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Douglas et al.

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[54] **METHODS AND APPARATUS FOR SUBMERGED COMBUSTION (WITH AIR POLLUTION CONTROL)**

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[73] Assignee: **Ozark-Mahoning Company,** Tulsa, Okla.

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[21] Appl. No.: **253,541**

[52] **U.S. Cl.** ..... **159/16 A,** 159/47, 261/16, 261/124, 126/360

[51] **Int. Cl.** **B01d 1/14,** F24h 1/20, B01d 1/00, F02m 25/10, B01d 47/02

[58] **Field of Search** ..... 159/16 R, 16 A; 126/360, 126/360 A, 91 A; 261/124, 16; 23/275, 307; 122/31 A, 515 A; 251/304

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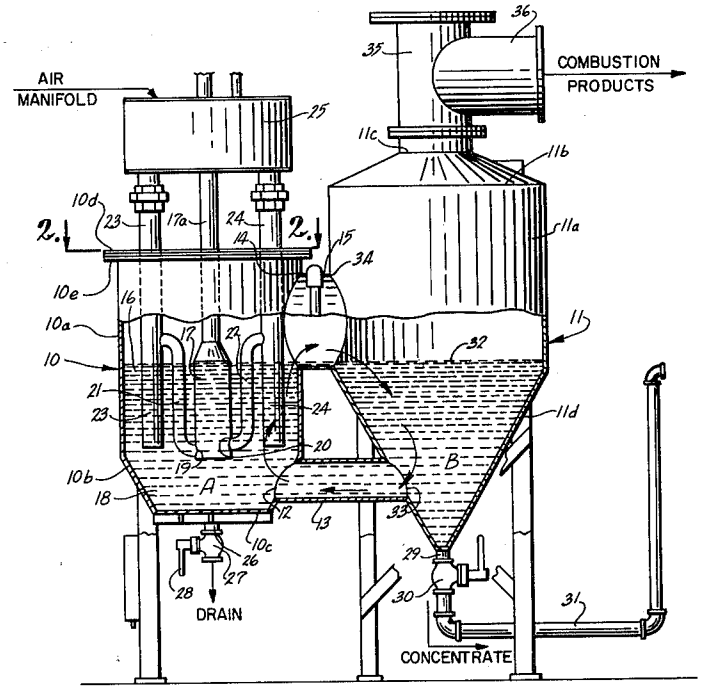
Primary Examiner—Jack Sofer
Attorney, Agent, or Firm—Thomas M. Scofield

[57] **ABSTRACT**

Improvements in submerged combustion evaporators and heaters particularly adapted to the heating and evaporation of various heat sensitive solutions, including both methods and apparatus therefor;

Improved apparatus and methods for the discharge of products of combustion from the combustion chamber of a submerged burner into and through the body of a heat-sensitive solution, said discharge handled in such manner as to reduce air pollution resulting from the practice of the submerged combustion process with respect to the given solution, as well as improve the effectiveness of the burner, per se, and the submerged combustion process.

9 Claims, 9 Drawing Figures



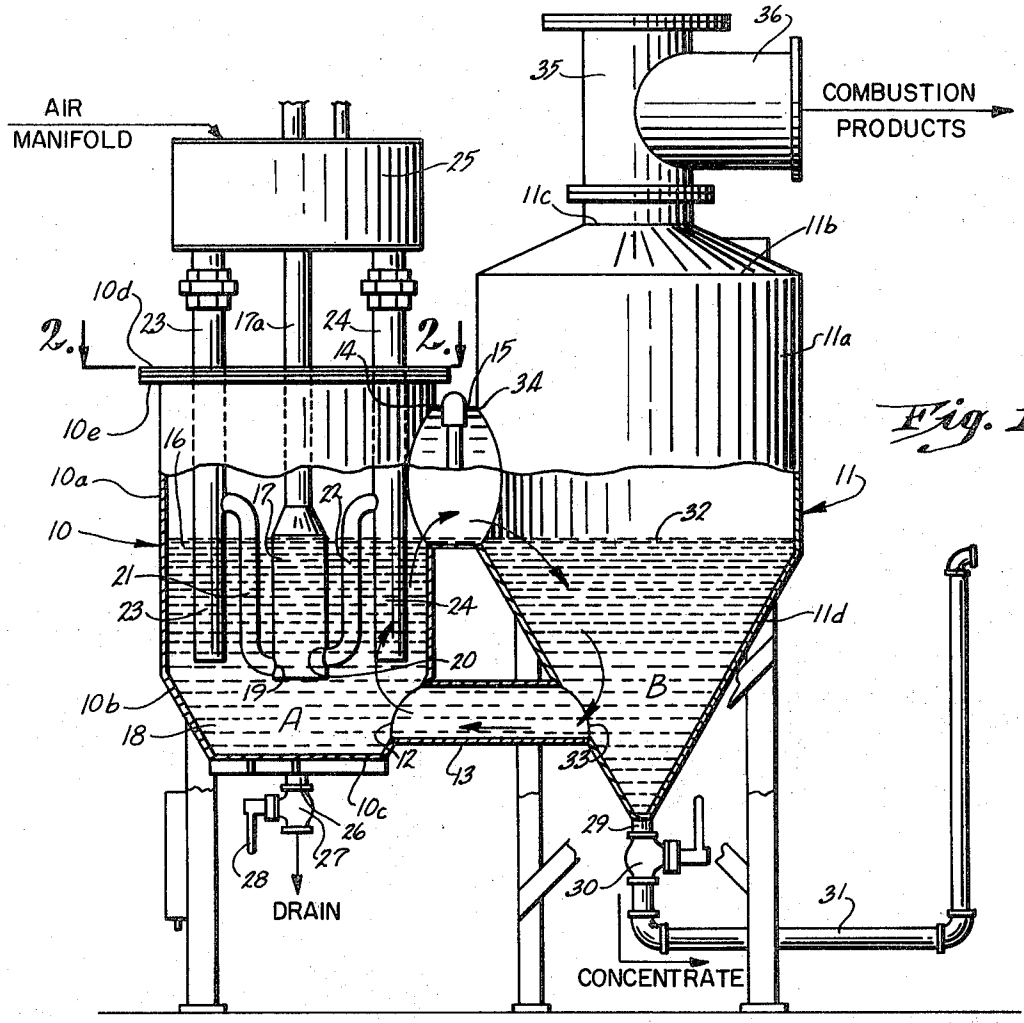


Fig. 1.

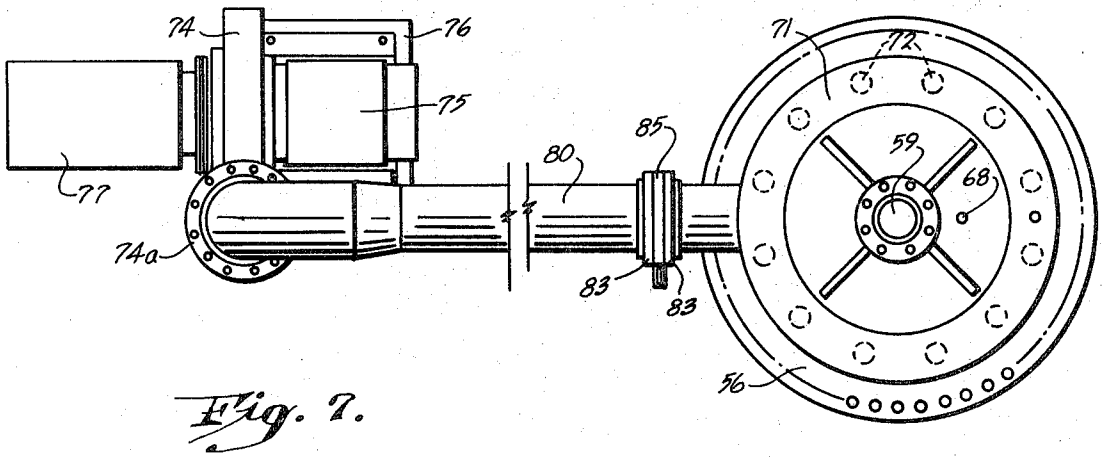


Fig. 7.

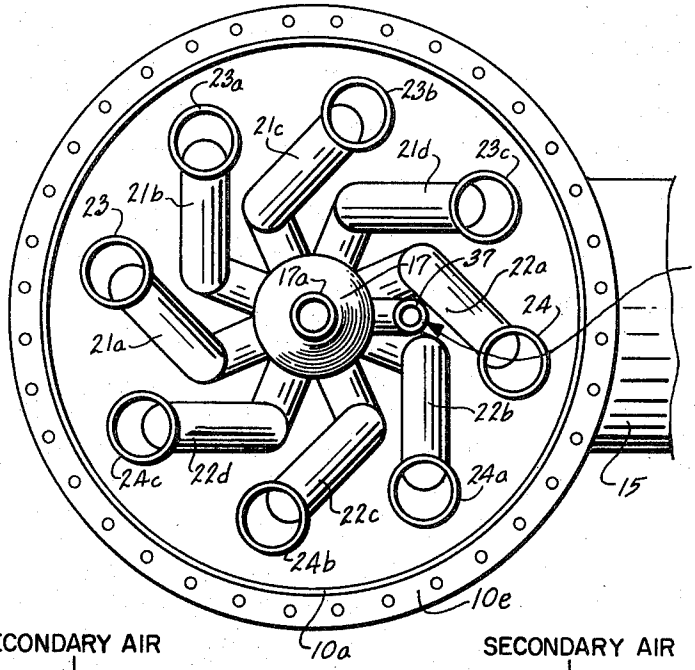

23a
23b
21c
21d
23c
23
21b
17a
17
37
22a
24
IGNITER TUBE
21a
22b
24c
22d
24a
15
22c
24b
10e
10a

Fig. 2.

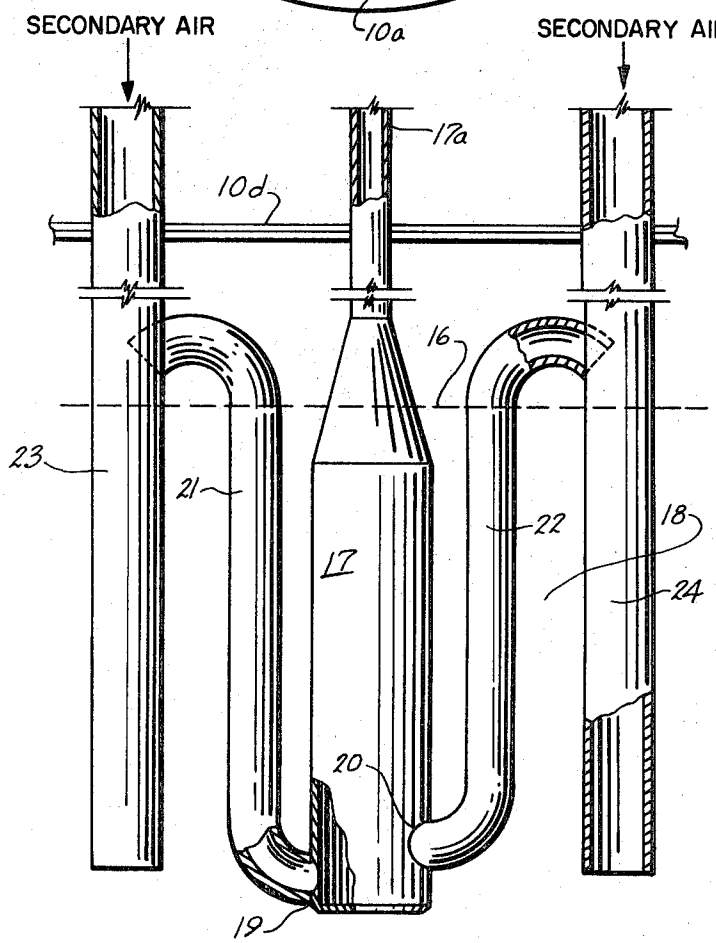

SECONDARY AIR
SECONDARY AIR
17a
10d
16
23
21
22
18
17
24
20
19

Fig. 3.

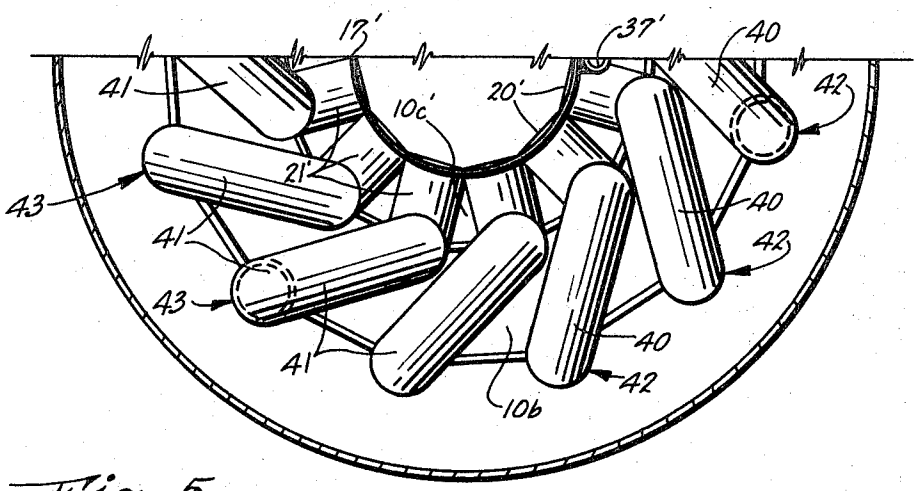

17'
37'
40
41
10c'
20'
42
21'
43
40
41
42
43
40
41
42
10b

Fig. 5.

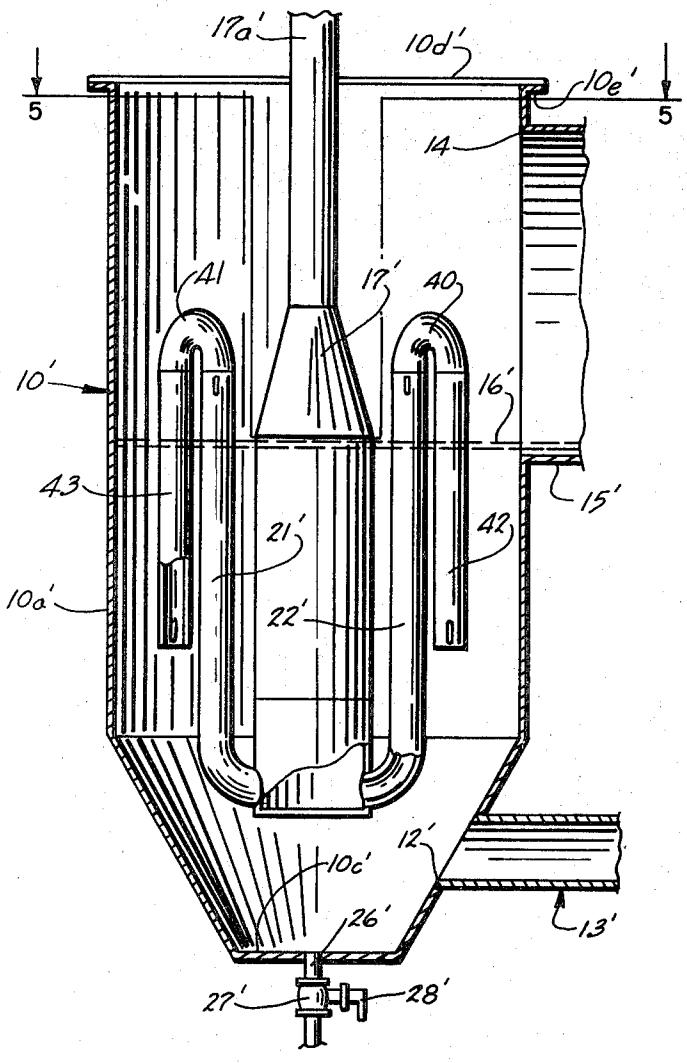

17a'
10d'
10e'
5
5
14
41
17'
40
10'
16'
43
15'
21'
42
10a'
22'
12'
10c'
13'
26'
27'
28'

Fig. 4.

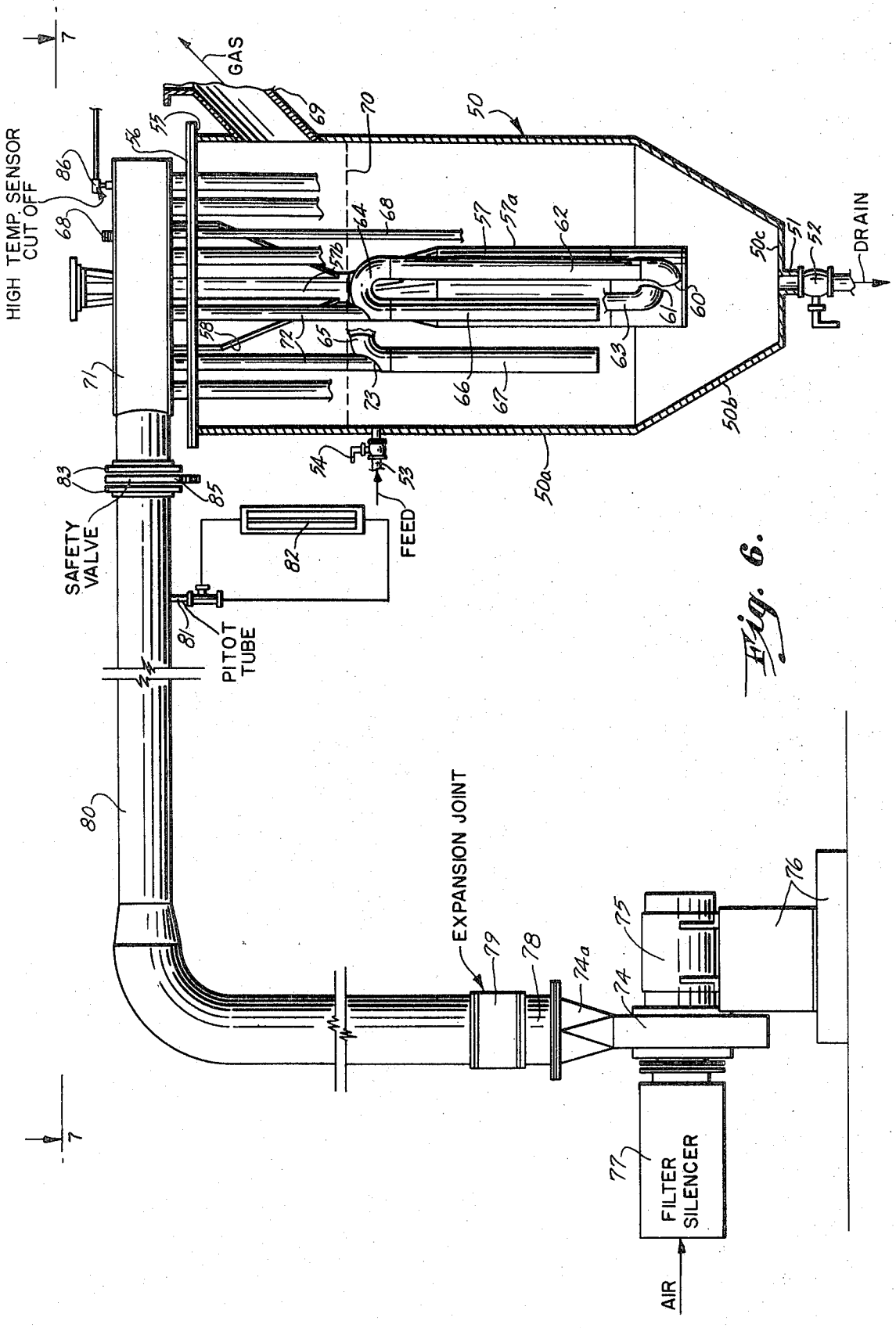

GAS
HIGH TEMP. SENSOR CUT OFF
DRAIN
SAFETY VALVE
PITOT TUBE
FEED
EXPANSION JOINT
FILTER SILENCER
AIR

Fig. 6.

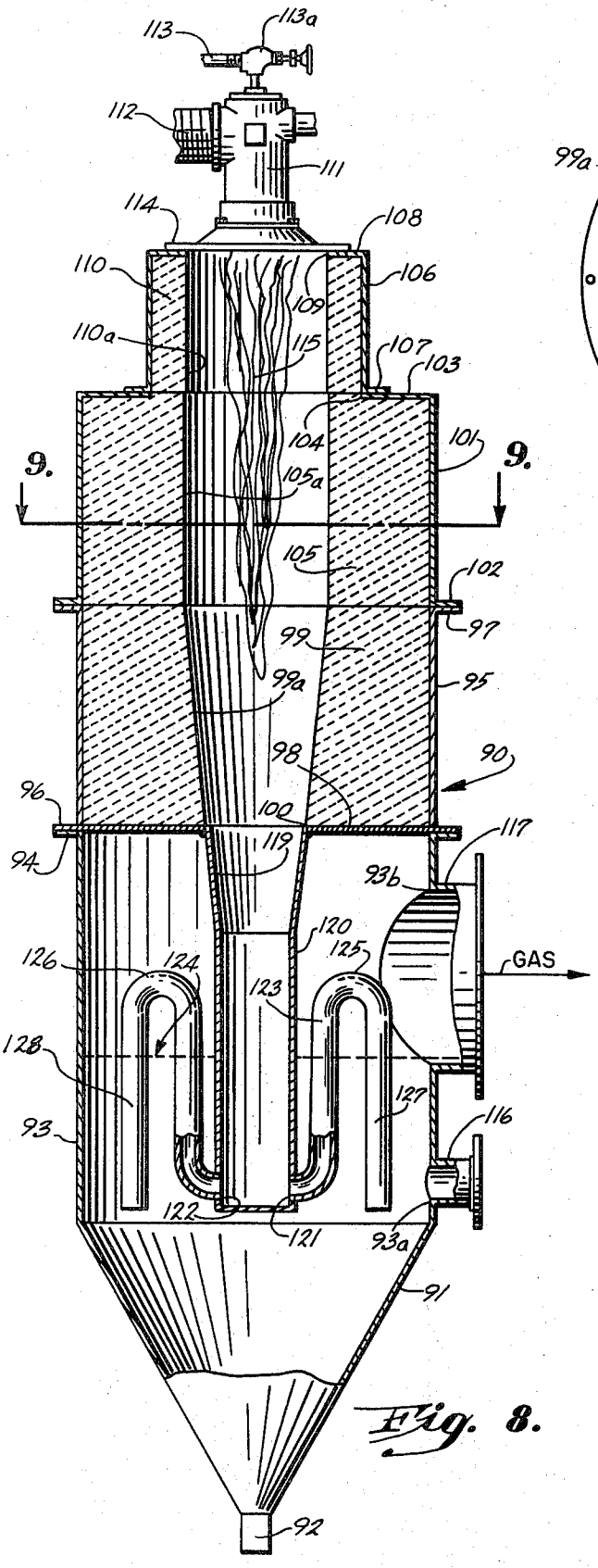

113
113a
112
111
114
108
110
106
109
110a
115
107
103
104
101
9.
9.
105a
105
102
97
99
99a
95
98
90
96
100
117
94
119
93b
120
125
126
124
GAS
123
128
127
116
93
122
121
93a
91
92

Fig. 8.

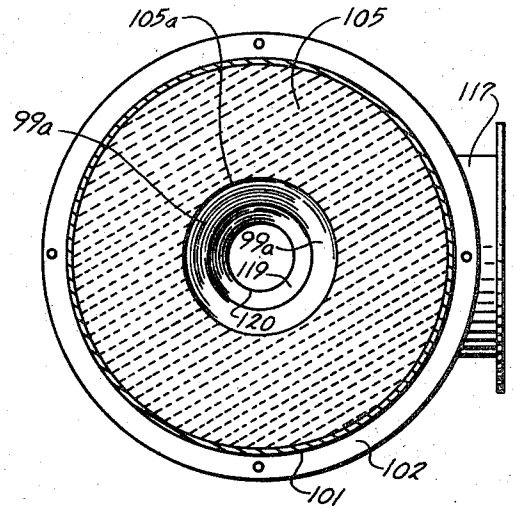

105a
105
117
99a
99a
119
120
102
101

Fig. 9.

METHODS AND APPARATUS FOR SUBMERGED COMBUSTION (WITH AIR POLLUTION CONTROL)

THE PRIOR ART

The following specifications are improvements relating to and over the submerged combustion apparatus and methods of the following patents:

1. Doennecke et al U.S. Pat. No. 2,086,902, "Method of Recovering Anhydrous Sodium Sulfate," issued July 13, 1937;

2. Doennecke et al U.S. Pat. No. 2,159,759, issued May 23, 1939 for "Apparatus for Recovering Anhydrous Sodium Sulfate And The Like;"

3. Cecil et al, U.S. Pat. No. 2,418,162, "Apparatus And Method For Producing Inert Gas," issued Apr. 1, 1947;

4. Stengl et al, U.S. Pat. No. 2,456,032, "Fuel Control Device For Submerged Burners," issued Dec. 14, 1948; and

5. Young et al, U.S. Pat. No. 2,723,659 issued Nov. 15, 1955 for "Submersible Burner."

Further see Young et al U.S. Pat. No. 3,526,264, 9/1/70, for "Method . . . "

Stewart U.S. Pat. No. 2,981,250, issued 4/25/61 for "Submerged Combustion Heating Apparatus"

Wolfersperger U.S. Pat. No. 2,787,318, 4/2/57, for "Burner . . ."

Norman U.S. Pat. No. 2,594,063, 4/22/52 for "Heating System"

Smith U.S. Pat. No. 2,556,984, 6/12/51 for "Immersion Heater"

Kemp U.S. Pat. No. 2,536,608, 1/2/51 for "Immersion Liquid Heating . . ."

Ekstrom U.S. Pat. No. 2,375,840, 5/15/45, for "Liquid Heating Apparatus"

Brosius U.S. Pat. No. 2,358,302, 9/19/44 for "Submerged Burner"

Stewart U.S. Pat. No. 2,025,695, 12/24/35, for "Domestic Heating Process . . ."

CONVENTIONAL SUBMERGED COMBUSTION BURNERS AND PROCESSES

A typical conventional submerged combustion process involves burning a gaseous fuel in a specially designed chamber under the surface of a heat sensitive liquid. A typical such burner will liberate between 4 to 5 million BTU/cubic foot/atmosphere/hour. Most submerged combustion process heat leaves the open mouth of the burner as sensible heat in the hot combustion gases passing directly into contact with the solution.

A conventional, open-mouth submerged combustion burner discharges hot combustion gases directly into the heat sensitive liquid, thereby involving both flame impingement on the liquid and liquid entering the combustion chamber. A first problem of the latter two effects involves the thermal decomposition of the heat sensitive liquid by direct contact withthe hot discharge gases from the burner. A second disadvantage involves the heat sensitive solution entering the burner combustion chamber through the hot gas discharge opening or ports. It should further be noted that decomposed heat sensitive liquid will travel with the products of combustion through the solution, leaving the evaporater or heater through the stacks and discharging into the atmosphere. Such discharge comprises both an objectionable direct loss of product and an air pollution nuisance.

In the conventional submerged combustion burner, air and the fuel mixture enter the combustion chamber through the velocity tube. Complete combustion of the air-fuel mixture takes place in the combustion chamber. Typically, the conventional submerged burner is completely or largely submerged into the heat sensitive solution.

Some solutions are more heat sensitive than others. Ammonium nitrate and magnesium nitrate decompose when hot. Sodium chloride vaporizes and condenses in fine particles of the aerosol type.

With sodium sulfate, there are typically losses of less than one-half percent utilizing standard or conventional submerged burners. On the other hand, there is some entrainment of sodium sulfate (which entrained product drops out close to the plane, typically) and some aerosol effect which drops out miles away therefrom. On the other hand, in ammonium nitrate, with a conventional submerged combustion burner, 50 percent losses may be experienced, mostly through decomposition. In such case, ammonia and nitrous oxide gases are also given off. With respect to sodium nitrate, this compound does not typically decompose much, but some aerosol effect is encountered.

One does not want drawback of solution into the burners. For example, there is a problem of possible explosion in concentration of ammonium nitrate. In any case, if one gets solution into the conventional (or any other) burner, the water or liquid tends to evaporate and solids build up and cake in the burner.

In the art of submerged combustion liquid concentration, there has been much speculation as to what causes given materials to break down. Prior to the instant improvement, the theory was that the greater part of material breakdown or decomposition was because solution was actually entering the burner chamber and being partly incinerated. The instant improvement and invention has proven this theory.

OBJECTS OF THE INVENTION

Therefore, an object is to provide a submerged combustion burner construction effectively operating to prevent heat sensitive solution from entering the combustion chamber of the burner or area of highest temperature gases therein, where same would decompose thermally.

Another object of the invention is to improve submerged combustion burner construction, thereby minimizing decomposition of heat sensitive liquids by preventing direct contact of hot discharge gases and flame therwith. This also prevents loss of valuable materials being concentrated and, additionally, minimizes air pollution produced by the use of the apparatus and practice of te process.

Yet another object of the invention is to provide a greatly improved submerged combustion burner design which, by virtue of considerably increasing the heat exchange surface in contact with the heat sensitive liquid, considerably lowers the temperature of the combustion gases from the burner before they discharge directly into the heat sensitive solution. This also further prevents thermal decomposition of the solution and further minimizes or prevents air pollution resulting from

operation of the apparatus and practice of the process.

Another object is to provide improvements in submerged combustion burner construction and methods of operating same, wherein process operation is feasible with less burner submergence than that required of a normal or conventional burner. This, under certain circumstances, reduces the back pressure on the system, thereby resulting in a reduction of horsepower requirement to overcome the static head or submergence of the burner in the liquid being concentrated.

Other objects of the improved submerged combustion burner construction and methods of operating a submerged combustion process include: (1) greatly heightened feasibility of control of air pollution from practice of the process and use of the apparatus (2) the provision of both multiple and indirect impingements of heat into the solution being concentrated with lower temperature gases being discharged ultimately into the heat sensitive solution than conventional; (3) minimal or no decomposition of notoriously decomposition-prone solutions and compounds; (4) effective and universal prevention of entrance of solution into the burner combustion chamber or area; (5) less actual loss of solution from practice of the process and use of the apparatus, whereby to provide a greater quantity of salable product.

Another object of the invention is to provide a submerged combustion burner of improved construction and operation wherein, where excess air is employed in the combustion process, the same amount of excess air will temper the heat more than in a standard burner.

Another object of the invention is to provide submerged combustion burner devices and methods of operating same which permit further and greater concentration of known compounds and solutions than ever before.

Another object of the invention is to provide burner devices and processes of use of same wherein solution concentration not only takes place with less decomposition losses, but, also, markedly less aerosol type losses, the latter type less usually causing difficult and offensive air pollution problems.

Another object of the invention is to particularly provide a new construction of submerged combustion burner which, by its very physical construction, results in a different heating and concentration process, particularly in that the device does not put all of the heat in all at one spot in the concentration vessel. In the instant improvement all of the heat produced goes into the solution, more uniformly, in two different ways. The first way involves indirect heat exchange between the burner body itself and the burner arms and extension parts therefrom. The second way involving direct heat input into the solution at spaced, dispersed, discreet outlets. As a result, compared to a conventional submerged combustion burner, there is markedly less local overheating than is present conventionally around the base of the burner, where all heat is concentrated coming out of the bottom openings.

Another object of the invention is to provide unique combinations and arrangements of the novel burner construction and solution tanks or vessels employed therewith, where a lower level of solution is feasible in the vessels, less violent agitation is employed, aeration of the burner containing tank is effected and circulation between at least a pair of tanks is created by the structure of the tanks and their inter-connections. In addition, a higher level may be employed for a given solution and, with respect to the relatively quiescent zone of the paired vessel, solids present are agitated.

Other and further objects of the invention will appear in the course of the following description thereof.

DESCRIPTION OF THE DRAWINGS

In the drawings, embodiments of the invention are shown and, in the various views, like numerals are employed to indicate like parts.

Referring to the figures, FIG. **1** is a side, partly sectional view of liquid concentrating apparatus involving a pair of interconnected tanks utilizable for the concentration of heat sensitive solutions with one form of the improved burner (utilizing secondary air) installed in the left hand tank in the view.

FIG. **2** is a top view of the left hand tank in the view of FIG. **1** taken along the lines **2—2** of FIG. **1** in the direction of the arrows.

FIG. **3** is an enlarged detail of the burner construction of FIGS. **1** and **2** (using secondary air).

FIG. **4** is a side, partly sectional detail of an improved submerged combustion burner construction (not using secondary air) installed in a tank analogous to the left hand tank in the view of FIG. **1.**

FIG. **5** is a fragmentary top view of the submerged combustion burner of FIG. **4.**

FIG. **6** is a side, partly sectional view of a third form of submerged combustion burner and tank construction (utilizing secondary air).

FIG. **7** is a top view of the construction of FIG. **6.**

FIG. **8** is a side sectional view of a liquid concentrating tank employing a refractory lined burner.

FIG. **9** is a view along the lines **9—9** of FIG. **8** in the direction of the arrows.

DESCRIPTION OF THE INVENTION

Submerged combustion burners may vary in capacity from 15,000 BTU/hour up to 30,000,000 BTU/hour. With conventional burners the products of combustion may be discharged from the end of the burner at 2,200° F. for 150,000 BTU/hour pilot plant burners and may be as high as 3,200° F. for 30,000,000 BTU/hour burners.

With respect to the burner construction improvements, per se, the burner may or may not employ secondary or excess air. In either case, heat exchanger tubes are installed at the normal or conventional burner hot gas discharge openings. The hot combustion gases from the burner must then pass through the heat exchange tubes before discharge from the ends thereof. The heat exchange tubes are so configured and of sufficient length and number whereby to cool (to some extent) the hot gases directly from the burner, thereby aiding in preventing thermal decomposition of heat sensitive solutions. The passage of the combustion gases through these configured, multiple heat exchange tubes operates to indirectly cool the heat sensitive solution contacting the outside of the heat exchange tubes, thereby lowering the temperature of the hot combustion gases passing therethrough, as well as their exit temperature.

The tubes are typically spaced equally around the perimeter of the lower end of the combustion chamber of the burner. The presence and structure of the tubes also prevents heat sensitive solution from entering the

conventional gas discharge openings and coming into contact with the flame in the combustion chamber. Yet further, the provision of heat exchange tubes (configured as shown) enables the products of combustion to be discharged at a plurality of spaced, positioned, discreet points within the solution away from the centrally positioned burner body. Thus, there is indirect heat exchange between the gases and the solution from the submerged burner body and the heat exchange tubes and multiple contact direct heat exchange between the combustion gases and the solution at the plurality of discharge points.

There is no change in the mechanics or mechanisms of flame combustion in the burner, per se.

If secondary air is added, there is typically a manifold and blower involved. Secondary air added typically functions as cooling air, it is not employed as an aid to complete combustion. No marked increase in efficiency with respect to fuel comsumption is achieved because the gas going off from the concentrating vessels (and the solution leaving) depart at the same temperature as they would utilizing a standard or conventional burner. However, there are markedly less deleterious effects on the heat sensitive solutions being concentrated.

It should be understood that, in the use of a submerged combustion burner, level controls (solution level with respect to the burner in the concentrating vessel) are typically employed. Thus, typically, there are four level controls. First, there is a high level contact which monitors and limits the upper level of solution permitted in the vessel. Secondly there is a "normal" and preferred level below high level. The third level monitored and controlled is below the "normal" level, identified as the "low" level contacts. Therebelow is the fourth level monitored and controlled, comprising a shut-down and alarm level. These are conventional and will not be re-described with respect to the instant system, although the positioning of these four levels with respect to a given burner or burner and heat exchange arm configuration may vary for a given system.

FIGS. 1–3, INCLUSIVE

Referring first to FIG. **1**, therein is shown a pair of vessels generally designated **10** and **11**, here employed in an evaporator system. Tank **10** typically has a cylindrical side wall **10***a* with a frusto-conical lower section **10***b* and flat circular bottom wall **10***c*. The upper end of tank **10** is capped by flat circular top **10***d* received on circumferential ring flange **10***e*. An opening **12** is provided in one side of frusto-conical wall portion **10***b* to which connects elongate pipe or duct **13**. A second circular opening **14** is provided in cylindrical upper wall portion **10***a* to which connects larger diameter pipe or duct **15**. Optimal and preferred liquid level in vessel **10** is seen at **16**, just overflowing the lower boundary of pipe or duct **15**.

A burner body **17** is shown substantially submerged in the liquid **18** being concentrated having feed tube or duct **17***a* extending upwardly therefrom and through an opening provided in top or cap **10***d*. This burner construction is conventional and the lower portion of the burner body is provided with conventional outlet openings designated in FIGS. **1** and **3** as **19** and **20**. Attached to and running from each of said openings **19** and **20** are elongate heat exchange tubes **21** and **22** which connect into elongate, vertical tubes or ducts **23** and **24** (FIGS. **1** and **3**) which serve to provide secondary air and are connected at their upper ends to manifold **25**.

A drain pipe **26** having valve fitting **27** and hand control lever **28** thereon are provided centrally of bottom wall **10***c*.

Vessel **11** has elongate cylindrical side wall **11***a* and top wall **11***b* with central opening **11***c* therein. The lower portion of vessel **11** comprises elongate conical shell **11***d* having drain pipe **29** therefrom controlled by valve **30**. Pipe **29** connects to and leads into discharge or product withdrawal pipe **31**. The liquid level in tank **11** is seen at **32**. Opening **33** is provided through the side of conical wall portion **11***d* connecting to the other end of duct or passage **13**, whereby there is liquid flow intercommunication between the lower portions of the vessels **10** and **11**. Circular opening **34** is provided in cylindrical wall portion **11***a* of vessel **11** to receive the end of duct **15** opposite that connecting to opening **14** in vessel **10** wall portion **10***a*.

Arrows are provided within ducts **13** and **15** and the lower portions of vessels **10** and **11** to show the direction of liquid flow under the action of the burner system in vessel **10**.

At the upper end of vessel **11**, gas discharge pipe **35** is provided having right angle take-off pipe **36** therefrom.

Referring to FIG. **2**, this shows a plan view of vessel **10** of FIG. **1**. The centrally located burner body **17** and the multiple heat exchange tubes **21***a*, **21***b*, **21***c* and **21***d* and **22***a–d*, inclusive, connecting to the secondary air tubes **23**, **23***a–c* and **24**, **24***a–c* may be clearly seen. The geometry of tubes **21–22** is for maximum inclusion thereof in the vessel. The multiplicity of heat exchange tubes and secondary air input ducts for said tubes seen in FIG. **2** are not shown in FIGS. **1** and **3** for clarity. Additionally, in those views, the angling in plan view of the heat exchange tubes is also not illustrated for clarity. Such angling and geometry, as noted, serves the purpose of crowding more heat exchange tubes and secondary air input tubes into a relatively lesser diameter tank. There is also seen igniter tube **37** of conventional structure and purpose, connecting into the lower portion of burner body **17** in FIG. **2**.

From FIG. **3**, an enlarged detail of the structure seen in FIG. **1**, it may be seen that the burner outlet openings **19** and **20** may be vertically displaced from one another for better spacing and fitting of multiple heat exchange tubes on the burner body radially, with respect to one another.

Turning now to the form of the invention seen in FIGS. **4** and **5**, there is no substantial distinction between the burner construction in the left-hand side of FIG. **1** and the view of FIGS. **2** and **3** as that shown in FIGS. **4** and **5**, save for the fact that no secondary air is employed in or in conjunction with the burner. Accordingly, all of the parts of both the vessel and the burner which are identical or substantially identical to like parts in FIGS. **1–3**, inclusive, are numbered the same as the parts in those views, but primed. These parts will not be redescribed for brevity. Another slight distinction between the views is that the lower passage **13′** is positioned slightly higher on the cylindrical portion **10***a* of the wall.

It may also be observed that, in the lower portion of the view of FIG. **4**, two of the burner arms only are il-

lustrated for clarity, taken off at the same level. However, reference to FIG. 5 will show, first, that burner arms are provided at two levels, for optimum distribution of the products of combustion and the pipes or channels themselves and, secondly, an even greater number is shown packed into the given volume of the vessel.

A plurality of U-shaped connecting members, inverted, are seen at **40** (for the right-hand side of the vessel in the view of FIG. **4**) and **41** (the left-hand side of the vessel in the view) which make connection between the members **22'** and **21'** respectively and vertically downwardly extending pipe or duct members **42** and **43**, respectively. The downward extension of the members **42** and **43**, both with respect to the burner outlets **19'** and **20'** (at the two levels) and the passage **13'** will be discussed with respect to description of the function of the device. (Referring to FIGS. **4** and **5**, the solution level **16'** is always maintained a few inches above the bottom of opening **15'**. Opening **13'** is always located below the bottom of the burner.)

FIGS. **6** and **7** show a third form of submerged combustion burner and tank construction, utilizing secondary air in the manner of FIGS. **1–3**, inclusive. FIG. **6** is a side, partly sectional view of a vessel having the improved burner construction seen in the view of FIG. **6** at the right, with the blower and ducting for inputing secondary air seen in the left side of the view. In FIG. **7**, there is seen a plan view of the apparatus of FIG. **6**.

In this modification, it is contemplated that a relatively lesser volume of secondary air be mixed with the hot combustion gases from the burner, whereby the secondary air pipes are of lesser diameter and their connection into the or with the hot gas heat exchange tubes from the burner is different. Thus, in this modification, the volume of secondary air is such that the hot gases from the burner are entraining secondary air. In the modification of FIGS. **1–3**, inclusive, the volume of secondary air input is such that the opposite is true, namely, the secondary air is entraining the hot gases from the burner.

Turning to the figures, at **50** there is generally designated a liquid concentrating tank having an upper cylindrical portion **50*a*** and a lower frusto-conical portion **50*b*** with bottom **50*c***. An opening is provided centrally of bottom **50*c*** with drain pipe **51** thereon controlled by valve **52**. The upper portion of the vessel has an inlet pipe or feed pipe **53** controlled by a valve **54**. Top circumferential flange **55** removably mounts lid or top **56** in sealing fashion. Gasketing may be provided and bolts controlling the engagement also.

Burner **57** has a lower larger diameter burner body **57*a*** with combustion mixture feed tube or duct **57*b*** leading into the top thereof. Suitable support forms or struts **58** connect the burner **57** to the cover or lid **56** and settler the burner within the tank **50**. The input of the gaseous combustion mixture to feed tube **57*b*** is centrally down upper pipe **59**.

A plurality of openings **60** and **61** are provided, spaced and staggered in the lower portion of the burner body **57*a*** from which lead hot gas heat exchange tubes **62** and **63**. The configuration and geometry of these tubes is analogous to that seen best in FIGS. **2** and **5** and will not be redescribed. However, in the particular members just described and numbered, upper U-bends **64** and **65** connect to vertical, downwardly leading discharge portions **66** and **67** of the heat exchange tubes.

Conventional igniter pipe **68** is provided with respect to said vessel, as well as gaseous output pipe **69** connected to the upper portion of cylindrical vessel wall **50*a***. The liquid level in the vessel is seen at **70**.

A ring manifold **71** has connected to the lower end thereof and extending through the cap **56** a plurality of secondary air discharge pipes or tubes **72**. The latter connect into the outer portions of the U-bends (**65** and **64**, for example) as at **73**. Pipes **72** connect to each of the U-bend portions of the hot gas heat exchange tubes.

The secondary air is provided, typically, by a blower **74** of conventional type driven by motor **75** mounted on a suitable structural support as at **76**. A filter-silencer **77** may be provided if desired over the blower inlet. Duct **78** leads from the outlet **74*a*** of the blower through expansion joint **79**, connecting with suitable piping of desired length, composition and diameter **80**.

A pitot tube **81** connecting to manometer **82** may be provided. Flanges **83** on duct **80** and inlet pipe **84** to mainfold **71** preferably carries wafer valve **85**. At **86** there is seen sensing means cooperating with means providing a high temperature cutoff. Wafer valve **85** is a butterfly valve used to regulate the amount of secondary air.

Referring now to FIGS. **8** and **9**, this drawing shows the improved burner construction in use with respect to a refractory lined oil burner.

At **90** is generally designated a heater tank having the following parts. At the lower end thereof is a conical or frustoconical drain section **91** having a drain pipe **92** connected at the lower portion thereof, controlled by any suitable valve means of conventional type, not shown. Integrally connected to the upper end of conical portion **91** is a cylindrical liquid receiving heater tank portion **93** having a circumferential mounting flange **94** at the upper end thereof. Carried by the latter is a cylindrical refractory containing and carrying cylindrical pipe section **95**. Section **95** has a lower flange **96** mating and engaging with flange **94** and an upper circumferential mounting flange **97**. Continuous with or connected to lower flange **96** is a plate or sheet **98** serving as a floor for the refractory **99** and having a central opening **100** therewithin.

Above section **95** there is provided a second cylindrical section **101** having lower mounting flange **102** mating with and engaging with mounting flange **97** of section **95** and an upper partial ring cap **103** having a central opening **104** therein. Cap **103** overlies the central block or portion **105** of refractory and further serves as a mounting base for the upper cylindrical portion **106**. The latter has lower support flange **107** and upper, inwardly extending ring cap **108** having central opening **109** therewithin. The upper portion or body **110** of refractory material is positioned within section **106**. Refractory bodies **110**, **105** and **99** have central openings **110*a***, **105*a*** and **99*a***, respectively. The former two are cylindrical and of uniform diameter, while the latter, **99*a***, tapers downwardly in frusto-conical (inverted) shape as shown in the view.

A conventional oil burner **111** having an air input line **112** and a fuel input line **113** connected thereto (the latter controlled by valve **113*a***) is provided, mounted on flange **114** at the upper end of the tank,

centered on flange **108** whereby to provide combustion therebelow as indicated schematically at **115.**

Returning to cylindrical section **93,** there is provided a pair of openings **93***a* (lower) and **93***b* (upper) connected to or having connected therewith relatively small duct or pipe **116** and relatively large pipe or duct **117,** respectively. The liquid level **118** within tank portion **93** is carried just over the lower boundary of upper large pipe or duct **117.**

Welded or otherwise fixedly attached to ring plate **98** and extending downwardly therefrom is frusto-conical duct or pipe portion **119.** Fixed to or fastened to the lower end of the latter is cylindrical pipe or duct portion **120,** commonly referred to as the dip pipe. A plurality of openings **121, 122** are provided spaced circumferentially around the lower portion of pipe **120** whereby to carry hot gas heat exchange tubes **123** and **124** thereon or connecting thereto. It should be understood that any configuration of openings **121** and **122** analogous to the openings **19, 20, 19'** or **20'** seen in the previous figures may be employed. Thus, the opposed arms **123** and **124** are just illustrating this latter for convenience, clarity and simplicity. Likewise, the plan configuration of the arms **123** and **124,** as well as the attachments thereto, may be as in previous figures.

Connected at the upper ends of members **123** and **124** are U-bends **125** and **126** to which are connected vertically oriented, downwardly extending members **127** and **128.**

Contrasting this form of burner and tank with respect to the previous air-gas forms, the following is noted. In the oil burner, air and fuel are introduced and mixed into the desired ratio, discharging into the combustion chamber. The combustion chamber is the area in which the combustion process takes place. This is defined by passages or openings **110***a*, **105***a* and **99***a*. This may be refractory lined as shown, or it may be of metal construction, depending upon the temperatures of the combustion gases, the amount of cooling to which the chamber is exposed, etc. The chief purpose of dip pipe **120** is to discharge the hot gases beneath the surface of the liquid.

SPECIFIC EXAMPLE

In the use of the system and process improvements of the instant invention, utilizing the improved apparatus, as a specific example, the problem was to concentrate a 40 gpm effluent stream of 3 percent nitrogen solution (Wt. percent) to 20 percent. The goal was to recover only the concentrate. The nitrogen was in a water solution of ammonium nitrate with smaller amounts of sodium nitrate. The primary purpose in concentrating this solution was for waste disposal; in addition, the 20 percent nitrogen solution concentrate could be used as fertilizer.

Utilizing a conventional submerged combustion unit, there were discouraging results, with the most serious observation being that the ratio of sodium nitrate to ammonium nitrate was increased in the product compared to the feed. The obvious conclusion was that ammonium nitrate was being decomposed in the unit. The decomposition rate being in the range of 50 percent, it was evident that same was probably caused by high temperature gases, whereby it would be necessary to cool the exhaust gases in some way to reduce the temperature.

Previous conventional solutions had involved fitting the conventional submerged combustion burner with a jacket and introducing excess air to blend with the hot gases leaving the burner. However, the burner gases at approximately 3,000° F., even introducing excess air, proved to be supercritical in certain temperature ranges and, further, there were more stack gases leaving the evaporator. Thus, with the solution temperature at 195° F., getting a concentration of 11 percent nitrogen with only 5 percent decomposition of ammonium nitrate had to be contrasted with the decomposition rate going up to approximately 50 percent when the temperature of solution went up another 10° F. Utilizing air-gas ratios from the theoretical air-gas ratio to 33 percent excess air still resulted in ammonium nitrate being decomposed (from appearance of the stack gases — brown fume) and analysis of the product still showed an increase in the sodium nitrate to ammonium nitrate ratio).

When the improved burner construction employing twelve distribution points into the solution tank (a dozen heat exchange tubes of the type shown in the drawings) was employed, the stack appearance was greatly improved. Thus, afer ignition of the burner, after an hour-and-a-half, the solution temperature was up to about 200° F. The stack looked very good at this temperature and the steam disappeared after drifting about 500 to 600 feet. In 2 more hours, the normal operating temperature of 218° F. was reached. At this temperature there was a slight yellow hue to the steam as it left the stack and, after the steam disappeared, there was a slight gray hue left. Laboratory samples indicated the ammonium nitrate-sodium nitrate breakdown to nitrous oxide to be about 8 percent at 218° F., this comparing to about 50 percent at an even lower temperature, because this was the first time the system was ever operated at 218° F.

On a later 52 hour run, 41.9 gallons per minute of product was fed with 6.3 gallons per minute of product taken out at 19 percent nitrogen concentration. The ratio of ammonium nitrate to sodium nitrate in the feed solution was 65 percent and the ratio in the product solution was 63 percent, with very little decomposition loss.

At a later date, the submerged combustion unit performed with a feed rate of 41.9 gallons per minute, product rate 6.3 gallons per minute, at a BTU/lb. water evaporated of 13.5. Some decomposition of ammonium nitrate occurred and the loss was estimated to be about 4 percent of that in the feed. The stack plume was much improved. The visual evidence of nitrous oxide in the gases was no longer seen but evidently there was some minor loss of material in the form of aerosols.

The improvement in the appearance of the stack gases and production of the ammonium nitrate loss from 8 to 4 percent was accomplished by blanking off a line from the vapor disengagement tank to the heater tank, causing a greater flow of solution through the line past the lower end of the burner.

At a feed rate of 41.9 gpm (8.92 lbs. per gallon) of 10.13 percent ammonium nitrate solution, the feed will contain 27.2 tons per day of ammonium nitrate. A 50 percent loss would be 13.6 tons per day; an 8 percent loss would be 2.18 tons per day and a 4 percent loss would be 1.09 tons per day. The submerged combustion unit was 24,000,000 BTU/hour whereby, utilizing

12 heat exchanging pipes on the burner, emitted the gases at twelve points equivalent to 2,000,000 BTU's/-hour from each pipe.

GENERAL STRUCTURAL AND FUNCTIONAL CONSIDERATIONS

It should be noted that the system of FIG. **1** shows the burner tank **10** coupled with a disengagement tank **11.** Also, the burner tanks of FIGS. **4** and **8** are shown with duct or pipe connections for coupling with disengagement tanks if desired. The second or disengagement tank **11** helps in the entrainment problem.

The advantage or advantages of the coupled tanks lie in the following. First, one may operate with lower levels in the tanks and thus there is a lower static head that the burner must operate against. Secondly, there is a quiescent zone in the disengagement tank **11** where the vapor disengages and there is less entrainment.

In tank A (**10**) there is an aerated column from the burner gases which causes circulation according to the arrows.

With respect to quantity of solids in the double tank system illustrated utilizing the improved burner, if there are heavy solids present, one preferably does not employ the two tank system with the circulation illustrated in FIG. **1.** It is preferred to use a cone bottom tank as in the B tank of FIG. **1** to remove solids. A sharper angled tank cone is employed when solids are coming off the bottom. This angle is preferably 45° to 60°. Without the sharp angle, solids might build up on the side walls.

With respect to the function of the burners, generally speaking, the purpose of the lesser diameter (upper) velocity tube above the burner body is to prevent actual combustion within it, whereby to force combustion in the body of the burner therebelow.

With respect to the number of heat exchanging arms or pipes employed with respect to a given size burner body, if too few are employed, (less tube cross sectional area than the cross sectional area of the burner), there will be back pressure on the burner and blower powering same. It is better to have more tubes than the area of the burner and thus have lower pressure therewithin.

The devices may be operated with the solution level above the backbend of the heat exchange tubes if the operator will blow the device out before starting up. This gives the advantage of more area for indirect heat exchange, but, in some solutions, there might be a problem with explosions (ammonium nitrate). One does not want drawback of solution into the burner. Thus, if one gets solution into the burner, this will result in liquid evaporating and solids caking within the burner and arms.

The basic purpose of having the solution level up on the burner body is to keep the burner cool. One further considers the splash level on the burner and arms. The level is controlled by suitable conventional level controls on the tank (not described).

Providing the instant arm improvements (and more and longer of same) or adding an air manifold on the burner body operate to achieve the same effect. It is possible to combine the two, using the heat exchanging ducts of the instant invention, more and longer ones of some and adding an air manifold to the burner body. The provision of the return bends and their height corresponds to both the burner body height and the splash area.

Since the combustion gases and air are always hotter than the solution, one can add secondary air despite the number of additional heat exchanging ducts employed. Secondary air addition lowers the boiling point of the solution.

Having thus described my invention, I claim:

1. In a submersible burner for the submerged combustion of fuel beneath the surface of a liquid and substantially out of contact therewith,

said burner having an elongate hollow vertical combustion chamber,

said chamber having at the distal end thereof a plurality of ports at a plurality of levels for discharge of combustion products from said chamber,

said chamber at the proximal end thereof connecting directly with the larger end of a frusto-conical expansion chamber, and

means connecting with the smaller end of said expansion chamber for continuously supplying thereto a gaseous combustible mixture,

the improvement which comprises pipe means connecting at one end thereof to each said chamber discharge port, extending substantially parallel with the combustion chamber axis but in the opposite direction with regard to gas flow in a portion of the length thereof and further having an open submerged end return bend of sufficient length,

whereby, when the combustion chamber is substantially submerged in fluid to be heated, a portion of the return bend is above the liquid surface and the portion thereof furthest from the combustion chamber discharge port is submerged in said liquid.

2. In a submersible burner for the submerged combustion of fuel beneath the surface of a fluid and substantially out of contact therewith,

said burner having an elongate, hollow, vertical combustion chamber,

said chamber having at the distal end thereof a plurality of ports for discharge of combustion products from said chamber,

said chamber at the proximal end thereof connecting directly with the larger end of a frusto-conical expansion chamber, and

means connecting with the smaller end of said expansion chamber for continuously supplying thereto a gaseous combustible mixture,

the improvement which comprises pipe means connecting at one end thereof to each said chamber discharge port, extending substantially parallel with the combustion chamber axis but in the opposite direction with regard to gas flow in a portion of the length thereof and further having an open submerged end return bend of sufficient length,

whereby, when the combustion chamber is substantially submerged in liquid to be heated, a portion of the return bend is above the liquid surface and the portion thereof furthest from the combustion chamber discharge port is submerged in said liquid, and

means connecting into each said return bend for the addition of secondary air to the combustion products flowing downwardly through said return bend.

3. In a submersible burner for the submerged combustion of fuel beneath the surface of a fluid and substantially out of contact therewith,

said burner having an elongate, hollow, vertical combustion chamber,

said chamber having at the distal end thereof a plurality of ports for discharge of combustion products from said chamber,

said chamber at the proximal end thereof connecting directly with the larger end of a frusto-conical expansion chamber, and

means connecting with the smaller end of said expansion chamber for continuously supplying thereto a gaseous combustible mixture,

the improvement which comprises pipe means connecting at one end thereof to each said chamber discharge port, extending substantially parallel with the combustion chamber axis but in the opposite direction with regard to gas flow in a portion of the length thereof and further having an open submerged end return bend of sufficient length,

whereby, when the combustion chamber is substantially submerged in liquid to be heated, a portion of the return bend is above the liquid surface and the portion thereof furthest from the combustion chamber discharge port is submerged in said liquid,

means connecting into each said return bend for the addition of secondary air to the combustion products flowing downwardly through said return bend,

the means for supplying secondary air comprising the portion of said return bend which is above the liquid surface.

4. A process of concentrating liquids comprising the steps of:

a. burning a combustible mixture of fuel and air in a combustion chamber positioned substantially entirely below the surface of the liquid body being concentrated, the combustion chamber being in direct contact with said liquid body,

b. discharging the products of combustion from the lower portion of the combustion chamber at a plurality of locations in said liquid body,

c. then passing said products of combustion from said combustion chamber in indirect heat exchange with said liquid body and below the surface thereof through and within a plurality of tubes which first rise in said body substantially above said discharge locations at least substantially to the top of the combustion chamber and thereafter descend in said body at least substantially to the level of said locations, and

d. finally passing said products of combustion into said liquid body at a level substantially below the liquid body surface and at a plurality points in said liquid body substantially spaced away from said chamber for direct contact with said liquid body.

5. A process as in claim 4 wherein the tubes discharge at or below the level of the combustion chamber discharge locations.

6. A process as in claim 4 wherein the tubes in part each extend substantially radially from the combustion chamber.

7. A process as in claim 4 wherein the number of tubes and their cross-sectional area is greater than the burner cross-sectional area so that the pressure therein is less than in said combustion chamber.

8. A process as in claim 4 wherein secondary air is added to the products of combustion after discharge thereof from the combustion chamber.

9. A process as in claim 8 wherein said secondary air is added on the return of the tubes downwardly.

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