March 22, 1966 WALTER G. SEE ETAL 3,241,548

SUBMERGED COMBUSTION APPARATUS EMBODYING A SHALLOW, CLOSED, RECTILINEAR TANK AND UPSTANDING LIQUID SEPARATION CHAMBER AT ONE END THEREOF

Filed May 7, 1962 2 Sheets-Sheet 1

FIG. 1

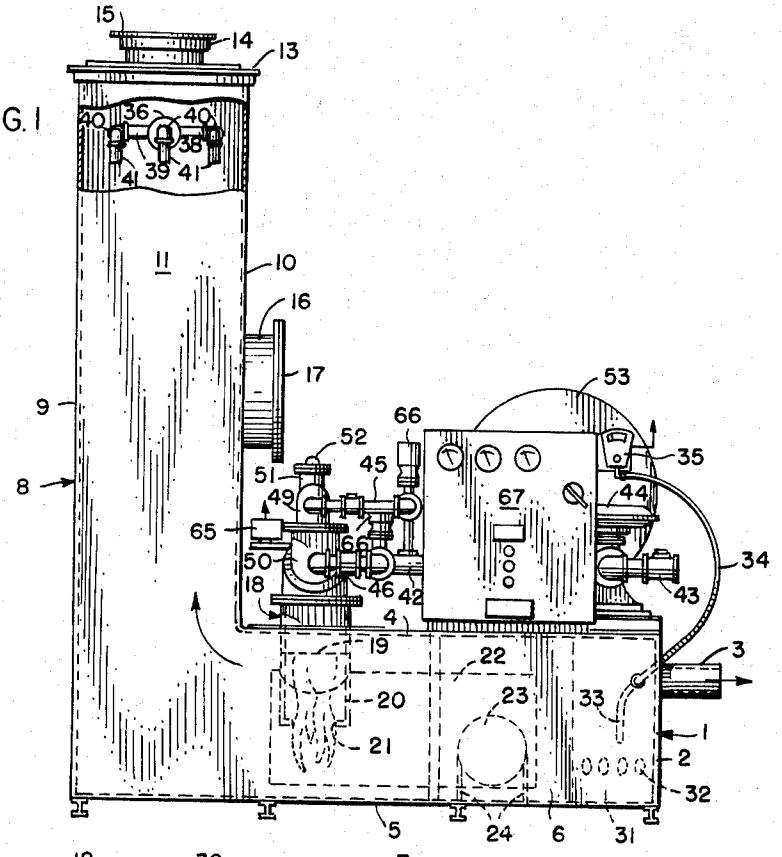
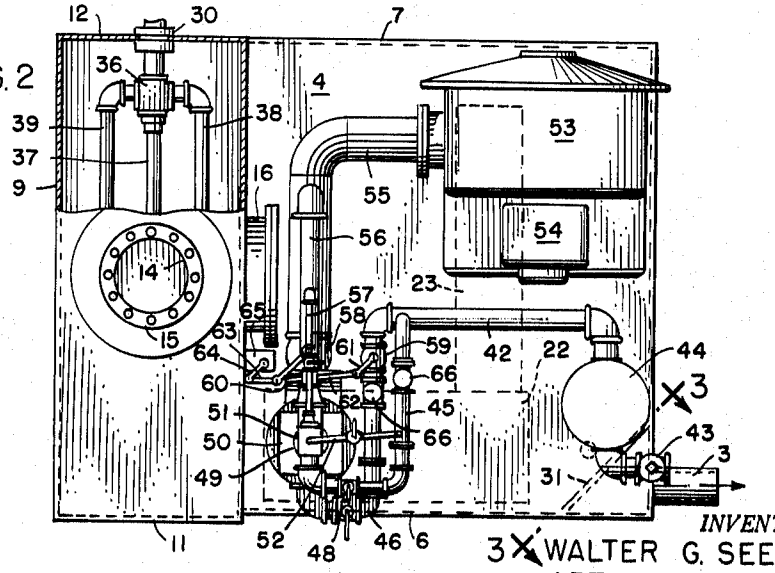


FIG. 2



INVENTORS:
WALTER G. SEE
ARTHUR WILLIAMS
BY Marzall, Johnston, Cook & Root
ATT'YS

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FIG. 3

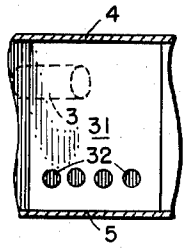


FIG. 6

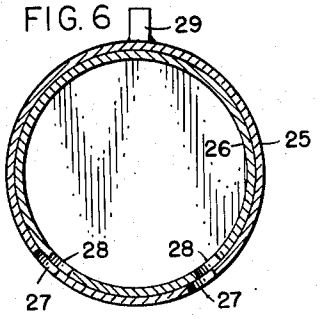


FIG. 4

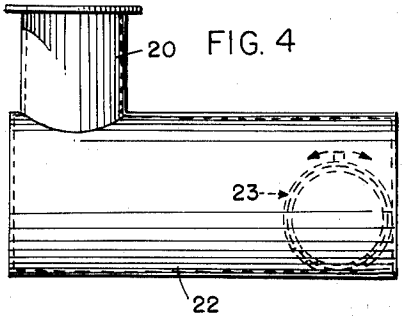


FIG. 5

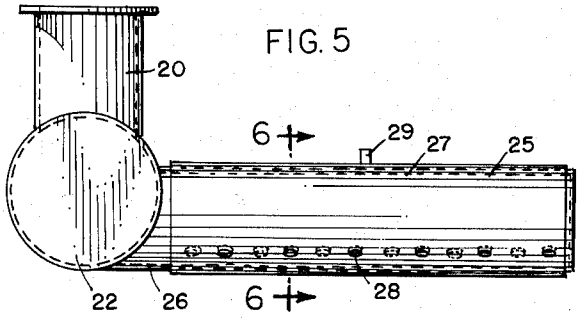
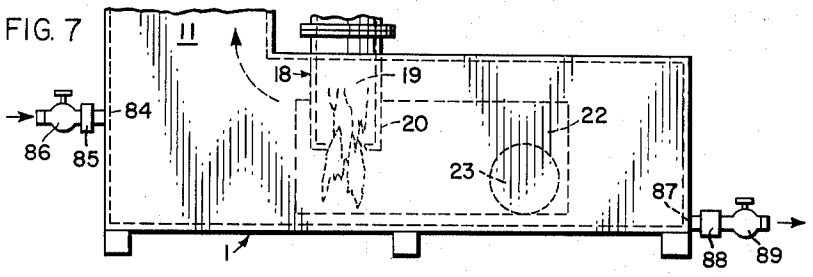


FIG. 7



INVENTORS:
WALTER G. SEE
ARTHUR WILLIAMS
BY Marzall, Johnston, Clark & Root
ATT'YS

United States Patent Office 3,241,548 Patented Mar. 22, 1966

3,241,548

SUBMERGED COMBUSTION APPARATUS EMBODYING A SHALLOW, CLOSED, RECTILINEAR TANK AND UPSTANDING LIQUID SEPARATION CHAMBER AT ONE END THEREOF

Walter G. See, Crown Point, and Arthur Williams, Munster, Ind., assignors, by mesne assignments, to Selas Corporation of America, a corporation of Pennsylvania

Filed May 7, 1962, Ser. No. 192,768
3 Claims. (Cl. 126—360)

This application is a continuation-in-part of our application Serial No. 21,310, filed April 11, 1960, now abandoned.

This invention relates to submerged combustion apparatus embodying a shallow, rectilinear, closed tank in which heat is supplied to a body of liquid by direct contact with hot combustion gases and also by indirect heat exchange between the liquid and the walls of hollow members conveying the hot combustion gases to a point or points of discharge into the liquid.

One of the primary objects of this invention is to provide highly efficient apparatus for the heating of liquids by submerged combustion.

Another primary object of this invention is to provide submerged combustion apparatus capable of highly efficient heat transfer of the heat of hot combustion gases into the body of liquid.

Another object of the invention is to provide improvements in water heating vessels.

A further object of the invention is to provide improvements in submerged combustion vessels. These, and other objects and advantages of the invention hereafter described or made apparent to those skilled in the art, may be attained by utilizing the principles of the invention described hereafter with respect to specific embodiments of the invention illustrated in the accompanying drawings wherein:

FIG. 1 is a side elevation of a water or other liquid heating apparatus with a portion thereof broken away to facilitate the illustration of the embodiment;

FIG. 2 is a top plan view of the embodiment of FIG. 1 with a portion thereof broken away to facilitate the illustration of the embodiment;

FIG. 3 is a sectional view taken on section 3—3 of FIG. 2;

FIG. 4 and FIG. 5 are side and rear elevations, respectively, of combustion gas distributing means used in the embodiment of FIGS. 1 and 2;

FIG. 6 is a cross-sectional view taken on section 6—6 of FIG. 5; and

FIG. 7 is a fragmentary view of the side elevation of a modified form of the apparatus of FIGS. 1 and 2.

In FIGS. 1 through 6 there is shown apparatus which is especially adapted for the heating of water or other liquid by means of direct contact between hot gases of combustion and the liquid. This apparatus comprises a tank **1**, which is relatively shallow in relation to its length and width. The rectilinear tank **1** is made of an end wall **2** having in its upper corner an outlet pipe **3** for the heated water or other liquid. The top of the tank **1** is closed by a top wall **4** extending thereacross. The top wall **4** is shorter than the bottom wall **5**. The remaining walls of the tank **1** are the side walls **6** and **7**. These walls form a water-tight, liquid-holding tank with a riser section or tower section **8** at the end of the tank **1** remote from the outlet pipe **3**. The riser section or tower section **8** is of a width coextensive with the width of the tank **1** and is made up of an end wall **9**, which also is the end wall for the tank **1**, together with end wall **10** and side walls **11** and **12**. The top of the rectilinear riser section

or tower section **8** is closed by a cover plate **13** through which extends a vapor outlet pipe **14** having a flange **15** for use in connection of the outlet pipe **14** to vapor and gas-conveying piping (not shown).

The end wall **10** has a manhole tube **16** thereon. This manhole tube is closed by removable cover plate **17**. The purpose of the manhole tube is to allow operating or maintenance personnel to enter the tank **1** for purposes of cleaning, repair or the like.

There is mounted in the top wall **4** a burner unit **18** of the submerged combustion variety. The burner shown in FIGS. 1 and 2 is a dual combustion burner which will be described in detail hereinafter. The burner plate **19** of the burner unit **18** discharges a fuel gas and air or oxygen gas into the combustion chamber **20**. The hot combustion gases are discharged through an opening **21** in the end wall of the combustion chamber **20** into a cylindrical leg **22** of the burner unit. Thereafter, the hot gases flow from the cylindrical leg **22** into a gas outlet tube **23** extending across the lower portion of tank **1**. This gas outlet tube **23** is positioned near the end of the tank **1** remote from the tower section **8**. The gas outlet tube **23** is supported on the bottom wall **5** of the tank **1** by support plates **24** attached to the bottom wall **5**.

The gas outlet tube **23** is illustrated in detail in FIGS. 5 and 6. It comprises an outer tube **25** rotatably supported about an inner tube **26**. The tubes **25** and **26**, respectively, have gas outlet ports **27**, **28** in their lower sides. These ports can be brought into any desired degree of alignment by rotation of the tube **25** about tube **26** by means of pressure against the post **29** fixedly mounted on the tube **25**. This adjustable positioning of the ports **27**, **28** permits the adjustment of the effective area of the gas outlet ports for a purpose later described.

Water or other liquid to be heated is admitted to the heating unit through the inlet pipe **30** located in the upper portion of the side wall **12** of the tower section **8**. Heated water, on the other hand, is discharged through the outlet pipe **3** located in the corner of the end wall **2**. The corner of the tank **1** from which the heated water is discharged is divided from the rest of the tank by a diagonal corner plate **31**. The corner plate **31** contains near its lower end a series of ports **32** which communicate the triangular corner compartment and the main body of the tank **1**. The corner compartment has a temperature sensing probe **33** therein, which probe is connected by cable **34** to an automatic temperature controller **35**. The temperature controller **35**, in turn, controls the quantity of fuel gas and air or oxygen gas supplied to the burner so that a substantially level temperature is maintained in the heated liquid discharged from the heating apparatus.

The water supply unit in the tower **8** comprises a coupling **36** attached to the inlet pipe **30**. A series of three branch, distributing pipes **37**, **38**, **39** are mounted in the coupling **36**. Each of these branch pipes has a right elbow **40** at its outer end with short vertical pipes **41** depending downwardly from the elbows **40**. Water admitted to the heating vessel is discharged from the three pipes **41**, which are located near the gas and vapor outlet pipe **14**. The water falls through the warm gases rising in the tower section **8**. If desired, the outlet pipes **41** may be provided with coarse spray nozzles to increase the contact between the water and the rising gases so that there is a greater transfer of the residual heat in the rising gases to the descending water. Fine sprays are ordinarily to be avoided because of the tendency of the entrainment of mist in the gases emitted through the outlet pipe **14**.

Fuel gas is supplied to the burner through the fuel gas main supply pipe **42**, which has a shut-off valve **43** and a gas pressure regulator **44**. The main supply pipe **42**

is branched into an inner burner gas supply pipe 45 and an outer burner gas supply pipe 46, each of which is connected to a distributing head in the gas burner. The details of the gas burner will be described hereinafter.

Each of the gas supply pipes 45 and 46 have manually operable shut-off valves 48 by which gas flow can be shut off to either or both of the inner burner distributor head 49 or outer burner distributor head 50. The inner burner gas supply pipe 45 has a small branch pipe 52 by which gas is supplied to the pilot tube distributing head 51 of the combustion burner.

For economical reasons, it is usually preferable to use air as the combustion supporting gas. Accordingly, the heating vessel of the invention has an air blower-compressor 53 mounted on the top wall 4 of the tank 1. The blower-compressor is driven by an electric motor 54. The air is discharged from the blower-compressor 53 through the main air supply pipe 55 to the distributing head of the outer burner. A portion of the air in pipe 55 flows through branch pipe 56 to the distributing head of the inner burner and a small portion of the air flowing through branch pipe 56 flows through branch pipe 57 to the distributing head of the pilot burner.

One of the important features of the apparatus of this invention is in the burner turn down control system by which the amount of gas supplied to the outer burner and the amount of air supplied to the outer burner is accomplished at predetermined, variable ratios. This aspect of the invention is provided by a butterfly valve 58 in the main air supply pipe 55 and a butterfly valve 59 in the main gas supply pipe 46, both of which pipes are connected to the distributor head for the outer burner. The butterfly plates of each of the butterfly valves are rotated by link arms 60 and 61 for the valves 58 and 59, respectively. Link arms 60 and 61 are connected by a connecting link arm 62 pivotally connected to the ends of each of the arms 60 and 61. These interlinked arms are, in turn, connected by a pivot link 63 to a rotatable arm 64 of a reversible motor 65. The motor 65 is controlled by known means by the temperature regulator 35. The electrical connection between the temperature controller 35 and the reversible motor 65 is shown symbolically by the arrows on these members in FIG. 1.

It will be noted from FIG. 2 that the link arm 60 for the butterfly valve 58 in the main air supply pipe 55 is longer than the link arm 61 to the butterfly valve 59 in the main gas supply pipe 46. The purpose of these link arms of greater length is to provide a different degree of rotation of the butterfly plates in the valves 58 and 59 when the arm 64 is rotated by the motor 65. It has ben found that the outer burner cannot be turned down from its maximum gas and air flow by equally proportionate decreases of the air and gas flow through the outer burner without encountering a rough or banging operation. For example, it has been found in the operation of the dual combustion burner that when the fuel gas flow is turned down to a flow of 40% of the maximum flow of gas through the outer burner, the air flow cannot be decreased to 40% of the maximum air flow without encountering a rough or banging operation. In order to have a smooth outer burner operation, the air must be decreased in the order of only about 70% of the maximum air flow of the outer burner when the gas flow is turned down to a value of 40% of the maximum gas flow, in order to maintain sufficient velocity at the orifices of the burner plate to prevent the encountering of the rough or banging operations.

Therefore, the link arm 60 is proportionately longer than the link arm 61 so that a given amount of movement of the link arm 63 by the motor arm 64 causes the butterfly plate of the valve 58 to rotate a lesser degree of angular rotation than the rotation of the butterfly plate of the valve 59. Thus, the turn down or turn up of the outer burner by adjustment of the butterfly valves via the mechanical linkage is done under conditions wherein there is a lesser amount of turn down in the air supply than in the gas supply during burner turn down and a greater amount of turn up in the outer burner gas supply than in the outer burner air supply during burner turn up.

The foregoing burner turn up and turn down mechanism is especially useful in burners which operate under discharge of gases into the body of liquid through orifices having a constant size opening, e.g., the tube 26 without the rotatable outer tube 25 thereon. Where, however, means is provided to partly close the gas discharge holes or orifices when the burner is turned down and to open the holes or orifices when the burner is turned up in direct proportion to the change in combustion gas supply resulting from the turn down or turn up, i.e., the tube structure illustrated in FIGS. 5 and 6, the outer burner can be turned down or turned up under conditions of equally proportionate changes in the air-gas supply rate. With a burner operating under automatic temperature control, it is usually more feasible to use a structure having the mechanical linkage illustrated in FIGS. 1 and 2 for turning down or turning up the outer burner along with a gas discharge tube 26 having constant size orifice openings.

The gas supply pipes 45 and 46 have a pressure regulator 66 therein for maintaining the desired gas pressure. The control panel 67 is mounted on the tank 1. It contains the control buttons for activating and deactivating motor 54, pressure gauges, and other instrumentation and controls for operating the combustion burner.

Thus, it will be seen that the apparatus of FIGS. 1 through 6 is especially suitable for the heating of water to a predetermined temperature by direct heat exchange between hot combustion gases and the water, or other liquid, if desired. The burner control system is one in which the quantity of combustion gas output can be controlled automatically in relation to the temperature of the water or other liquid being heated. The function of the tower section 8 is one of containing substantially any entrained water rising with the hot combustion gases out of the liquid being heated. The height to which the entrained drops rise in a given heating apparatus under maximum combustion gas output can be determined under operating conditions. It is considered the best practice to make the height of the tower 8 18 to 24 inches greater than the highest rise of entrained liquid. The release of hot combustion gases is done in the portion of the tank under the plate 4 so that these gases will rise in the part of the tank 1 under the plate 4. They then pass along the bottom of the plate 4 into the tower section 8. Under these conditions, excellent utilization of the total heat of the combustion gases is attained, i.e., a transfer of about 95% or more of the usable heat from the gases to the liquid being heated.

The burner 18 shown in FIGS. 1 and 2, with its dual burner structure, is shown in our U.S. Patent No. 3,192,920, issued July 6, 1965.

The inner and outer burners are concentric, independently operable burner units having a large range capacity of B.t.u. output. The inner burner has a lesser B.t.u. output capacity than the larger, outer burner. With this type of concentric burner relationship, the smaller inner burner can be ignited relatively smoothly by the ignited gases of the pilot tube. The inner burner, once ignited, can then serve as the pilot burner for ignition of the higher B.t.u. capacity outer burner which is in surrounding relationship therewith. Each burner can be turned down, turned up or shut down independently of the other burner to give a readily variable range of B.t.u. output of the burner as a whole. The orifices for the air passages of the inner and outer burners are preferably large ports, while the orifices for the fuel gas passages in the burner plate are preferably relatively small orifices spaced closely together.

Various types of burner plates may be employed to

provide varying amounts of air and combustible gas to be burned by the burner. For example, the size and/or number of the openings in the burner plates may be varied to provide the desired amount of gas supplied at the burner plate. Also, the size of the ports may be varied to conform the amount of combustion-supporting gas, such as air, with the amount of gas being supplied to thereby provide maximum efficiency of the burner. It is, thus, possible to vary the B.t.u. output of the main burner or the pilot burner by merely changing the burner plate.

By way of illustration, the pilot burner may be one having a capacity of approximately 5×10^6 B.t.u. and the outer or main burner may have a maximum output of about 10×10^6 B.t.u. The outer or main burner may be used to add from 1×10^6 to 10×10^6 B.t.u. to the 5×10^6 B.t.u. pilot burner. Thus, in one unit there is a maximum capacity of 15×10^6 B.t.u. and a minimum capacity of 5×10^6 B.t.u. Further, it is possible to cut the pilot burner back to a lesser B.t.u. output value, as for example, 2.5×10^6 B.t.u.—giving a range in the capacity of heat supplied from this single burner from about 2.5×10^6 to 15×10^6 B.t.u. By providing an additional burner in surrounding relationship with the main burner it is possible to achieve even much larger values in maximum B.t.u. output while still retaining the desirable features of smooth ignition and operation of the burner as a whole.

The foregoing values of B.t.u. output are not to be construed as anything but illustrative of the invention herein described. The pilot burner may have a smaller or greater maximum B.t.u. output, and the outer or main burner may also have a smaller or larger B.t.u. output than the values given above by way of illustration. In the preferred practice of the invention, however, the maximum B.t.u. output of the outer burner will be substantially greater than the maximum B.t.u. output of the inwardly adjacent burner.

The embodiment of FIG. 7 is one especially adapted for use in the evaporation or condensation of a liquid by vaporization thereof. Since temperature control is not a significant factor in most evaporation processes, the temperature control mechanism and automatically responsive mechanical linkage for turning down or turning up the outer burner air and fuel gas flow can be omitted in most evaporating vessels. Structurally, the evaporating vessel of FIG. 7 is very similar to the heating vessel of FIGS. 1 and 2 with the temperature control regulator **35** and the butterfly valves **58**, **59** and their associated parts omitted. In this embodiment, the burners are turned down and turned up by the manual control valves. Because the main structural change in the embodiment of FIG. 7 with respect to the embodiment of FIGS. 1 and 2 lies in the liquid supply and discharge arrangement for the tank **1**, only the lower portion of the tank has been illustrated. The remaining portions are similar to the parts illustrated in FIGS. 1 and 2 and, hence, need not be repeated.

In the evaporating vessel of FIG. 7, the liquid, such as water containing dissolved salts or the like, is admitted to the tank **1** through the inlet pipe **84** connected by an union **85** to a manual valve **86**. The solution is heated by gases discharged from the tube **23** beneath the level of the liquid. The concentrated solution is withdrawn through the outlet pipe **87**, to which it is connected by an union **88** to the manual valve **89**. The submerged combustion burner **18** may be a dual combustion burner or it may be a combustion burner having only a single burner.

The evaporating vessel of the embodiment of FIG. 7 ordinarily will not need temperature control instruments for regulating the heat output of the submerged burner inasmuch as the primary objective of these embodiments is to provide an apparatus for concentrating the liquid with highly efficient heat exchange between the hot gases and the liquid. Where, however, the liquid is being concentrated is susceptible to decomposition or the like, a liquid temperature control of the type shown for the embodiment of FIGS. 1 and 2 may be employed. Hence, the gas flow control to the combustion burners for these embodiments of the invention may be either a manual type control or an automatic type control. An automatic type control for the dual combustion burner of our aforesaid U.S. patent is shown therein.

The various illustrated embodiments of the invention have a number of structural similarities. In each case, the liquid is heated by indirect heat exchange through the walls of the combustion chamber and combustion gas-conveying means located below the surface of the liquid in the vessel and by direct heat exchange with the hot combustion gases discharged into the liquid from a plurality of small orifices in a submerged tube or tubes. The gases and vapors are discharged from a vapor and gas chamber extending above the liquid-holding tank a sufficient distance to preclude substantial entrainment of liquid particles (to be contrasted with vapors from the liquid). The combustion gases are discharged into the liquid below a top plate so that, when the vessels are operated with the liquid level below the level of the said plate, the structures of the illustrated embodiments have the advantage of improved removal of entrained liquid particles from the gases and vapors because they must travel under the plate before they reach the vapor and gas chamber. By such structure, the release space in which the entrained liquid is released from the gases is extended over a substantial length, i.e., the space in which they flow through the liquid-holding tank plus the space in the vapor and gas chamber. These spaces must be sufficiently large to provide a low enough gas velocity to allow the entrained liquid to be released from the gases.

A submerged combustion apparatus of the type characterized above has been disclosed previously in our copending application Serial No. 21,310, filed April 11, 1960, the disclosure of which is herein incorporated by reference as if it had been set forth in its entirety. The apparatus of this copending application is a liquid heating apparatus in which the tank and the liquid-separation tower are similar in structure to the apparatus of FIGS. 1 and 2 herein. The hot combustion gases are conducted from a submerged combustion burner via a hollow arm or arms and discharged below the surface of a liquid in the tank, the point of discharge being below the top, cover plate of the tank. Liquid is introduced into the tower as in FIGS. 1 and 2 herein.

The tower in our aforesaid copending application may be a tower containing packing through which the liquid introduced into the tower gravitates. This aids in the removal of entrained liquid in the combustion gases discharged through the tower and also provides a better surface contact between the incoming liquid and the vapors carried with the combustion gases so that these vapors will condense and be returned to the body of liquid along with the liquid gravitating through the packed tower. In liquid heating apparatus, as contrasted with evaporating apparatus, the tower packing has the advantage of minimizing liquid loss through vaporization. Vaporization is not a desired characteristic in a liquid heating apparatus, whereas in evaporating apparatus, vaporization is desired.

In the embodiments herein disclosed which are used as liquid heating apparatus, i.e., FIGS. 1 and 2, the towers **8** and **118** may contain, if desired, packing such as Raschig rings, spiral rings, stoneware, Berl saddles, and the like for the purposes above described.

Other features of the invention such as the dual burner and its fuel gas and air flow control devices, the liquid-temperature-responsive system for adjusting the heat output of the burner in response to the liquid temperature, and others heretofore described usually are employed to best advantage in certain types of liquid heating applications.

The illustrated embodiments are those which we now consider to be the best modes for practice of the generic principles and concepts of the invention. The invention includes within its spirit and scope, as defined in the appended claims, still other embodiments thereof.

The invention is hereby claimed as follows:

1. Submerged combustion apparatus comprising an extended, horizontal, closed, rectilinear tank having a length which is much greater than its depth and adapted to hold a liquid to be heated therein, the top wall of said tank constituting a substantially horizontal plate having a length which is also much greater than said depth and covering all but one end of said rectilinear tank, wall means on said tank located at said one end of said tank defining a closed, rectilinear, upstanding liquid-separation chamber extending across said end of said tank the full width of said end, projecting upwardly from said tank and communicating with the upper portion of said tank, means for venting combustion gases and vapor from said liquid-separation chamber, a combustion burner mounted on said tank with the combustion chamber extending into the bottom portion of said tank, hollow arm means extending outwardly from said combustion chamber substantially adjacent the opposite end of said tank along the bottom thereof, and a plurality of gas discharge orifices in said hollow arm means through which hot combustion gases are adapted to be discharged beneath the surface of a liquid in said tank, whereby the upper portion of said tank constitutes an extension of said liquid-separation chamber and forms therewith an extended path for the release of entrained liquid in the gases and vapors before said gases and vapors are discharged through said means for venting the gases and vapors.

2. The apparatus of claim 1 wherein the hollow arm means has means for varying the effective sizes of said orifices.

3. The apparatus of claim 1 including means adapted to admit liquid to said tank and to discharge heated liquid from said tank, said liquid discharge means located at a corner of said tank, said corner located at said opposite end of said tank and divided from the rest of the tank by a diagonal corner plate having a series of ports therein.

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FREDERICK L. MATTESON, JR., *Primary Examiner.*

JOHN J. CAMBY, JAMES W. WESTHAVER, *Examiners.*