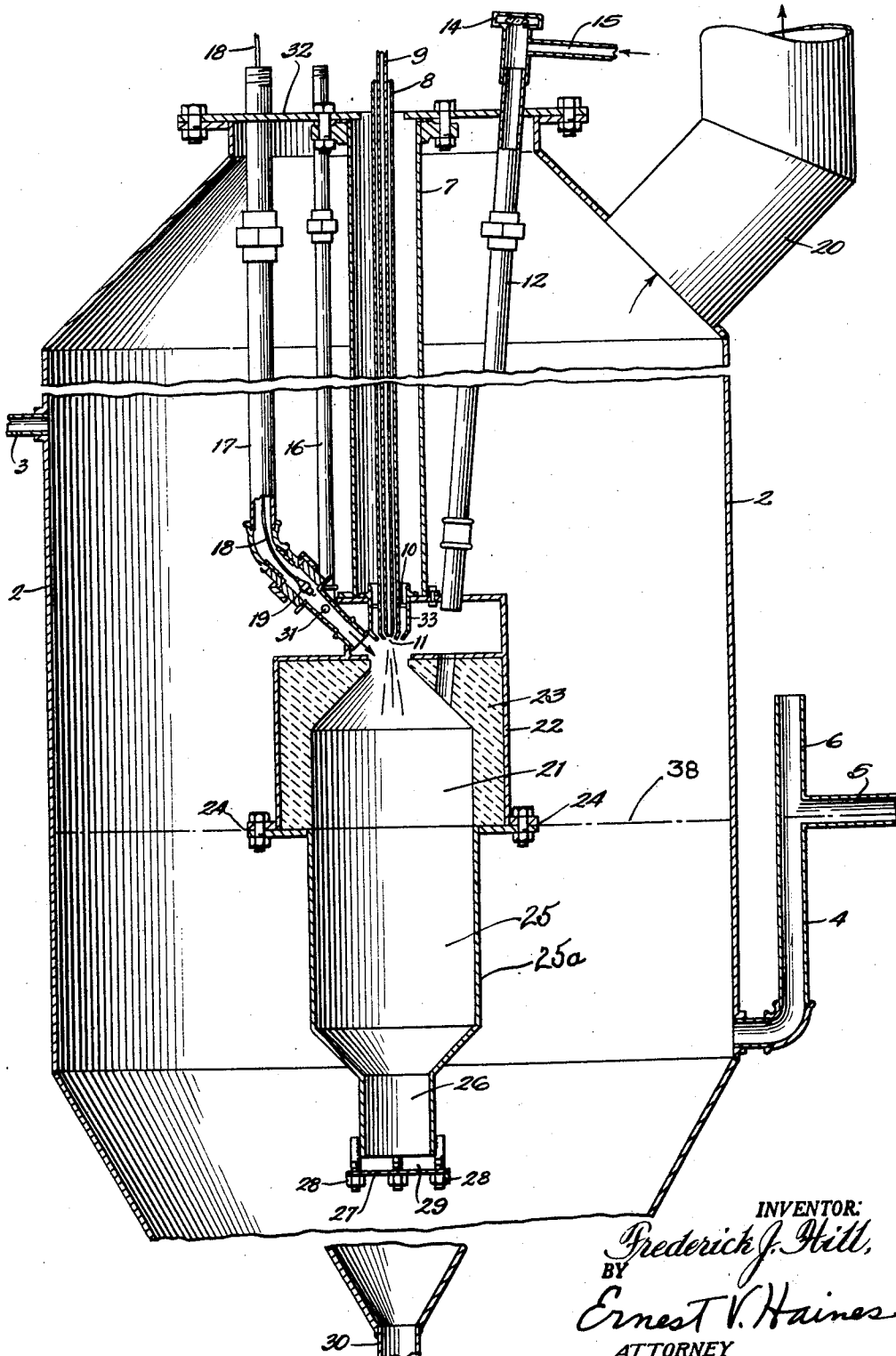


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HEATING APPARATUS EMPLOYING SUBMERGED
SECONDARY COMBUSTION CHAMBER
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2,902,029

HEATING APPARATUS EMPLOYING SUBMERGED SECONDARY COMBUSTION CHAMBER

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2 Claims. (Cl. 126—360)

The present invention relates to improvements in the design and construction of a heating apparatus especially adapted for the concentration or evaporation of liquids, wherein a direct fired burner is positioned within the container holding the liquids to be heated or evaporated, so that the gases of combustion are directly introduced into the liquid for the purpose of heating and/or evaporation of these liquids.

More particularly, the present heating apparatus, together with its accompanying burner are particularly designed and constructed so that it is possible to employ a normally liquid hydrocarbon fuel, such as #2 fuel oil or bunker C residual oil, as the burner fuel. In the past, burner mechanisms had been devised especially adapted for the combustion of normally gaseous hydrocarbon fuel, such as natural gas, or for manufactured gas. Such burner mechanisms have been employed in conjunction with the so-called submerged combustion type of operation. But in each instance the positioning of the burner with respect to the liquid being heated has been such that the burner mechanism itself and a large portion of the combustion chamber or plenum chamber has either been entirely outside of the container holding the liquid, or if it is within the container holding the liquid, then only an insignificant amount of the accompanying combustion chamber has been placed below the liquid level, for example below the level of the liquid to be heated or evaporated. Thus, for example, Swindin, U.S. 2,638,895, although employing a normally liquid hydrocarbon fuel and permitting the combustion gases to emerge below the liquid surface, so constructs his burner that the entire burner mechanism including the combustion chamber is situated entirely outside of the liquor tank which contains the liquid materials to be heated. Thus, the control of the temperature of the ignition zone and the combustion zone is entirely carried out by means of air. The same is true of See et al., U.S. 2,118,479 and U.S. 2,174,533, the burner mechanism in this case also being wholly located outside of the liquid tank into which the hot combustion gases are to be introduced.

The shortcomings of the burner designs heretofore devised for use of normally liquid hydrocarbon fuel do not exist in the case of burner devices employing normally gaseous hydrocarbon fuel. Thus, for example, Donnecke et al., U.S. 2,159,759, discloses a satisfactory device employing normally gaseous hydrocarbon fuel, or manufactured gas as fuel, to a submerged burner in which the burner mechanism itself is entirely below the surface of the liquid to be heated or evaporated. Heretofore, however, this type of operation when employing normally liquid hydrocarbon fuel has not been thought possible due to difficulty in maintaining and controlling a proper temperature for combustion of the normally liquid hydrocarbon fuel. For example, a temperature sufficiently high to maintain combustion, but not sufficiently high as to melt or corrode the materials of construction of the burner and combustion zones has not heretofore been possible for liquid fuel burners contained wholly

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within the heating and/or evaporation units. Additionally, surging and pulsating of back pressures within the combustion zone due to rapid changes in the liquid level tended to extinguish the flame.

It is an object of the present invention to employ a burner having at least a substantial portion of its combustion zone below the liquid level of the material to be heated, but wherein the entire burner mechanism and combustion zones are situated within the container holding the liquid to be heated.

It is a further object of the present invention to design the upper portion of the combustion zone, of materials, such that upon splash cooling by the liquid being heated, the temperature of combustion will be maintained sufficiently high to maintain combustion during operation of the burner with normally liquid hydrocarbon fuel, but not sufficiently high so that the splash cooling is ineffective for removing the necessary quantities of heat so as to avoid deleterious action on the burner mechanism and combustion zone construction materials.

It is a further object of the present invention to position the entire burner mechanism including the zones of combustion and exits for the combustion gases entirely within the heater or evaporator chamber so as to more efficiently utilize all of the heat of combustion in heating up and/or evaporating the liquid through an efficient transfer of heat to the liquid maintained in the heater or evaporator, and to minimize pulsations and surges of back pressure within the combustion zones in order to avoid extinguishing the burner flame.

In order to accomplish these objects as well as others which will be readily apparent to those concerned with the design, manufacture, and operation of burners of the so-called submerged combustion type and wherein those burners are fired with normally liquid heavy hydrocarbon fuel of the heavy distillate type, or of the residual type, there is provided a suitable container capable of holding liquids having positioned therein an oil burner of the so-called jet or gun type, the burner (of conventional design) permitting combustion of the air-fuel combustible mixture in a primary combustion zone suitably lagged or surrounded by refractory material, which in turn is held in place by means of a suitable metallic housing. Co-extensive with and as a continuation of the primary combustion zone, there is a further or secondary combustion zone or area for moving the hot combustion gases ultimately into the liquid being heated. This zone, however, is not provided with any lining of refractory materials, but is defined or confined by a relatively thin metallic wall which is constructed of material having relatively efficient heat conducting properties, so that the heat may be dissipated rapidly through the walls, while the gases may then be further conducted to an exit neck, of relatively smaller cross sectional area than either of the two combustion zones, and having one or more outlets of variable cross sectional area whereby it is possible, because of the exit area restricted and variable cross sectional area, to impart greater velocity to the combustion gases and to quickly introduce them directly, without imparting marked surging, into the liquid being heated. One of the important features of the present novel construction and design lies in the fact that the secondary combustion zone differs fundamentally in design and materials of construction from that of the primary combustion zone. The purposes to be served and the positioning of these two combustion zones are significantly and wholly different from similar zones employed in the past. It is a significant feature of the present invention that the juncture of the primary combustion zone with the secondary combustion zone be located at, or approximately at, the air-liquid interface when the liquid in the heating apparatus is maintained

in a quiescent condition and if the burner and its combustion zones are stationary in the heater or evaporator. Heretofore, it has not been thought possible to operate a burner fired with normally liquid heavy hydrocarbon fuel in such a manner, because no means had been satisfactorily found for controlling the temperature of the combustion zone or the oil being fed to the zone within combustible limits and without having the heated liquid undergo backfire or partial suction so that it contacts the hot refractory materials in the primary combustion zone. Such contact, particularly in the case of many types of liquids which are heated, i.e., pickle bath liquids, phosphoric acid, monocalcium phosphate, solutions containing dissolved inorganic salt, such as magnesium chloride, sodium sulfate, potassium chloride, sodium chloride or similar solutions, which liquids may be especially evaporated or heated in applicant's apparatus, gives such excessive reaction with and corrosion of the refractory materials lining the combustion zone as to make the entire burner construction practically useless and inoperative for more than a very few minutes.

It will, of course, be realized that the proper air and oil pressure is required to be maintained in order to prevent the snuffing out of the burner flame. Another expedient which directly contributes to the successful operation of a burner for normally liquid hydrocarbon fuel in the present device lies in the fact that a suitable variable opening is provided for the release of the gases of combustion directly into the liquid being heated. This is accomplished either through the use of a variable opening orifice or through the use of a baffle across a fixed opening, which baffle can be moved to provide the exact opening required, so that the gases of combustion are smoothly introduced into the liquid being heated, i.e., without excessive bumping, which is sometimes experienced in operating evaporators and heaters of the submerged combustion type.

The effective variability of the size of the opening of the fixed orifice from the secondary combustion zone is achieved by means of an adjustable baffle across the opening which may be adjusted to various distances away from the opening. Usually, the adjustment, which must be carefully achieved, is made so that the bubbles of combustion gases entering the liquid to be heated are fairly finely divided. If large bubbles are introduced into the heated liquid, there is a great pulsation with respect to the average level of the liquid being heated, and for this reason a large amplitude of pulsations occurs instead of slight amplitude of pulsations. This causes extreme and sudden changes in back pressures in the primary combustion zone, which, of course, contains the flame. If too great an amplitude or too great a back pressure is attained, the flame is extinguished. This has been one of the reasons why in the past it has not been possible to achieve a satisfactory operation in burners of this type using heavy or residual fuel oils as the fuel. By regulating the amplitude of the back pressure on the primary combustion zone, and consequently on the flame, through the adjustment of the baffle, it has been discovered that it is possible to achieve a satisfactory flame propagation and a satisfactory operation of a submerged burner unit of the type herein described. For each burner type selected, and for each particular combined primary and secondary combustion unit manufactured, a specific adjustment of the area between the secondary chamber opening and the baffle through which the combustion gases leave the unit must be made in order to minimize the pulsating amplitudes causing the back pressure; but once adjusted, by means of nuts on the baffle supports, and once the proper size of the openings at the bottom of the secondary combustion unit is determined and set, a flame stability is likewise achieved. In the use of low volatility or residuum type fuels, it is necessary to minimize the pulsating effect in the secondary and primary combustion zones in order to maintain uni-

form and consistent fuel atomization and fuel-air mixing action for successful and efficient operation of the burner unit.

Another significant result, which is a vast improvement over previous heaters of this type and makes possible the successful operation of an oil fired burner of this type, lies in the method of operation wherein the gases emerge from the second combustion zone directly into the liquid being heated and through the resultant turbulence they continuously cause the liquid being heated to splash over and come in contact with the exterior surfaces of the primary combustion zone. In this way, the liquids are receiving the heat from the primary combustion zone and the primary combustion zone is thus losing heat, thus insuring that its materials of construction will not be subjected to temperatures higher than those found safe for the successful maintenance of the burner and combustion structures. The transfer of heat from the primary combustion zone to the splashing liquors being heated is not sufficiently great, however, nor sufficiently rapid to lower the temperature of the combustion zone below that required for maintaining combustion of the atomized or vaporized fuel oil. Also, the thickness of the refractory material lining in the combustion zone need not be excessive nor need it be so great as would be required in the case where no splashing of the liquid is provided for. It will be readily apparent, however, that there is no provision made for cooling the refractory material by means of air, the sole cooling effect being by means of the liquid being heated. Prior devices where normally liquid hydrocarbon fuel is utilized, do not have the primary combustion zone either in whole or in part below the level of the liquid being heated, when the liquid is in the quiescent state, for the reasons heretofore stated.

The tank or container holding the liquid to be heated may be of any desired form. It may be conical; it may be cylindrical, or rectangular, either with the long axis vertical or horizontal, or it may be of any suitable design, so long as the burner is positioned within the tank or container with the quiescent liquid level being at, or approximately at, a juncture of the primary combustion zone with the secondary combustion zone at start up or shut off of the burner. The jet or gun type oil burner mechanism may be of any suitable conventional design, the invention not being primarily related to the type or design of the oil burner employed. The tank and burner parts may be fabricated of any suitable metallic material, but in cases where corrosive liquids are to be heated, such as pickling liquors, phosphoric acid, and the like, it is desirable to use the non-corrosive or acid resistant materials for construction, i.e., Monel metal, or stainless steel, which may be used as a fabrication material for those portions of the device or apparatus coming into contact with the liquids being heated.

In general, the combined lengths of the two combustion zones to the inner diameter of the combustion zone will average between about 2.5:1 and about 6:1, preferably between about 3:1 and about 5:1. These ratios of length to diameter are not critical. Other ratios outside of these ranges may be employed, but, in general, it has been found that efficient transfer of heat is effected if combustion chambers of this size are employed. It is preferred, however, that the exit orifice or orifices for the hot gases of combustion be readily adjustable for the reason that the viscosities of various types of liquids being heated will vary greatly. It is well within the skill of the operator to adjust the exit orifice so as to give a minimum of bumping and back pressure as the hot gases enter the liquid being heated.

The accompanying drawing shows partly a sectional elevation and partly a diagrammatical elevation of the spatial arrangement of the component parts of the heating apparatus.

More specifically, a container suitable for holding liq-

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uids to be heated or to be concentrated by evaporation is provided with a liquid feed inlet 3, and product outlet 4, for the heated or concentrated liquid. The actual liquid product is discharged through discharge port 5 which is provided with a vent pipe 6, which permits discharge of the liquid through port 5 by gravity. Additionally, an outlet or stack 20 is provided near the upper end of container 2 for gases of combustion and for vapors which may have been evaporated from the liquid. To facilitate clean-out or minor internal repairs or adjustment within container 2 or the burner mechanism contained therein, clean-out port 30, which may be provided with a valve (not shown), allows for drainage of residual liquid in container 2.

Within container 2 means are provided for positioning a combination burner and combustion chamber. The burner, generally designated 7, consists of a tubular housing within which pipe 9 containing suitable liquid fuel, such as Number 2 or 3 heating oil or Bunker C, is forced by pressure regulating means (not shown) to the orifice, or jet 11. By the outer pipe 8 and housing 7 air is introduced under pressure by means (not shown) so that it supports combustion of the atomized fuel coming through nozzle 11. The nozzle structure is of conventional design. More particularly, it may be of the type shown in Figure 3 of U.S. Patent 2,134,471, or the equivalent thereof. Liquid fuel atomizing and burner mechanisms, generally designated as 7, are of conventional design and may be of the conventional low pressure or high pressure oil burner design. In order to position the fuel atomizing nozzle 11 within the aperture of the burner cup 33, and because of the considerable distance between the upper support of the burner mechanism in cover 32 and the burner cup 33, guide members 10 secured to the pipe 8 and free to slide on the inner surface of cup 33 are employed. By suitable raising or lowering of the orifice 11, with respect to stationary burner cup 33, the proper degree of atomizing and vaporization of the liquid hydrocarbon oil with the proper amount of air is attained. Thus, substantially complete combustion of the fuel is secured through adjustment of a nozzle 11. Pipe 17, containing ignition wire 18, connects with a spark-plug or other conventional sparking device 19. Pipe 16 is a conduit for a combustible air hydrocarbon gas mixture which is introduced into pipe 17 at outlet 31. This provides, upon ignition by sparking device 19, a pilot flame for igniting the atomized or vaporized fuel emitted through orifice 11. Conduit 12, provided with sight glass 14 and air inlet 15, serves the dual purpose of providing a look tube for inspection to see whether or not, by reflection, the pilot flame is on and at the same time to observe the burning characteristics and flame of the atomized oil so that proper adjustment of oil and air mixture may be made.

In a large installation wherein many thousands of gallons of liquid are heated or evaporated, tubes 8, 9, 12, 16, and 17 may all be consolidated within housing 7, which is supported by cover 32 to produce a more compact unit and to facilitate removal of the entire structure within container 2 by removal of cover 32. When it is necessary to make repairs or adjustments within the burner mechanism, all of these structures may be removed as a single unit through the opening closed by cover 32. Additionally, the burner mechanism shown in the present drawing as being within supporting column 7 can also be independently removed without resorting to removing the remaining structures, i.e., the combustion chambers and auxiliary conduits previously described.

The combusting air-fuel mixture is directed into primary combustion chamber 21 within housing 22 which is lined or lagged with suitable refractory material 23. Dead air space immediately below look tube 12 during operation of the burner is purged by forcing air through inlet pipe 15 in order to prevent blow-out of the main burner flame. If desired, however, additional air for

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combustion may be introduced through inlet 15. As will be hereinafter more fully explained, the thickness of the refractory material 23 and the height of combustion chamber 21, which is lined with refractory material, may be varied, depending upon the particular heating or evaporation requirements of any particular installation. In general, it may be said that a thick lining of refractory material provides a cooler surface on housing 22, provides less conductivity of heat through the refractory material, and much higher temperatures on the inner refractory lining. Conversely, any elongated chamber 21 having a relatively thin lining of refractory material 23, necessitates the use of considerably increased cooling means, i.e., splashing of liquid, contacting the housing 22. The proper refractory lining temperature necessary to maintain good ignition of the oil-air mixture must be maintained at the inner refractory wall.

Through liquid-tight seal 24 a secondary combustion chamber 25 is bolted to or otherwise sealed to, is co-extensive and continuous with primary combustion chamber 21. It is of substantially the same cross sectional area and may be of any desired length, as previously discussed, provided it is sufficiently elongated to allow efficient dissipation of the heat through the walls 25a of combustion chamber 25 to the surrounding liquid and to also provide for submergence of the exit orifice 29 for the combustion gases below the liquid level so that a most efficient dispersion of hot gases and transfer of the heat of the combustion gases to the liquid are secured. Combustion chamber 25 may be of the same cross sectional area as combustion chamber 21. It may also, in order to provide increased velocity for the hot combustion gases, be of a lesser cross sectional area than primary combustion chamber 21. In any event, it has been found to be advantageous to supply the combustion chamber 25 with an exit tube or neck 26, which is of considerably lesser cross sectional area than either combustion chamber 21 or combustion chamber 25. A preferred modification of the present invention involves the use of an adjustable baffle plate 27, secured by bolts 28. Opening 29 may be so sized as to secure efficient evolution of the combustion gases without undue surging or bumping of the liquid being heated. The adjustment and positioning of the baffle plate 27 determines the size of the outlets for the combustion gases. As previously stated, the proper cross sectional area for the outlets for the combustion gases is determined with reference to the amplitudes of pulsations of the back pressure in the primary and secondary combustion zones. Generally speaking, a fine dispersion of combustion gases into the liquid being heated results in the mean level of the liquid being fairly stable and thus achieves a minimizing of pulsations in the lower portion of the secondary combustion zone. This results in maintaining a stable flame propagation and avoids the extinguishing of the flame through the build up of sudden and excessive back pressure. The adjustment of the cross sectional area of the orifices for the exit gases is made with two purposes in mind: one, to avoid extinguishing the flame through sudden and excessive back pressure, and two, to have a sufficient agitation of the liquid being heated to maintain a splashing effect on the surface 22 of the primary combustion zone to attain partial cooling of that zone. Adjustment of the bolts 28, supporting baffle 27, secures the proper cross sectional area for the variable opening 29 to accomplish these two purposes. Additionally, pipes (not shown) may be placed radially from exit tube 26 and these in turn may have orifices of variable cross sectional area so that efficient distribution of the combustion gases throughout the liquid may be secured.

It may be desired that the burner and combustion zones as a unit be raised or lowered with respect to the quiescent liquid-air interface once the burner unit has been placed in operation. It may be lowered in order to obtain greater splash cooling effect for the primary combustion chamber and greater thermal conductivity efficiency for

the secondary combustion chamber. It may be raised in order to accomplish the reverse effects, i.e., less splash cooling on the primary chamber, and less bumping of the unit due to uneven emergence of the hot combustion gases into the heated liquid. Also, less heat transfer through the secondary combustion chamber walls is effected in this manner. At any event, the burner unit should be raised or remain sufficiently high upon ceasing operation, so that the liquid upon returning to its quiescent level does not contact the refractory lining of the primary combustion zone.

The positioning of the combustion chambers 21 and 25 with respect to their point of juncture 24 is critical in the successful operation and useful life of the submerged burner unit. This is for the reason that when the liquid to be heated in unit 2, with the burner mechanism shut off, is in a quiescent state and the liquid or slurry being heated or evaporated is of a corrosive nature, the refractory material 23, and the delicate parts of the burner mechanism, for example, the orifice 11, should not at any time be in contact with liquid or slurry being heated because of the possible destructive action of the liquid on these structures. The positioning of the primary combustion zone 21 is therefore of a critical nature, particularly in cases where, for example, phosphatic solution such as phosphoric acid or mixtures containing substantial amounts of phosphoric acid are being heated or evaporated. The same consideration holds true where solutions having a tendency toward chemical reaction on the materials of construction are being heated or evaporated. The particular mechanism described is especially useful in such operations. When the container 2 and burner 7 are being prepared for initial operation, the liquid level 38 should be adjusted so that it does not rise above joint 24. Although in operation, considerable foaming, bubbling, and turbulence are experienced, the burner and combustion chamber design is especially suited for taking advantage of this turbulence in that a certain amount of splashing occurs on the surface 22, at least to a sufficient extent to effectively remove the required quantities of heat being conducted from primary combustion chamber 21 through refractory 23 to the surface of the housing 22. It will be appreciated that the relationship of the primary and secondary combustion chambers and the outlet tube 26, together with the positioning of exit orifice 29 relative to these parts, results in the products of combustion being expelled laterally into the liquid surrounding the exit orifice whereupon the buoyancy of the bubbles of combustion gases causes them to commence to rise adjacent to and encircling the metal wall of the secondary combustion chamber. Varying the cross sectional area of exit orifice 29, as heretofore noted, alters the dispersion of the gases into the liquid such that the desired splashing of the liquid against the exterior of the primary combustion chamber by the combustion gas bubbles breaking the liquid surface adjacent the perimeter of the lower end of the primary combustion chamber may be obtained. External surfaces 22 and 25a are unobstructed so that the liquid is free to contact them while being agitated. Insufficient quantities of heat through such splashing action may permit housing 22 to become too hot and thus decrease its useful life. Too large an amount of heat is not removed in this manner through the specific design of combustion chamber 21 so that there is very little if any danger of cooling chamber 21 to such an extent that the oil flame produced in chamber 21 will be extinguished through a lowering of the temperature of the ignition tile or refractory 23 to such an extent that the oil vapors are not readily ignited. The walls of secondary combustion chamber 25 are relatively thin which permits a high rate of heat transfer to the relatively cool liquid which is being heated. This eliminates destruction of the combustion chamber wall 25a and increases its useful life.

The liquid level diagrammatically shown at 38, although

it must not rise above joint 24 when the burner is not in operation, may be held if desired at any point below juncture 24 as long as orifice 29 for the combustion gases is maintained at the required depth below the surface of the liquid being heated to insure that the hot combustion gases are passing through the liquid before leaving container 2 through stack 20. Obviously, a most efficient transfer of the heat of the combustion gases to the liquid necessitates the maintenance of the quiescent liquid level 38 as nearly as possible to joint 24. Joint 24 may be lowered below level 38 after the burner is in operation as long as it is raised at least as high as level 38 before the burner 7 is shut off. The determination of the liquid level 38 is only indirectly related to the point of outlet 5 of the product. Outlet 5 is positioned so that the quiescent level 38 of the liquid within container 2 is not above the junction 24 when the burner is not operating, permitting the liquid in container 2 and surrounding the combustion chamber 25 to flow into and upward into the secondary combustion chamber 25 to joint 24. The important factor is to prevent the liquid material from rising above the junction 24 into the refractory-lined combustion chamber 21, which would permit the corrosive chemicals to contact the hot refractory lining 23 and thus decrease its useful life.

This application is a continuation-in-part of my co-pending application Serial No. 410,606 filed February 16, 1954, and entitled Heating Apparatus, now abandoned.

Having thus fully described the character of the instant invention, what is desired to be protected by Letters Patent is:

1. A heating apparatus for liquid comprising a container having a liquid inlet for introduction of liquid to be heated and an outlet in the upper portion thereof for discharge of vapors and products of combustion from said container, metallic walls forming an upstanding combustion zone within said container including an upper primary combustion chamber and a lower secondary combustion chamber communicating with the lower end of said primary combustion chamber, said metallic walls being substantially unobstructed along the exterior of the upstanding combustion zone, said primary combustion chamber having a lining of refractory material and said secondary combustion chamber being unlined with the inner surface of said secondary combustion chamber forming a continuation of the inner surface of said lining to form said secondary combustion chamber of a cross sectional area substantially equal to that of the interior of said lining at the junction between said primary and secondary combustion chambers, a liquid hydrocarbon fuel burner in said container and having a fuel atomizing nozzle directed downwardly into the upper end of said primary combustion chamber, an outlet tube for products of combustion communicating with and extending downwardly from the lower end of said secondary combustion chamber, a baffle horizontally disposed beneath and spaced from the lower end of said outlet tube to provide an exit orifice for products of combustion opening laterally outwardly relative to the longitudinal axis of said combustion zone, means to withdraw liquid from said container and maintain the quiescent liquid level within said container at approximately the junction between said upper primary combustion chamber and said lower secondary combustion chamber, and means mounting said baffle to be adjustable relative to the lower end of said tube to vary the cross sectional area of said exit orifice to alter the splashing of liquid against said upper primary combustion chamber caused by entry of products of combustion into such liquid from said exit orifice below the surface of such liquid.

2. A heating apparatus for liquid comprising a container having a liquid inlet for introduction of liquid to be heated and an outlet in the upper portion thereof for discharge of vapors and products of combustion from said container, metallic walls forming an upstanding com-

bustion zone within said container including an upper primary combustion chamber and a lower secondary combustion chamber communicating with the lower end of said primary combustion chamber, said metallic walls being substantially unobstructed along the exterior of the upstanding combustion zone, said primary combustion chamber having a lining of refractory material and said secondary combustion chamber being unlined with the inner surface of said secondary combustion chamber forming a continuation of the inner surface of said lining to form said secondary combustion chamber of a cross sectional area substantially equal to that of the interior of said lining, a liquid hydrocarbon fuel burner in said container and having a fuel atomizing nozzle directed downwardly into the upper end of said primary combustion chamber, an outlet tube for products of combustion communicating with and extending downwardly from the lower end of said secondary combustion chamber, said tube having a lesser horizontal cross sectional area than said secondary combustion chamber such that the walls of said outlet tube are recessed inwardly beneath the secondary combustion chamber disposed thereabove, means to withdraw liquid from said container and maintain the

quiescent liquid level within said container at approximately the junction between said upper primary combustion chamber and said lower secondary combustion chamber, and an adjustably baffled exit orifice of variable cross sectional area for combustion products at the lower end of said outlet tube to alter the splashing of liquid against said upper primary combustion chamber caused by entry of products of combustion into such liquid from said exit orifice below the surface of such liquid.

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