone and simultaneously injecting the live steam into the liquid filled heating zone as a plurality of gaseous streams, as for example through a plurality of orifices directing the steam into the zone near the axis of rotation thereof. To accomplish injection of the live

steam near the axis of rotation, it is generally most practical to maintain a heating zone having a hollow portion from which the steam is directed thereto. This will be apparent from the disclosure hereafter given. This method of heating by means of direct live steam injection through a plurality of orifices located near the axis of rotation has been found to be most advantageous when the liquid undergoing a temperature rise also has solid matter associated therewith. Although this method of heating is preferred for slurries, the method of heating may, of course, be employed with clear liquids and the invention is not to be limited to any one particular liquid to be heated.

It has also been found that the method of heating by the injection of steam into a rapidly rotating liquid filled heating zone near the axis of rotation may be advantageously combined with insertion of steam through a plurality of orifices located about the periphery of the heating zone, especially when the liquid undergoing a temperature rise does not have suspended solid matter associated therewith. Accordingly, the inventive concept is not to be limited by the characteristics of the liquid undergoing treatment or as being the only means for insertion of the condensible media. Nevertheless, the injection of the steam as a plurality of gaseous streams entering the rapidly rotating liquid in the heating zone from a point within the zone has certain definite advantages as regards the elimination or minimization of the water hammer, as will be apparent from the disclosure herein.

Accordingly, it is an object of the herein described invention to provide a process for heating liquids and/or slurries by the direct injection of live steam therein. It is, furthermore, an object of the invention to provide a process for heating liquids and/or slurries over wide ranges of operating conditions. It is a further object of the invention to provide apparatus which may be employed for heating liquids and/or slurries. It is still another object to provide apparatus which may be employed for heating liquids and/or slurries whereby the heat transferred will be unaccompanied by the dangerous and annoying water hammer over wide ranges of operation. It is a further object to provide a simple apparatus for the injection of steam into liquids and/or slurries whereby a wide range of operating conditions may be employed merely by varying the relative proportion of liquid and steam. It is, furthermore, an object to provide an apparatus which may advantageously be employed for heat transfer purposes. Other and further objects will be apparent from the following description and figures accompanying same.

Fig. I is a partially fragmental sectional view of an apparatus employing the principal concept of the herein described method for heating liquids and/or slurries and is the preferred type of apparatus to be employed when the liquid undergoing treatment contains suspended solid matter. Fig. II is a sectional view of Fig. I taken along the lines A—A and shows the preferred disposition of the plurality of orifices through which the steam is injected as a plurality of gaseous streams into the liquid heating zone. Fig. III is a partially fragmentary sectional view of another type of apparatus employing the basic concept of the herein described method for heating liquids wherein, a portion of the steam is also injected into the heating zone about the periphery thereof. The apparatus depicted in Fig. III has a greater utility when employed for heating clear liquids than when employed for heating slurries, as will be apparent from the disclosure given herein. Fig. IV is a sectional view of the apparatus in Fig. III through the lines B—B thereon and shows a preferred orifice arrangement for delivering the steam to the liquid in the heating zone.

With particular reference to the apparatus shown in Fig. I and Fig. II, the apparatus in which the preferred method for heating is carried out comprises a cylindrical vessel 1 having flange portions 4 and 5 at either ends thereof and to which blind flanges 2 and 3 are secured as by means of bolts 6 and 7, respectively. Centrally disposed in vessel 1 and penetrating blind flange 2 is a closed cylindrical conduit 11 having a plurality of spaced holes 12, therein, disposed at the periphery thereof. The centrally disposed conduit 11 having the holes 12 therein, through which the steam is injected into the vessel, is generally referred to herein as a "steam finger." Heating zone 9 is defined by the annular space between the centrally disposed conduit 11 and the outer shell of vessel 1 and because the steam finger does not extend the entire length of the shell 1, the heating zone within the vessel 1 is hollow throughout only a portion thereof. Feed pipe 8 is employed to convey the cold liquid to the vessel and is located tangentially in the wall thereof and communicates with heating zone 9 at one end thereof. Discharge pipe 10 is in the preferred form tangentially connected with heating zone 9 at the other end thereof. Steam finger 11 extends, in this case, through blind flange 2 and is connected to an outside steam source conveyed to the heater by pipe 13. Pipe 13 is connected to the steam finger 11 by means of flanges 14 and 15 which are secured together by bolts 16.

According to the method of heating liquids or slurries by the direct injection of steam as carried out in the apparatus depicted in Fig. I and Fig. II, the liquid or slurry is fed to the heating zone 9 by means of tangential feed pipe 8 and the liquid is caused to rapidly rotate about the longitudinal axis of the apparatus in the partially annular space defining heating zone 9. In effect, the heating zone, in this case, is an elongated closed zone of liquid which is hollow throughout a portion thereof, and it is apparent that the steam finger may also extend the entire length of the heating zone in other apparatus employed for carrying out the concept of the invention. Thus, the conduit 11 conveying the steam to the holes 12 defines a hollow portion within the rapidly rotating liquid body in zone 9. Steam from the outside source is fed to the conduit 11 or steam finger through pipe 13 and the steam is transmitted to the heating zone through the orifices defined by the holes 12 which form passageways for the steam from the conduit 11 to the heating zone 9. The steam thus fed to the heating zone 9 is condensed therein and the heated liquid is discharged from the heating zone 9 by means of tangential discharge pipe 10 located at the other end of heating zone 9.

The effectiveness of this method of heating liquids in overcoming dangerous water hammer over wide ranges of operation as regards throughput and heating capacity is believed to be a combination of several factors. The centrifugal action imparted to the liquid by means of the tangential delivery to the annular space apparently facilitates creation of a cold zone 17 and a hotter zone 18 of liquid rotating about the steam finger in the heating zone 9 as well as a difference in existing static pressures at the periphery of the heating zone 9 and in the regions near the steam finger 11. This cold and hot zone are most effective in minimizing the water hammer at the liquid feed end of the vessel where the greatest temperature differentials are maintained and is less pronounced after the liquid in the heating zone has progressed on the route to the discharge pipe where a greater amount of mixing has apparently taken place. The colder liquid, because of its relatively greater density, tends to remain at the periphery of the heating zone; whereas, the hot liquid tends to remain or migrate to the vicinity immediately around the hollow portion of the steam finger 11. The sum effect of this apparent hotter zone 18 and the lower static pressure, which is maintained in the vicinity of the steam jets, is such as to decrease the overall temperature difference between the steam and the liquid receiving the heat content and to decrease the forces causing implosion. This produces a result similar to decreasing the temperature of the steam employed for heating a given volume of liquid in other type apparatus as well as producing a similar result which is often accomplished by recycling heated liquid in order to raise the temperature of the feed to a heater. Recycling heated liquid, as has previously been mentioned, decreases the overall temperature difference between the steam and the liquid undergoing heat treatment and accordingly, affords conditions less conducive to water hammer. It is apparent, of course, to those skilled in the art that as the liquid undergoing the temperature rise progresses through the heating apparatus from the feed pipe 8 to the discharge pipe 10 that the overall temperature thereof rises and, furthermore, that the apparent temperature difference between the hot zone 18 and the cold zone 17 decreases as greater mixing is accomplished over the route taken by the liquid in progressing through the apparatus. Actually, it is believed that the hot and cold zone temperature differences of consequence are only maintained effectively for a relatively short length of the apparatus as the liquid is heated, the zones being more or less indistinguishable as the liquid approaches the discharge pipe 10.

The static pressure, on the other hand, in the immediate vicinity of the steam orifices is less near the axis of rotation than at the periphery of the heating zone and this is obviously apparent throughout the entire length of the apparatus. The centrifugal action developed within the apparatus materially aids, consequently, in also minimizing water hammer. Thus, when the steam is inserted closer to the axis of rotation where the static pressure is less and where the highest vapor pressure is present, the dangers of obtaining water hammer are appreciably diminished and wider ranges of operation of the equipment are facilitated. Consequently, because of the hotter liquid into which the steam is inserted at the feed end and whereat the conditions are most drastic for implosion because of the initially colder liquid near the feed pipe 8, the liquid contacting the steam has a higher vapor pressure associated with a lower static pressure at the point of steam insertion, the latter being caused by the lower centrifugal forces, and therefore the principal driving forces for the implosive violence caused by the rapid collapse of the steam is minimized. It is apparent to those skilled in the art that the vapor pressure of the liquid which is determined by its temperature, and the static pressure on the system at the point of steam injection are the major factors contributing to the implosions associated with water hammer. Increasing the consumption of steam to vary the operating conditions is believed merely to increase the temperature of the liquids in the hot zone and to aid in the mixing of the hot and cold liquids. Regardless of the theory of operation heretofore given which is believed to facilitate the effectiveness of the method of heating liquids and/or slurries suffice it to say that it has been found that the method herein described materially broadens out the range of operation for which a heating unit may be employed without the accompaniment of the undesirable water hammers associated with other known types of heating apparatus employing live steam injection.

It should be stated that it is preferable to have the orifices located below the point of liquid feed in order for the steam from the first orifices contacted by the liquid to accomplish an initial hotter zone instead of being too thoroughly mixed at this point because of the initial velocity of the incoming liquid.

In the preferred form of the apparatus, it is desirable to have the steam entering the zone 9 through the plurality of orifices 12 in a manner such as to impart to the liquid additional motion in the direction of tangential delivery. Thus, the centrifugal forces to which the liquid undergoing heating is subjected may be imparted thereto in substantial amounts by the jetting action of the steam from the steam finger such as to augment the centrifugal forces caused by the tangential delivery of the liquid to the heating zone. This added centrifugal force, of course, also aids in maintaining a low static pressure in the vicinity of the steam jets. In general, it has been found that inclination of the holes from the radius of the steam finger in amounts from about 30 to 45° are, for practical purposes, preferred to accomplish the mixing of the liquid and steam without water hammer and to adequately augment the centrifugal action. It is apparent that the centrifugal force developed in the apparatus is governed by the inlet velocity of the liquid to be heated, the radius of the heating zone and the extra forces imparted by the jetting action of the steam entering the liquid in the heating zone. It has been found that the size of the inlet and the radius of the vessel should be such that the centrifugal force developed at the periphery of the heating zone in order to substantially fully realize the benefits of the herein described invention should be in the range of about from 300 to 1000 ft. sec.$^{-2}$.

Likewise, for realization of substantially the full benefits of the invention it has been determined that the size of the holes through which the steam is inserted from the finger to the heating zone should be from about ⅛ to ¼ of an inch in diameter and so spaced apart from one another about the surface area of the steam finger 11 as to accomplish a steam input to the heating zone from between about 5000 and 15,000 lbs. of steam per hour per sq. ft. of steam finger surface area employed for steam passage purposes. Coalescense of steam from separate orifices is thereby prevented by this preferred operation. The orifice coefficient for the size holes employed in the preferred case wherein the orifices are merely holes drilled at an angle into the conduit 11 is about the same as for a sharp edge orifice or about 0.6. Of course, other type orifices, including nozzles and venturi type nozzles, may also be employed within the generic scope of the invention.

Still further, in line with obtaining the full benefits of the herein described invention so as to minimize substantially completely the steam hammer, and to facilitate wide ranges of operation, it has been determined that the allowable pressure drop through the orifices expressed as a pressure ratio of the hydraulic pressure at the discharge of the apparatus to the pressure of the steam within steam finger should be between about .7 and .95 with the most advantageous results being obtained when this ratio is between about .85 and .90. It is also desirable in order to operate in the most efficient manner that there be employed an over pressure expressed as a ratio of the vapor pressure of the heated liquid to the hydraulic pressure on the system between about .6 to .95 and preferably between about .85 and .90.

In practice, it has been found that the method of heating herein described may be employed over wide variations of operating conditions as regards the volume of liquid or slurry treated and the temperature rise thereof and can be accomplished without the steam hammer which would be associated with similar varying conditions with other methods of operations. Likewise, apparatus designed according to the specifications herein indicated may also be employed over wide operating conditions when employed for treating liquids. For example, operating within the pressure ranges above referred to and within the peripheral velocity range heretofore mentioned 1600 gallons per minute of a caustic liquor such as found in Bayer operations for producing alumina and which contain solid particles of bauxite was heated from 300 to 407° F. by employing 110,000 lbs. of steam per hour in apparatus having 572 holes, each of which were $\frac{7}{32}$ of an inch in diameter.

The herein described method for injecting steam into liquids for the purpose of heating may, likewise, be combined with other methods of heating such as, for example, that depicted in Fig. III and Fig. IV where the heat transfer requirements call for large quantities of steam to be consumed and space requirements dictate a minimization of the size of the apparatus. The particular apparatus depicted in Fig. III and Fig. IV has the greatest utility when employed with liquids not containing solid particles unless certain precautions are taken for practical purposes as will be apparent from the disclosure hereinafter set forth.

With particular reference to Fig. III and Fig. IV, the heater comprises a cylindrical elongated shell portion having flange portions 31 and 32, respectively, at either end thereof. The flange portions 31 and 32 connect with blind flanges 33 and 34, respectively, and are secured thereto by means of bolts 35 and 36, respectively. Centrally disposed steam finger 37 is located co-axially with the cylindrical shell portion 30 and communicates with an outside source of steam through blind flange 33 as at 38. Steam finger 37 has a plurality of spaced holes 46 angularly arranged therein whereby steam fed thereto is inserted into heating zone 39. Heating zone 39 is defined by cylindrical shell portion 30 and the steam finger 37 which extends throughout a portion thereof. The cold liquid is fed tangentially to heating zone 39 by means of pipe 40 and the heated liquid is discharged by means of pipe 41 located at the other end of heating zone 39. The function of the apparatus so far described is substantially the same as that described with reference to Fig. I and Fig. II.

Steam jacket 43 is disposed about the periphery of the cylindrical shell portion 30 and is in direct communication therewith. The steam jacket 43 is fed steam as through pipe 44 and serves to distribute steam to orifices defined by holes 45 disposed in spaced relationship through the elongated shell portion 30 about the periphery thereof within the confines of the steam jacket 43.

The same factors as regards the method of operation heretofore set forth with regard to apparatus shown in Fig. I and Fig. II are equally applicable to the apparatus shown in Fig. III. Likewise, it is believed that because of the high centrifugal forces developed as a result of the rapid rotation of the liquid in the annular space forming heating zone 39 defined by steam finger 37 and elongated shell portion 30, a hotter zone 47 having a lower static pressure is maintained closer to the steam finger; whereas, a colder zone 38 is believed maintained having a higher static pressure near the periphery of the heating zone 39. It is preferable in this combination to have the first holes of the group of holes 45 contacting the liquid and disposed in the periphery of the heating zone located at a point somewhat further disposed from the feed pipe 40 than the holes 46 in the steam finger 37 are placed so as to obtain the benefit of the heating accomplished by the steam from the steam finger which first contacts the cold liquid in the heating zone 39. Thus, to obtain the full benefit of this method of heating by means of steam from a steam finger, it is preferable to subject the liquid to a partial heating by steam from the hollow portion of the heating zone prior to further heating with the steam inserted about the periphery of the zone. In this manner, the overall temperature of the liquid is raised to a certain extent depending on the time of contact of the liquid with the steam from the hollow portion prior to communicating with the peripherally injected steam, and consequently, the vapor pressure of the liquid in the cold zone is increased by the time the liquid reaches the steam being inserted from the periphery to a point where the difference in temperatures are not as controlling a factor as regards steam hammer. In general, because of the severe mixing accomplished in the heating zone, the different hot and cold zones are practically indistinguishable after a very short length of passage of the liquid through the apparatus as has heretofore been indicated. As explained previously, the increase in temperature of the liquid decreases the tendency to have implosive violence from rapid collapse of the steam.

It is also advantageous to impart added centrifugal motion to the liquid in the heating zone by means of the jetting action of the steam inserted from the periphery of the elongated vessel. Accordingly, it is preferred to direct the holes in the periphery of the vessel at an angle so as to accomplish this result in the preferred embodiment. In general, the ratios of pressure heretofore given, as well as the particular spacing of the holes and sizes thereof with regard to the steam finger in Fig. I, are equally applicable to the conditions and arrangements associated with the addition of steam from the periphery of the vessel.

When the combined method of heating liquids shown in Fig. III is employed with liquids containing solid particles, it is preferred to have the holes in the periphery arranged at an angle with the radius of the vessel in order to prevent plugging thereof because of the high centrifugal forces developed at the periphery thereof.

It is apparent to those skilled in the art that although the herein described invention has been described with regard to a centrally disposed conduit extending only a portion of the overall length of the heating zone, that extensions thereof throughout the entire heating zone is a matter of choice with regard to the particular result to be accomplished. Although tangential delivery of the liquid to be heated is an important feature of the invention whereby the requisite swirling or rapid rotation of the liquid is developed, tangential discharge of the heated liquid from the heating zone is not critical, although advisable. It is apparent to those skilled in the art that a tangential discharge presents a decreased pressure drop condition across the vessel as compared to axial removal of the liquid or other similar means for discharging same.

In general, the orifices, either in the centrally disposed means for insertion of steam or at the outlying periphery of the heating zone, may be disposed radially, at an angle whereby the steam jetting action will increase the centrifugal movement of the liquid by impartation of the kinetic energy of the steam thereto, or the holes may be placed so as to counteract said movement. Nevertheless, it is advantageous and the preferred method of operation to employ a jetting action which enhances the centrifugal nature of the rotation so as to minimize the pressure drop across the apparatus and accordingly, the hydraulic head against which the liquid must be forced tangentially into the vessel. It is not to be construed that the invention is limited in any way to the particular type of orifice through which the steam is inserted into the heating zone, but rather nozzles protruding into the heating zone may be employed as well as protractions which carry the steam further into the rotating liquid than do the orifices which are formed merely by drilling holes, as for example, through the periphery of the shell or through the centrally disposed pipe.

The apparatus depicted herein has been found to have great utility in mixing operations also and accordingly, the nature of the invention is not to be limited except as indicated by the claims.

The generic nature of the invention is not to be confused with those of devices which impart a rapid rotation of the liquid about the axis of the heating zone by means of vanes or obstructions to the flow of liquid, but rather the herein invention is distinguishable therefrom by the fact that the rapid rotation is caused by a tangential delivery of the liquid to a heating zone which may also be aided by steam jetting action and that the transfer of the steam to the liquid is accomplished by the difference in densities between the steam and the liquids and the agitation caused by the steam insertion for the mixing operation. Although the flow of liquid is not laminar around the centrally disposed steam insertion element, the maintenance of a steam insertion element in a zone unobstructed by vanes or other mixing elements creates a difference in operating conditions adjacent to the points of steam insertion which greatly enhance the range of operation without the well known water hammer as compared to apparatus and methods employing obstructions to the flow thereof.

What is claimed is:

1. Apparatus comprising a closed substantially cylindrical vessel, conduit means fed from without and disposed axially within said vessel forming an annular space therein, a plurality of passageways located in said conduit means and communicating with said annular space, another plurality of passageways located in said cylindrical vessel at the diametric periphery thereof, and communicating with said annular space, means for feeding a fluid to said latter mentioned passageways, conduit means communicating within said vessel and located substantially tangential to the diametric periphery and relatively at one end of said vessel, and conduit means communicating within and located relatively at the other end of said vessel.

2. Apparatus for heating a liquid by condensing steam therein comprising a closed substantially cylindrical vessel, conduit means fed steam from without and disposed axially within said vessel forming an annular space therein, a plurality of passageways located in said conduit means and communicating with said annular space for delivering steam thereto, another plurality of passageways located in said cylindrical vessel at the diametric periphery thereof, and communicating with said annular space for delivering steam thereto, conduit means communicating within said vessel and located substantially tangential to the diametric periphery and relatively at one end of said vessel, and conduit means communicating within and located relatively at the other end of said vessel.

3. Apparatus for heating a liquid by condensing steam therein comprising a closed substantially cylindrical vessel, means for feeding said liquid tangentially within said vessel at one end thereof, means disposed centrally within said vessel for delivering steam thereto as a plurality of gaseous streams, further means disposed about the periphery of said vessel for delivering steam thereto as a plurality of gaseous streams, and means for discharging said liquid from said vessel at the other end thereof.

4. Apparatus for heating a liquid by condensing steam therein comprising a closed substantially cylindrical vessel, means disposed concentrically within and fed from without said vessel forming an annular space throughout at least a portion of the length of said vessel, said latter means having further means associated therewith to deliver said steam as a plurality of gaseous streams to said annular space, further means disposed about the periphery of said vessel for delivering steam thereto as a plurality of gaseous streams, means for feeding said liquid tangentially within said vessel at one end thereof, and means for discharging said liquid from said vessel at the other end thereof.

5. Apparatus for heating a liquid by condensing steam therein comprising a closed substantially cylindrical vessel, pipe means disposed concentrically within and fed from without said vessel forming an annular space throughout at least a portion of the length of said vessel, said pipe means having a plurality of passageways located around the periphery thereof to deliver said steam as a plurality of gaseous streams to said annular space, further means disposed about the periphery of said vessel for delivering steam thereto as a plurality of gaseous streams, means for feeding said liquid tangentially within said vessel at one end thereof, and means for discharging said liquid from said vessel at the other end thereof.

6. Apparatus for heating a liquid by condensing steam therein comprising a closed substantially cylindrical vessel, means connecting with an outside source of steam and disposed concentrically within said vessel forming an annular space throughout at least a portion of the length

of said vessel, said latter means having a plurality of passageways associated therewith for delivering said steam to said annular space as a plurality of gaseous streams, further means disposed about the periphery of said vessel for delivering steam thereto as a plurality of gaseous streams, means for feeding said liquid tangentially within said vessel at one end thereof, and means for discharging said liquid from said vessel at the other end thereof.

7. A process of continuously heating a liquid by condensing steam therein comprising feeding said liquid tangentially to one end of a confined elongated heating zone to rapidly rotate said liquid about the axis thereof, injecting steam into said zone from the periphery thereof as a plurality of gaseous streams, simultaneously injectting steam into said liquid as a plurality of gaseous streams discharging within said zone and discharging said liquid from said zone at the other end thereof.

8. A process of continuously heating a liquid by condensing steam therein comprising feeding said liquid tangentially at one end of a confined elongated heating zone that is hollow throughout at least a portion of the axial length thereof to rapidly rotate said liquid about said axis, injecting steam into said zone from the periphery thereof as a plurality of gaseous streams, simultaneously injecting steam into said zone as a plurality of gaseous streams from said hollow portion, and discharging said liquid from said zone at the other end thereof.

9. A process of continuously heating a liquid by condensing steam therein comprising feeding said liquid tangentially at one end of a confined elongated heating zone that is hollow throughout at least a portion of the axial length thereof to rapidly rotate said liquid about said axis, injecting steam into said zone from the periphery thereof as a plurality of gaseous streams, simultaneously injecting steam from said hollow portion as a plurality of gaseous streams entering said zone at the periphery of said hollow portion, and discharging said liquid from said zone at the other end thereof.

10. A process of continuously heating a liquid by condensing steam therein comprising feeding said liquid tangentially at one end of a confined elongated heating zone that is hollow throughout at least a portion of the axial length thereof to rapidly rotate said liquid about said axis, injecting steam into said zone from the periphery thereof as a plurality of gaseous streams, simultaneously injecting steam from said hollow portion as a plurality of gaseous streams discharging within the confines of said zone, and discharging said liquid from said zone at the other end thereof.

11. A process of continuously heating a liquid by condensing steam therein comprising feeding said liquid tangentially to one end of a confined elongated heating zone that is hollow throughout at least a portion of the axial length thereof to rapidly rotate said liquid about said axis, injecting steam into said zone as a plurality of gaseous streams from said hollow portion, simultaneously injecting steam into said zone from the periphery thereof as a plurality of gaseous streams, and discharging said liquid from said zone at the other end thereof.

12. A process of continuously heating a liquid by consing steam therein comprising feeding said liquid tangentially to one end of a confined elongated heating zone that is hollow throughout at least a portion of the axial length thereof to rapidly rotate said liquid about said axis, injecting steam into said zone as a plurality of gaseous streams from said hollow portion, simultaneously injecting steam from the periphery of said zone as a plurality of gaseous streams discharging therein at said periphery, and discharging said liquid from said zone at the other end thereof.

References Cited in the file of this patent

UNITED STATES PATENTS

145,538	Stoddart	Dec. 16, 1873
2,452,260	Peebles	Oct. 26, 1948
2,455,498	Kern	Dec. 7, 1948
2,545,028	Haldeman	Mar. 31, 1951

FOREIGN PATENTS

403,082	Great Britain	Dec. 7, 1933
600,807	Germany	Aug. 1, 1934
1,040,298	France	May 20, 1953