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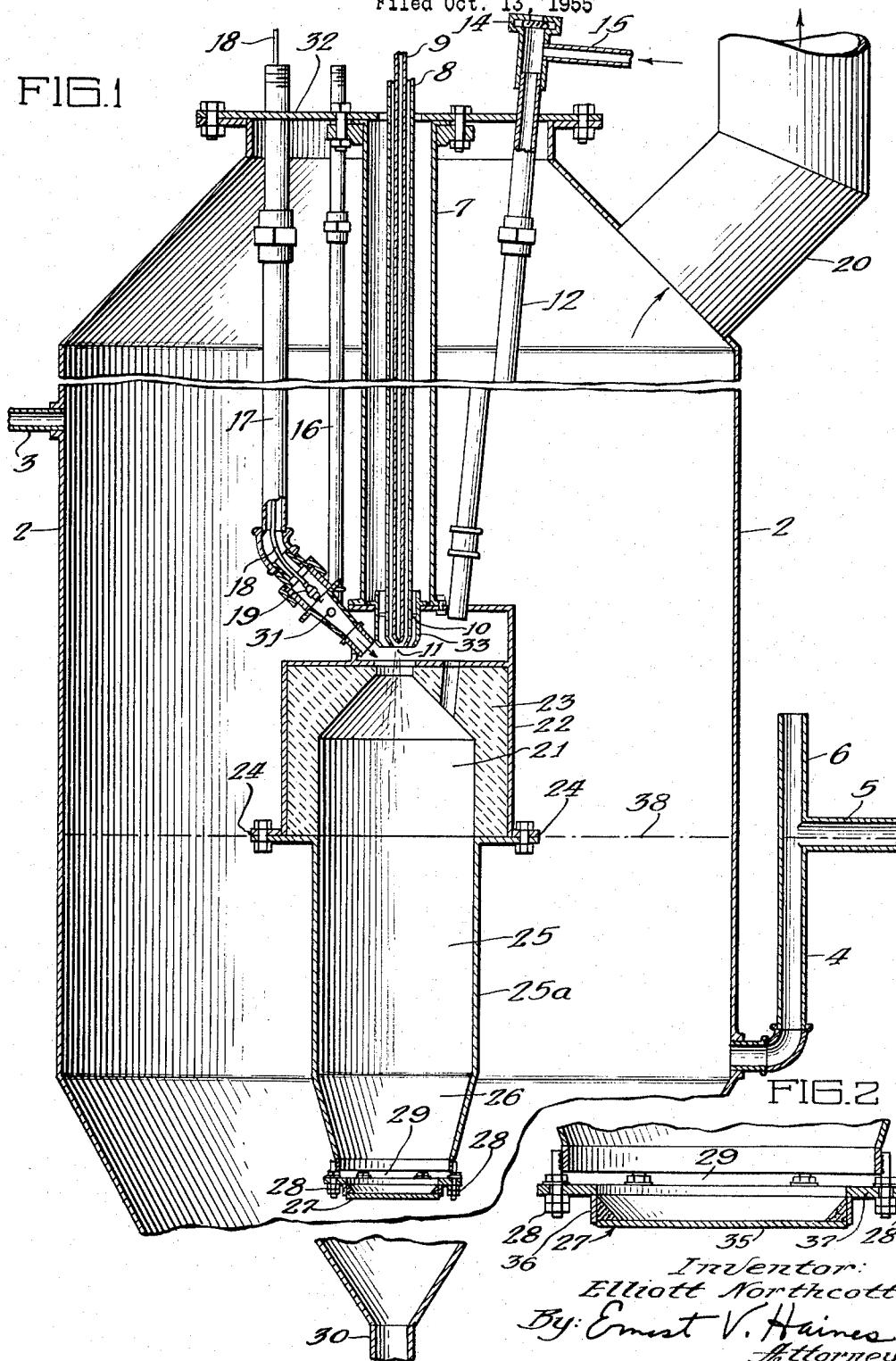
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2,900,975

SUBMERGED HEATING APPARATUS

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FIG. 1



1

2,900,975

SUBMERGED HEATING APPARATUS

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This invention relates to the art of concentrating liquors. More particularly, this invention relates to improvements in the design and construction of heating apparatus wherein a direct fired burner is positioned within a container for liquids to be heated or evaporated, so that the gases of combustion may be directly introduced into the liquid for the purpose of heating and/or evaporation.

In the past, burner mechanisms have been used commercially which are especially adapted for the combustion of normally gaseous hydrocarbon fuel such as natural gas or manufactured gas. Such burner mechanisms have been employed in conjunction with the so-called submerged combustion type of evaporation. The positioning of the burner with respect to the liquid being heated in such apparatus arrangements has been such that the burner mechanism itself and a large portion of the combustion chamber or plenum chamber has been either entirely outside of the container holding the liquor, or if it has been within the container holding the liquor then only an insignificant portion of the combustion chamber has been placed below the liquid level. Thus, for example, Swindin U.S. 2,638,895, employing a normally liquid hydrocarbon fuel and permitting the combustion gases to emerge below the liquid surface, so constructed his burner that the entire burner mechanism including the combustion chamber is situated entirely outside of the tank which contains the liquid to be heated or evaporated. Control of the temperature of the ignition zone and the combustion zone in such an apparatus arrangement is entirely carried out by control of the air entering the combustion zone.

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. Operation with normally liquid hydrocarbon fuel has not been thought possible heretofore due to difficulty in maintaining and controlling a proper temperature for combustion, i.e., temperature sufficiently high to maintain combustion but not sufficiently high to melt or to accelerate corrosion of the materials of construction.

It is an object of the present invention to provide a liquid heating mechanism of improved design, a substantial portion of whose combustion zone will extend below the liquid level of the material to be heated and wherein the entire burner mechanism and combustion zones are situated within the container holding the liquid to be heated.

It is another object of this invention to provide gas discharge means of improved design whereby uneven discharge of gaseous combustion products from the combustion chamber is minimized.

It is a further object to provide a combustion gas discharge mechanism such that when submerged, a reasonable operating range of back pressures will be maintained on the combustion zone.

It is a further object of the present invention to de-

2

sign the upper portion of the combustion zone so that splash cooling by the liquid being heated will not be sufficiently effective to lower the temperature of combustion below that necessary for continuous operation of the burner with normally liquid hydrocarbon fuel.

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 hydrocarbon fuel of the heavy distillate or residual types, 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 permitting combustion of the air fuel combustion mixture in a combustion zone suitably lagged or surrounded by refractory material. Co-extensive with and as a continuation of the primary combustion zone, there is a secondary zone. This zone may or may not be provided with a lining of refractory materials. If the secondary zone is defined by a relatively thin metallic wall which is constructed of material having relatively efficient heat conducting properties, the metallic wall may if desired be segmented so that the lower portion of the metallic wall may be flanged to the metallic cover for the primary zone for easy disassembly in case of corrosion or operating difficulties due to plugging of gas outlets, warping of baffles and the like. Where the primary and secondary combustion zones are both provided with lining, it is generally preferred to make the lining continuous such as can be provided by an air set refractory which can be pounded into position and shape. Such a lining is preferred because of its greater density, greater corrosion resistance and lack of seams through which corrosive liquids may "eat." From the combustion zones, the combustion gases are conducted to an exit neck of relatively smaller cross sectional area than either of the combustion zones whereby the gases acquire velocity for quick introduction directly into the liquid being heated. When the secondary combustion zone is defined merely by a metallic shell, it is advantageous to have the juncture of the primary and secondary combustion zones 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.

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 the 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. Heretofore the outlet has been controlled by a variable opening orifice or through use of a straight baffle plate across a fixed opening which baffle was adjustable to provide the exact opening required. This arrangement has proven unsatisfactory because the plates warped closing off one side of the gas escape path, thus causing all the combustion gases to pass through a limited area with consequent burning out of the metallic portions around the gas escape path, remaining open after warping, or because of bumping of the liquid due to mal-distribution of the gases and because once the burner was shut off, ignition of fuel was impossible without pulling the unit from the submerged position. In the new apparatus arrangement, a so-called dished baffle of design hereinafter described is positioned at the outlet to a fixed opening from the combustion zones. This dished baffle is arranged to give an adjustable opening between the lip of the restricted opening from the combustion zone and the lip of baffle,

For evaporation of liquids, such as phosphoric acid having a specific gravity in the range of about 1.2 to about 1.7, this opening between the baffle and the lip of the burner unit generally ranges from about $\frac{1}{2}$ inch to about $\frac{3}{4}$ inch, the former making for easy ignition conditions but higher system back pressures while the latter gives lower back pressure but more difficult ignition conditions.

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 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 liquids 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 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 ratio of 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.

Referring to the accompanying drawing Figure 1 shows partly a sectional elevation and partly a diagrammatical

elevation of the spatial arrangement of the component parts of the heating apparatus and Figure 2 is an enlarged view of the lower part of the combustion chamber of the apparatus shown in Figure 1.

More specifically, a container 2 suitable for holding liquids 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 sparkplug 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 resort 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 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 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. At 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 dished baffle plate 27 secured to the housing 7 by bolts 28. Dished baffle plate 27 is generally circular and as shown in Figure 2 is made up of a flat base section 35 from which extends a rim 36. Rim 36 has formed preferably integrally therewith an outwardly extending lip 37. 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. Fixed openings may be used instead of the variable-spaced baffle plate 27 by merely sealing the entire opening 29 and perforating the tube 26 with fixed orifices in such number and location as desired. Additionally, pipes (not shown) may be placed radially from exit tube 26 and these in turn may have orifices of fixed diameter or variable cross sectional area so that efficient distribution of the combustion gases throughout the liquid may be secured.

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, phosphoric solution such as phosphoric acid or mixtures containing substan-

tial 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. 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 of the product 5. Outlet 5 is positioned so that the quiescent level 38 of the liquid within container 2 is not above the junction joint 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.

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 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 and spaced beneath the lower end of said outlet tube, said baffle having a dish central portion surrounded by a generally planar lip, said dish central portion facing upwardly toward the lower open end of said outlet tube and said lip lying beneath and aligned with the lower end of said outlet tube, adjustable means connecting said lip and the lower end of said tube to determine the spacing between said baffle and the lower end of said outlet 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 such exit orifice below the surface of such liquid, and 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.

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 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 lining of refractory material and said secondary combustion chamber being unlined with the inner surface of said secondary combustion cham-

ber 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 and spaced beneath the lower end of said outlet tube, said baffle having a generally flat base and an upstanding rim extending around the perimeter of said base with a generally planar lip connected to and extending outwardly from the upper end of said rim, said lip lying beneath and aligned with the lower end of said outlet tube, adjustable means connecting said lip and the lower end of said tube to determine the spacing between said baffle and the lower end of said outlet 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 such exit orifice below the surface of such liquid, and 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.

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