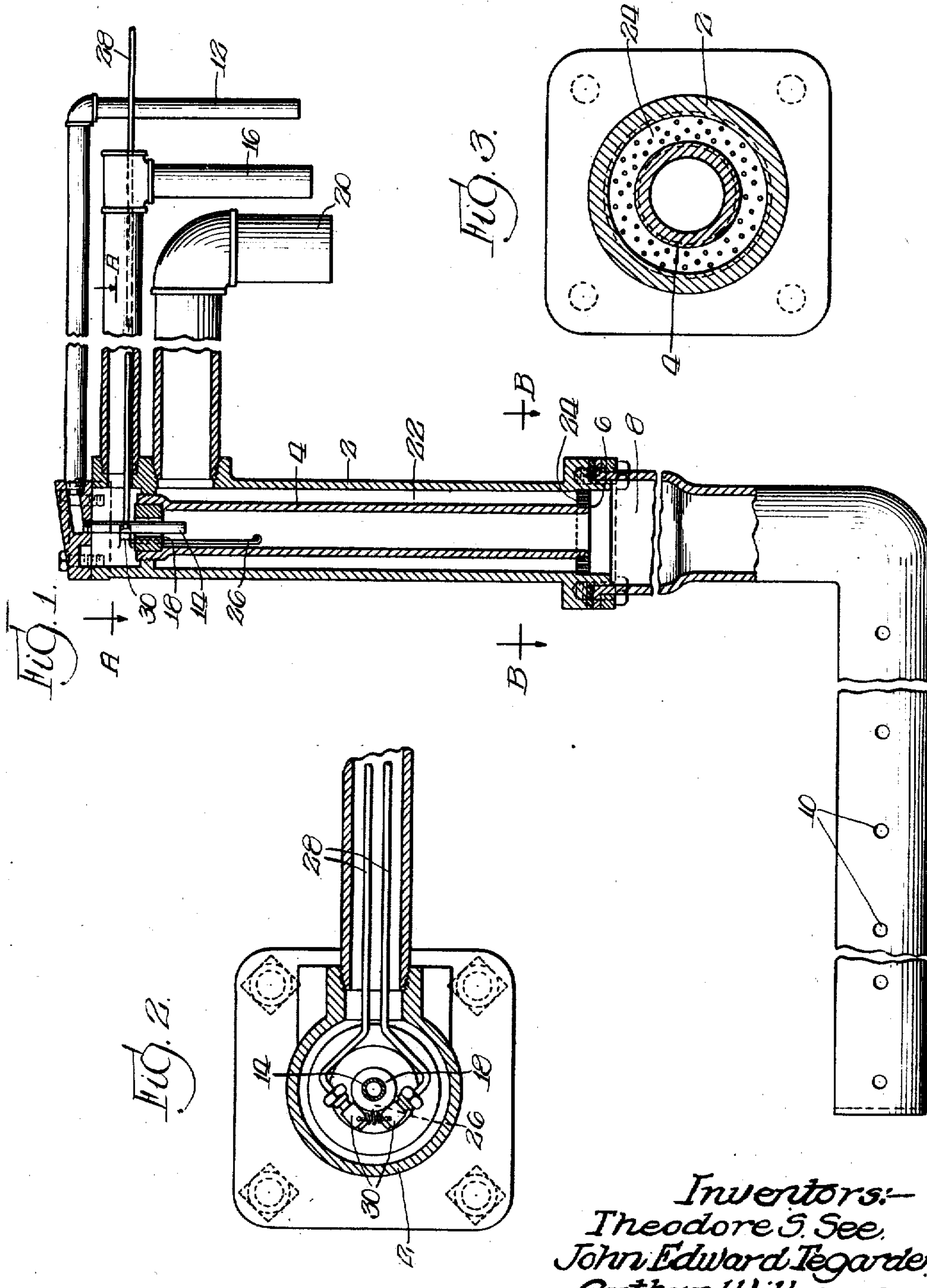
Oct. 3, 1939. T. S. SEE ET AL 2,174,533

SUBMERGED COMBUSTION CONTROL SYSTEM

Filed Feb. 23, 1937 3 Sheets-Sheet 1



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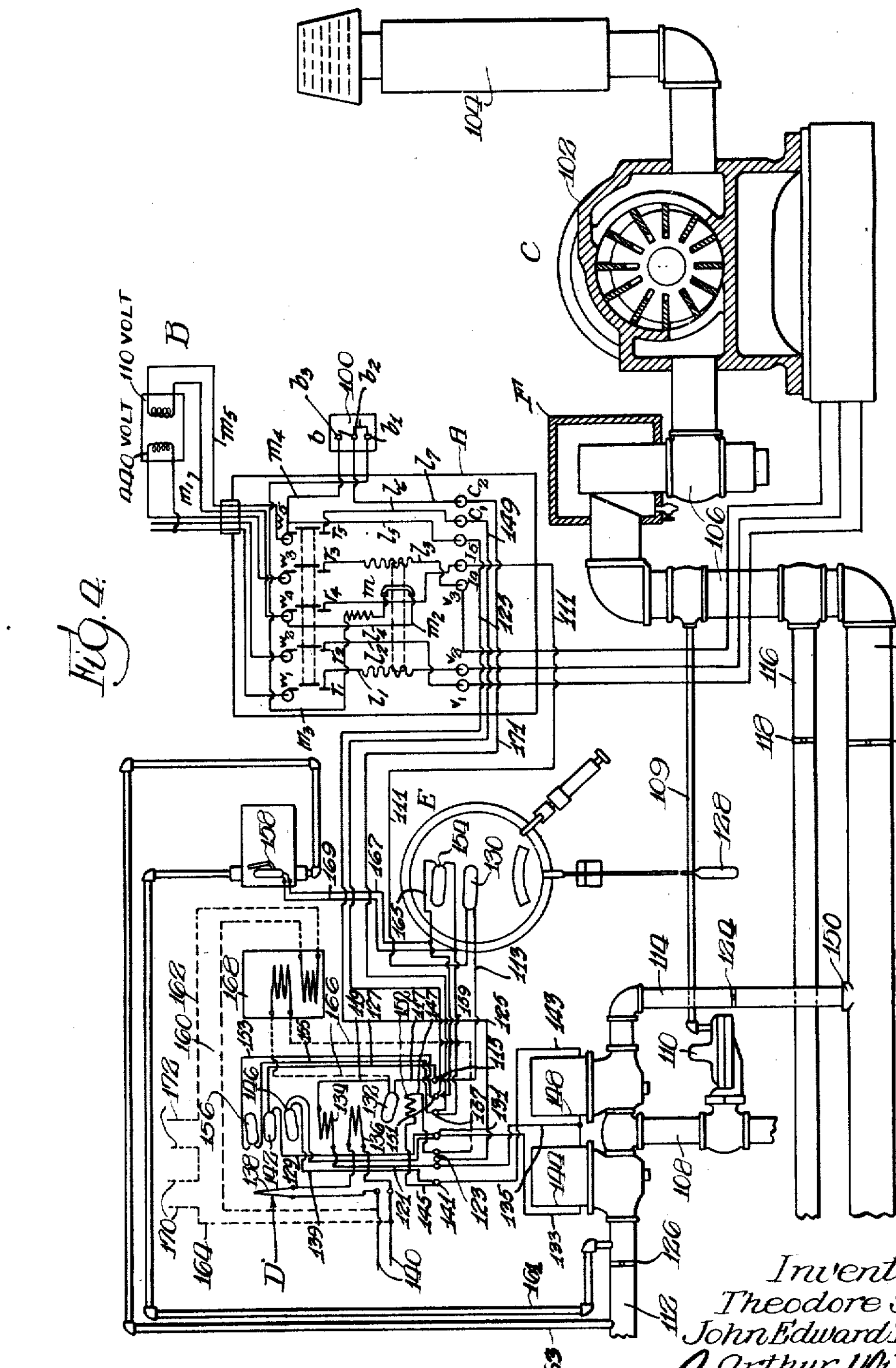
Filed Feb. 23, 1937   3 Sheets-Sheet 2



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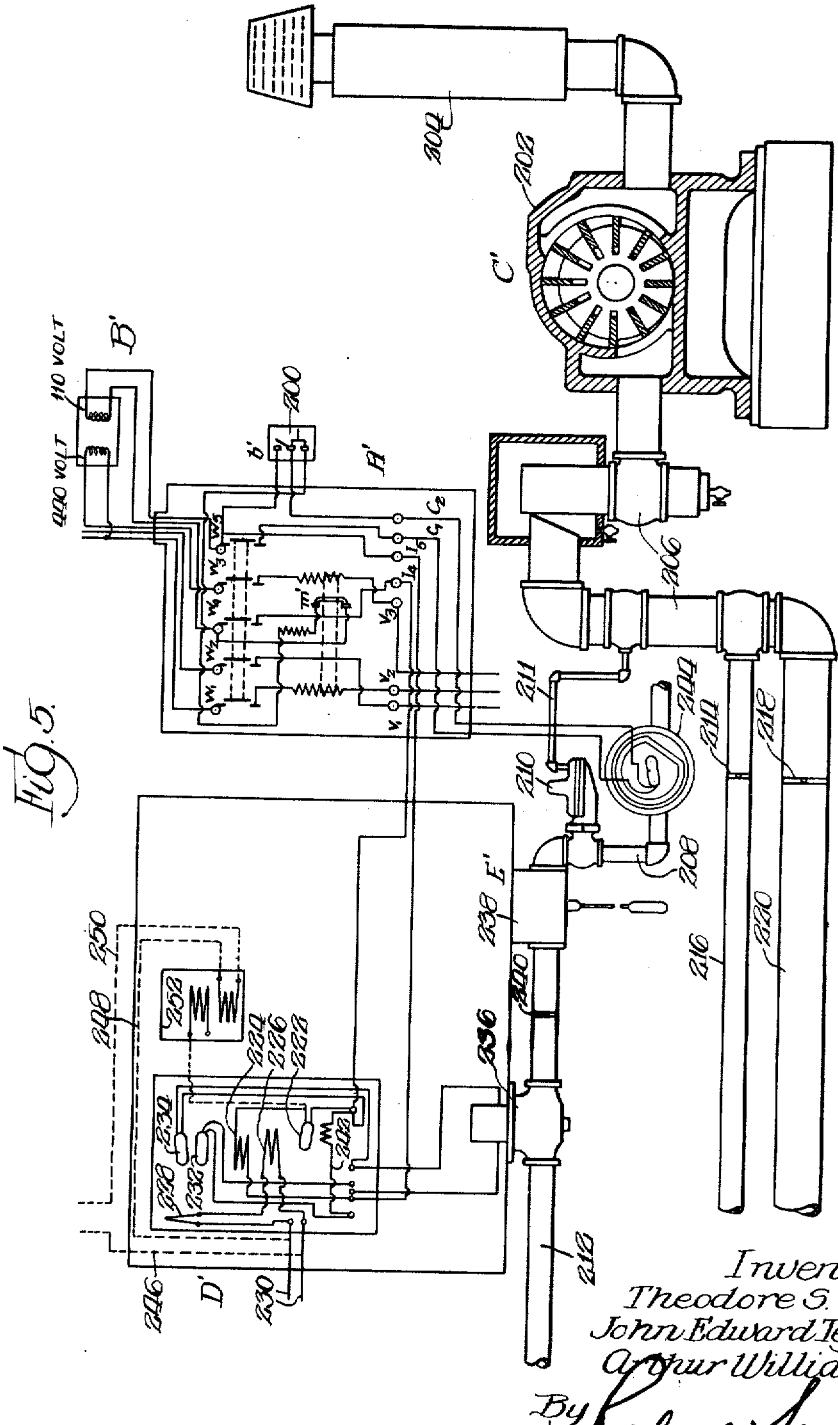
SUBMERGED COMBUSTION CONTROL SYSTEM

Filed Feb. 23, 1937 3 Sheets-Sheet 3



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SUBMERGED COMBUSTION CONTROL SYSTEM

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Application February 23, 1937, Serial No. 127,068

3 Claims. (Cl. 158—1)

This invention relates to submerged combustion, more particularly submerged combustion control systems and new and improved methods and apparatus for obtaining automatic submerged combustion control.

This application is a continuation-in-part of our copending application Serial No. 94,716, filed August 6, 1936.

The expression "submerged combustion" is used to describe combustion beneath the surface of a liquid in direct contact with the liquid. The older methods of heating liquids, which are still largely in use, involve the transfer of the heat from the products of combustion through a metal wall to the liquid to be heated, as, for example, in a steam boiler. Direct heating through a metal wall is much less efficient than submerged combustion because of heat losses during the process of transferring the heat from the products of combustion to the liquid.

In so far as is known, none of the submerged combustion burners heretofore described is provided with an automatic control system for regulating the thermal output of the burner according to the thermal requirements of the liquid being heated. In fact, most of the known submerged combustion burners are so constructed or used that automatic control would be extremely difficult. In our co-pending application, above referred to, we have described a submerged combustion burner which may be ignited while in place in the liquid and which may be automatically controlled.

It is an object of this invention to provide new and improved control systems for submerged combustion burners. A further object is to provide a new and improved method and apparatus for automatically regulating control of a submerged combustion burner, so that the thermal output of the burner is controlled according to the thermal requirements of the liquid being heated. A more specific object is the provision of a method and apparatus for automatically controlling a submerged combustion burner of the type described in our above identified co-pending application. A still further object is the provision of a new and improved means for controlling the thermal output of a submerged combustion burner by regulation of the fuel ignition. Another object is the provision of a means for controlling the thermal output of a submerged combustion burner by regulating the fuel flow. Other objects will appear hereinafter.

In accordance with this invention, we have provided a means for automatically regulating and controlling the thermal output of a submerged combustion burner. This will be illustrated by several control systems, which embody generally: (1) thermostatically regulating the ignition, and (2) thermostatically regulating the flow of fuel. These systems are especially well adapted for application in automatically controlling a submerged combustion burner such as described in our co-pending application, in which the combustion zone of the burner is positioned beneath the surrounding liquid level and the burner is ignited in place, preferably by first igniting a raw fuel jet above the liquid level and projecting the flame down to the combustion zone. In this type of burner and in the preferred methods of automatic control herein described, means are provided for agitating and at least partially displacing the liquid in the combustion zone by an air flow which is preferably continuous and preferably substantially constant both before and after ignition.

Other features of the invention will become apparent from a reading of the following specification in the light of the accompanying drawings, in which

Figure 1 represents the combustion burner in elevation, partly in section and with parts broken away;

Figure 2 is a plan view of a section of the burner along the line A—A;

Figure 3 is a plan view of another section of the burner along the line B—B;

Figure 4 is a diagrammatic view of an automatic control system which is designated herein as our ignition control system; and

Figure 5 is a diagrammatic view of an automatic control system which is designated herein as our fuel flow control system.

Description of the Submerged Combustion Burner

The burner, as illustrated in Figure 1, comprises an outer manifold **2**, an inner manifold **4**, a burner plate **6**, a combustion chamber **8**, equipped with outlets for the combustion gases **10**, a fuel supply line **12**, leading to an opening **14** in the inner manifold, an air supply line **16**, leading to an opening **18** in the inner manifold, a supply line **20** for air or air and fuel mixtures leading to the combustion chamber **8**, through the space **22** between the outer manifold and the inner manifold and openings **24** in the burner plate. The igniter **26** is connected with a source of electricity, not shown, through wires **28**.

In Figure 2, the plan view of the cross section along the line A—A shows connections **30**, which are connected to the igniter 26 (Figure 1) and a source of electricity, not shown, through wires 28. The igniter is preferably of the hot wire type in which an ignition element is heated by passage of a low voltage-high amperage current. Alternatively, a high tension spark may be used. The wires 28, illustrated in Figure 1, are within the air supply line 16 and pass around the fuel supply line 12.

As illustrated in Figure 3, which shows a plan of the cross section along the line B—B, the air or air-fuel mixture, preferably under pressure, from a positive displacement blower, illustrated at C and C' in Figures 4 and 5, passes into the combustion chamber 8, through openings 24 in the burner plate 6. The size of these openings may be varied to suit the desired flow of air or air-gas mixture.

The entire burner, including the manifolds 2 and 4, the burner plate 6 and the combustion chamber 8, may be constructed of the same or different corrosion and heat resisting materials, e. g., iron, steel, alloys, etc., and the various types of stainless or corrosion resisting materials. The choice of material may vary somewhat depending upon the conditions of operation, for example, the temperature and the type of liquid. Under most severe conditions, as in heating acid pickling baths, especially desirable results have been obtained by the use of a corrosion resisting alloy sold under the trade-name of "Hastelloy C", which is a high nickel, molybdenum, chromium, iron alloy. Whereas the usual type of burner involves combustion of the fuel against a refractory material, it has been found in the present burner that refractory materials are unnecessary and uneconomical for ordinary operations. However, they may be used if desired.

Description of Control Systems

The two systems shown in Figures 4 and 5 have some similarities. For instance, in each system there is a switch box generally indicated at A in Figure 4 and A' in Figure 5. This switch box is of the type in which the main contacts are closed by means of a holding magnet *m* in Figure 4 and *m'* in Figure 5. The holding magnet in turn is controlled by push button switch *b* in Figure 4 and *b'* in Figure 5. This magnet may also be controlled by certain safety devices, as hereinafter more fully described. The push button switch *b* in Figure 4 and *b'* in Figure 5 is on an electrical circuit which extends to a source of electricity generally illustrated by the transformer B in Figure 4 and B' in Figure 5. This transformer for the purposes of the present invention preferably has two circuits, a 440-volt circuit operating the blower assembly generally indicated at C in Figure 4 and C' in Figure 5, and an 110-volt circuit operating the ignition control system generally indicated at D in Figure 4 and D' in Figure 5.

The various conduits shown in Figures 4 and 5 connect with conduits in Figure 1 as follows: conduit 12 of Figure 1 is an extension of conduit 112 of Figure 4 and 212 of Figure 5. Conduit 16 of Figure 1 is an extension of conduit 116 of Figure 4 and 216 of Figure 5. Conduit 20 of Figure 1 is an extension of conduit 120 of Figure 4 and 220 of Figure 5. It will be noted that the numerals designating the various parts of the apparatus are below 100 in Figures 1, 2 and 3; 100 or above in Figure 4; and 200 or above in Figure 5.

In describing our automatic control systems, we refer to the system illustrated in Figure 4 as our ignition control system, because in this system each time the solution temperature falls below the minimum temperature fixed by the thermostat, the circuit to the ignition coil is closed and the fuel is reignited. When the proper temperature has been reached, the thermostat, through an electrical circuit to the main control valves, shuts off the supply of fuel entirely. The system referred to in Figure 5 has been described as a fuel flow control system, because in this system the flow of fuel is never entirely cut off unless the entire apparatus is shut down, and the ignition in this system is not repeated each time the solution temperature falls below the minimum temperature required to actuate the thermostat. In other words, ignition is only required in starting the apparatus. It will be observed of course that both of these systems to some extent involve ignition control but the second system does not involve repeated use of the igniter during each period of operation. It will be further apparent that a number of variations may be made particularly in the type of apparatus and in the combinations of the various parts of the system.

The operation of the submerged burner control systems shown in Figures 4 and 5 as well as various modifications of these systems will be illustrated by the following description in which for convenience we refer to the system of Figure 4 as System No. 1 and the system of Figure 5 as System No. 2. Another system combining certain features of both systems is described as System No. 3.

Operation of the Submerged Combustion Control Systems

System No. 1

Referring to Figure 4, pressing the push button 100 closes the circuit to the holding magnet *m*, which in turn closes the main contacts to the blower assembly illustrated generally at C and energizes the line to the ignition control generally indicated at D. This starts the blower 102, which draws in air through an inlet conduit 104 provided with a suitable air filter and forces it out through a line 106, provided with a suitable oil separator F. Conduit 106 connects with the main fuel supply line 108 through a pressure equalizing line 109 and a governor 110. The main fuel supply line 108 is connected with an ignition fuel supply line 112, which may also be called a pilot fuel line, and to a main fuel supply conduit 114. The air introduced through conduit 106 passes into an ignition air supply line 116, which may also be referred to as a pilot air line, provided with an orifice plate 118 and also into a main air line 120 provided with an orifice plate 122.

The air blower 102 is preferably of the positive displacement type and is run at a constant speed by means of an electric motor. With different depths of solution, it is necessary to work against different back pressures but with a positive displacement type of blower, the delivery pressure will suit itself to the back pressure and the flow of air will be substantially constant regardless of the solution depth in the liquid being heated. In this way, agitation is held constant and independent of the solution depth. It will be recognized that both the air and gas must be supplied at a pressure sufficient to overcome frictional resistances and the total pressure of the liquid against which the apparatus is delivering. Thus, if a gaseous fuel is used and is carried in the mains at a pressure of about 20 pounds per square inch, the pressure is usually more than sufficient for ordinary operations. If the gas is only available at a pressure of, say, 5 pounds per square inch, it would probably be necessary to use a blower or booster for the gas. This blower could be started up at the same time as the air blower. It could be a separate blower or on the same shaft as a single unit.

The governor 110 located in the main fuel line 108 is controlled by the air pressure in the line 106 between orifice 122 and the blower 102, so that the pressure in the main fuel line 108 is the same as the pressure in the air line 106 ahead of orifice 122. The drop across orifice 122 is proportional to the flow of air. Since the pressure in the main fuel line 108 is held the same as the air pressure in conduit 106 the drop across orifice 122 will be the same as the drop across orifice 124 in conduit 114. As the drop across orifices 122 and 124 is always the same, by suitably proportioning the areas of these orifices, any desired ratio of air to fuel can be fixed and maintained.

The ignition fuel in conduit 112 passes to the burner (Figure 1) through conduit 12 and opening 14 into the inner manifold 4. The main air-fuel stream flows from conduit 120 to the burner (Figure 1) through conduit 20, then through the space 22 between the outer manifold 2 and inner manifold 4 of the burner, and mixes with the ignition fuel stream in the combustion zone 8 at a point below the burner plate 6. The pressure drop from the main air conduit 106 (Figure 4) above the orifice 122 to the combustion chamber beneath the burner plate 6 of Figure 1 will depend upon the pressure drops across the orifice 122 and burner plate 6 (Figure 1). Since the pressure in main fuel line 108 (Figure 4) is maintained equal to the pressure in air line 106, the pressure drop across orifice 126 is the ignition fuel line 112 will be the same as the total pressure drop across orifice 122 and burner plate 6 (Figure 1). By suitably proportioning orifice 126 (Figure 4) to suit orifice 122 and the pressure drop through burner plate 6 (Figure 1), the desired flow of ignition fuel can be fixed and maintained.

It is also desirable to obtain a fixed supply of air to combine with the ignition fuel supply at opening 14 (Figure 1). This is maintained by orifice 118 (Figure 4) in pilot air line 116. As the main volume of air flows through conduit 120 to conduit 20 (Figure 1) and then through the space 22 between the inner and outer manifolds of the burner and the burner plate 6 to the combustion zone 8, it clears the burner of all solution which before starting is normally above the burner plate.

Assuming that the solution temperature is lower than desired, thermostat bulb 128 (Figure 4) actuates switch 130, so that the switch is in closed-position. This permits current to flow from the transformer B through the switch box A to the ignition control system illustrated generally at D. Ignition switch 122 is in on-position and the current flows through primary coil 134. By induction, the current is induced in secondary coil 136 and this current flows through bimetallic timing strip 138 and wires 140 to igniter coil 26 (Figure 1). The bimetallic strip 138 (Figure 4) bends as it is heated by the heavy current flowing through it and rotates a plate on which the pilot switch 142 and the main switch 146 are mounted. After an interval of time sufficient for the igniter coil to reach the correct temperature, pilot switch 142 makes contact and so opens solenoid valve 144. The ignition fuel supply flows through the solenoid valve 144, orifice 126, and conduit 112 to the burner (Figure 1) where it enters through conduit 12 and opening 14 into inner manifold 4. The jet of fuel is ignited by igniter coil 26, and the flame floats down inner manifold 4. A ring of air, forced by the blower 102 through conduit 106, orifice 118 and conduit 106, is admitted to the burner through conduit 16 (Figure 1) and enters the inner manifold 4 through opening 18. This air travels down the inner manifold of the burner at approximately the same velocity as the central fuel jet, so that combustion takes place slowly at the junction of the fuel and air, which is in the form of a ring. In this way a hollow flame is produced, burning continuously down the inner manifold 4 (Figure 1) to a point beneath the burner plate 6.

After a further interval of time, main switch 146 (Figure 4) makes contact, thereby opening solenoid valve 148, and fuel is admitted through conduit 114 and orifice 124 to mixing T 150. The combustible mixture flows through pipe 120 to conduit 20 (Figure 1) and down the space 22 between the inner manifold 4 and main manifold 2 to burner plate 6. The pilot flame and the main air-fuel mixture are moving at approximately the same velocity, so that ignition of the main air-fuel mixture takes place instantly and quietly. The products of combustion pass down through combustion chamber 8 and holes 10 to the solution.

Referring again to the ignition control D (Figure 4), a holding magnet 152 is in series with the main solenoid switch 146, and as soon as the main solenoid switch 146 makes contact, the current passing through holding magnet 152 pulls the ignition switch 132 to off-position and holds the entire system with the ignition switch 132 in off-position and the pilot switch 142 and main switch 146 in on-position. Thus, both of the solenoid valves 144 and 148 are open after ignition and as long at the solution is below the upper temperature setting of the thermostat. This results in combustion in the inner manifold 4 of the burner (Figure 1) as well as below burner plate 6.

If desired, by a suitable adjustment of mercury switches 142 and 146, switch 142 can be tilted to off-position after switch 146 is in on-position and sufficient time has been allowed for the fuel passing through main solenoid 148 to reach the burner and ignite. Instead of moving switch 142 to off-position, the same result can be attained by providing another mercury switch (not shown) in the circuit to solenoid valve 144 and mounted in such a way that it opens the circuit when the main fuel stream has ignited below the burner plate 6 (Figure 1). In either case, instead of having fuel burning down the inner manifold 4 and also below the burner plate 6 (Figure 1) while the solution is coming up to temperature, the effect is to have all of the combustion taking place below the burner plate 6 in the combustion zone 8.

When the solution attains the desired temperature, switch 130 is moved by the thermostat to open position, so cutting off the main circuit to the ignition control. The ignition control returns to the ready position, with the solenoid valves closed, so that only air is passing through the burner and solution. The solution will gradually cool, and after the solution temperature has dropped a predetermined amount, the thermostat bulb 128 actuates a switch mechanism which moves switch 130 to closed position, so starting the ignition cycle again.

As a precautionary measure, the holding magnet *m* in switch box A, in addition to being controlled by the push button 100 is also controlled by three mercury switches. One of these mercury switches 154 is located in the thermostat control generally illustrated at E, and moves with the switch 130 but is in reversed position, so that when switch 130 goes on, switch 154 will break contact and vice versa. The second mercury switch 156 is located in the ignition control system D on the same mounting plate as pilot switch 142 and main switch 146, so that all three move together. When pilot and main switches 142 and 146 are both off, switch 156 is making contact. The contact of switch 156 is broken after the pilot switch 142 makes contact and before main switch 146 makes contact. When the ignition control unit D is locked in running position, safety switch 156 is locked in open position.

The third safety switch 158 is controlled in response to the flow of fuel through orifice 126. At the correct rate, a pressure differential is set up through conduits 161, 163, causing switch 158 to make contact. Assume that this differential is of the order of 2 inches of mercury. If the rate of flow of pilot fuel should change sufficiently to cause the differential to fall to less than 1½ inches, or more than 2½ inches of mercury, switch 158 would be thrown to open position. Switches 154, 156 and 158 are conneted in parallel with each other and each one is connected in series with push button switch 100. The way in which these three switches operate is as follows:

With the entire apparatus shut down and the solution temperature below the temperature for which the thermostat is set, it will be noted from the above that switch 154 is in off-position, switch 156 is in on-position and switch 158 is in off-position. When push button switch 100 is depressed current will flow through the push button switch 100 and switch 156 in the ignition controller D, energizing the holding magnet *m* in the first starting switch box A and making contact in the main power circuit. As is usual in starting switches of this type the starting switch button has only to be depressed for a sufficient length of time to energize the holding magnet circuit, after which the circuit is automatically held closed until broken by some other means.

Current is now flowing to the ignition controller D, which is operating in the manner described above. As soon as the pilot switch 142 makes contact, solenoid valve 144 opens and the ignition fuel flows through orifice 126. If the ignition fuel flow is correct, pressure safety switch 158 makes contact immediately. After a few seconds the further movement of the bimetallic strip 138 causes the safety switch 156 to break contact but as switch 158 is in the closed position the holding magnet circuit to the starting swtich box is still unbroken. If, for any reason, the correct pilot fuel flow is not obtained and pressure switch 158 does not make contact, then before the main switch 146 makes contact, switch 156 will break contact, opening the holding magnet circuit to the starting switch box and shutting down the entire apparatus. It will be noted also that when in running position, switch 156 is held in off-position, so that any appreciable change from the correct fuel flow will shut down the entire apparatus immediately. In this case it will be necessary to restart the apparatus by pushing button 100 in switch box A, presumably after an investigation of the reason for failure.

It was described above how the fuel flow is proportional to the air flow. If the air flow changes more than a certain amount the pilot fuel flow will be altered sufficiently to move pressure switch 158 to open position, shutting down the apparatus.

When the solution is at the desired temperature, thermostat switch 130 opens the main circuit, thereby closing valves 144 and 148 and shutting off the fuel supply. At the same time, the safety switch 154 closes the safety circuit and holds the starting switch magnet circuit closed. To open the starting switch magnet circuit and shut down the entire apparatus, it is only necessary to press push button switch 100.

Provision may be made for igniting more than one burner from the same control system. This may be accomplished, for example, by an additional igniter circuit indicated by the lines 160, 162, 164 and 166. This circuit contains an additional induction coil 168. The wires leading to the igniters (not shown) are illustrated by lines 170 and 172.

It will be observed that the wiring diagram of the apparatus described in Figure 4 comprises five principal circuits exclusive of the circuits to the compressor C and the safety circuits. These circuits just referred to may be readily traced from the contacts I_4 and I_5 in switch box A. The circuits in question comprise (1) a circuit through primary coil 134, (2) a circuit through secondary coil 136 to the igniter, (3) a valve circuit through solenoid actuated pilot valve 144, and (4) a valve circuit through solenoid actuated main valve 148, and (5) a holding magnet circuit through magnet 152.

The first of these circuits may be traced as follows: Current from a positive source of potential passes from contact I_4 in starting box A through line 111 to temperature control switch 130 in temperature control unit E, from switch 130 through line 113 to contact 115, from contact 115 through conductor 117 to switch 132, from switch 132 through conductor 119 to primary coil 134, from primary coil 134 through conductor 121 to triple contact 123 and from triple contact 123 through conductor 125 to contact I_5 in switch box A, which is a negative source of potential.

This circuit serves to energize the primary coil 134, thus creating a current in secondary coil 136 and energizing the second circuit.

The second circuit through secondary oil 136 is connected by conductors 140, 140 to igniter 26 of Figure 1.

The circuit mentioned above starts from a source of positive potential at contact 115, which has already been traced from contact I_4 in switch box A, and passes through conductor 127 to pilot switch 142, from pilot switch 142 through conductor 129 to contact 131, from contact 131 through conductor 133 to pilot solenoid valve 144, from pilot solenoid valve 144 through conductor 135 to triple contact 123 which forms a negative source of potential connected to contact I_5 in switch box A by means of conductor 125. This circuit controls the operation of pilot solenoid valve 144.

A third circuit which controls the operation of main solenoid valve 148 originates at a positive source of potential at contact 131, passes through conductor 137 to main switch 146, thence through conductor 139 to contact 141, from contact 141 through conductor 143 to one side of main solenoid valve 148 and from the other side of main solenoid valve 148 through conductor 135 to triple contact 123 which is connected to a negative source of potential at I_5 in switch box A through conductor 125.

The last of the circuits mentioned above as forming a part of the ignition control system originates at a positive source of potential at contact 141, passes through conductor 145 to holding magnet 152, from holding magnet 152 through conductor 147 to triple contact 123 which is connected to a negative source of potential at I_5 in switch box A through conductor 125.

As already stated, the operation of these circuits is such that current passing through the circuit containing the primary coil 134 induces a current in the igniter circuit containing secondary coil 136. In the primary coil circuit, switch 132, which is preferably a mercury type switch, is normally closed in order to complete the circuit.

As current flows through the secondary coil circuit and through bimetallic element 138 this element 138 moves, causing pilot switch 142, which was heretofore open, to close, thus completing the previously traced circuit through solenoid valve 144 and causing said valve to open. By this time the igniter is hot and the gas flowing into the apparatus because of the opening of the pilot valve is ignited. As already described, the switches 142 and 146 are so arranged that switch 146 which controls main solenoid valve 148 is closed after switch 142, thus completing a circuit through main solenoid valve 148 and opening said valve, thereby allowing a mixture of primary gas and air to pass into the apparatus. The operation continues as long as switch 130 is not broken by the thermostatic control.

After the main solenoid valve 148 is open it is no longer necessary to keep the igniter wires hot, and simultaneously with the closing of main solenoid switch 146 to complete a circuit through and open main solenoid valve 148, another circuit is completed as previously described through holding magnet 152, which thereupon causes switch 132 to open and breaks the circuits through primary and secondary coils 134 and 136, respectively.

The safety circuits, as previously stated, comprise three controlling switches, namely, switches 154, 156 and 158, which are connected in parallel with each other and in series with the relay M in switch box A. Hence, if all three of these switches are open at once the apparatus will automatically shut down. The circuits including these switches may be traced as follows: A positive source of potential from contact C_1 in switch box A passes through conductor 149 to contact 151, from contact 151 through conductor 153 to switch 156, from switch 156 through conductor 155 to contact 157, from contact 157 through conductor 171 to a negative source of potential at C_2 in switch box A. Switch 154 in temperature control unit E is connected to a positive source of potential at contact 151 through conductor 165 and to a negative source of potential at contact 157, through conductor 159. Safety switch 158 is connected to a positive source of potential through conductor 167 which is connected to line 165 and to a negative source of potential through conductor 169 connected to conductor 159.

The operation of the switch box A is conventional and will be readily understood from the illustration in the drawings. Relay m is controlled by a 100-volt circuit extending from a positive source of potential through conductor m_1, contact w_4 and conductor m_2 and to a negative source of potential through conductor m_3, push button contacts b_1, b_2 and b_3, conductor m_4, contact w_5 and conductor m_5. This circuit, it will be noted, is open until closed by pushing push button switch b, which closes contacts b_2 and b_3. When relay m is energized by closing the contact across b_2 and b_3, thus completing the circuit previously traced, it closes the contacts across w_1r_1, w_2r_2, w_4r_4, w_3r_3, and w_5r_5. Closing the contacts across w_1r_1, w_2r_2, and w_3r_3 completes a circuit from the 440-volt source of potential generally illustrated at B, through lines l_1, l_2 and l_3 to contacts v_1, v_2 and v_3 and thence to the compressor generally illustrated at C. Likewise, closing contacts w_4r_4 and w_5r_5 completes a circuit from the 110-volt source of potential to contacts I_4 and I_5 as previously traced. Contact C_1 is connected to a source of potential through conductor l_6, contacts r_5 and w_5 and conductor m_5. Contact C_2 is connected to a source of potential through conductor l_7, contact b_2 and b_1, conductor m_3, relay m, conductor m_2, contact w_4 and conductor m_1.

System No. 2

Referring to Figure 5 of the drawings, air is supplied from a blower assembly shown at C'. The blower 202 is driven by an electric motor, controlled by starting switch box A'. The air is drawn in through inlet conduit 204 provided with a suitable air filter and forced through outlet conduit 206, which is provided with a suitable oil separator. Fuel is introduced into the system through conduit 208 and a governor 210 and flows to the burner through conduit 212, corresponding to conduit 12 of the burner (Figure 1). A pressure equalizing line 211 is provided between the air conduit 206 and governor 210.

The air from conduit 206 flows to the burner through two conduits 216 and 220, corresponding to conduits 16 and 20 of the burner (Figure 1). Conduits 216 and 220 are provided with orifice plates 214 and 218 respectively.

When the starting button 200 is depressed, the blower motor starts and current flows to the ignition control box generally illustrated at D'. Ignition switch 222 is in off-position and current flows through primary coil 224. By induction, current is induced in secondary coil 226 and this current flows through bimetallic timing strip 228 and wires 230 to igniter coil 26 (Figure 1). Bimetallic strip 228 bends as it is heated by the heavy current flowing through it and rotates a plate on which the switch 232 and magnet switch 234 are mounted. After an interval of time sufficient for the igniter coil to reach the correct temperature, valve switch 232 makes contact and opens valve 236. Valve 236 is of the slow opening type and as the valve slowly opens, fuel is allowed to flow through conduit 212 to nozzle or jet 14 (Figure 1). Soon after the valve 236 (Figure 5) is opened the flow through nozzle 14 (Figure 1) is correct for ignition, the fuel will ignite and the flame will burn down inner manifold 4 (Figure 1) to burner plate 6. A ring of air from conduit 16 (corresponding to conduit 216 (Figure 5)) is admitted through opening 18 to support combustion at the instant of ignition. Further opening of the valve 236 (Figure 5) increases the fuel flow up to an amount controlled by the position of thermostatically controlled valve 238 and the size of orifice 240, and the turbulent mixing of the fuel and air around burner plate 6 (Figure 1) will cause the main part of combustion to take place at the burner plate.

At a predetermined time interval after valve switch 232 has made contact, magnet switch 234 makes contact and energizes magnet 242. The magnet pulls down ignition switch 222 to off-position and locks the ignition controller D, with the ignition switch 222 off and valve switch 232 on.

The flow of fuel will be controlled by thermostatic valve 238. If the solution is cold, valve 238 will be wide open and the flow of fuel will be at a maximum, being limited by orifice 240.

As described above for System No. 1, the area of orifice 240, the area of orifices 214 and 218 and the area of burner plate 6 will be suitably proportioned to give the correct air-fuel ratio. When the solution is at the approximate temperature desired, valve 238 will assume a controlling position, determined by the thermostat pilot. There will be a set minimum flow past valve 238. In this way the fuel may vary between minimum and maximum flows in accordance with the solution temperature. It will be noticed that in System No. 2 the igniter only comes into operation at the beginning of each period of running, while in System No. 1 the igniter comes into operation each time that the thermostat calls for heat.

To guard against failure of the fuel supply a pressure switch 244 is located in the fuel conduit 208, ahead of governor 210. This pressure switch is of the type that closes an electrical contact when the pressure is at a predetermined figure and breaks contact in the switch when the pressure drops. The switch is in series with the holding magnet coil m' in starting switch box A'. If, for any reason, the fuel pressure drops below a set figure, the holding magnet circuit in the switch box is opened and the entire apparatus is shut down, requiring closing of the push button switch for restarting.

If desired, a second igniter (not shown) may be operated from the same ignition control D'. This may be accomplished by adding another circuit as shown by wires 246, 248 and 250 and a second induction coil 252.

System No. 3

By variations in the two systems described above, a third system has been devised. In this system the flow of fuel is controlled by solenoid valves as in System No. 1, but the main fuel supply, instead of being mixed with the air before being introduced into the burner, is separately introduced into the burner and becomes mixed with the air therein. This may be accomplished by constructing the apparatus so that conduit 114 (Figure 4), instead of being joined to the main air conduit 120, is joined to the ignition fuel conduit 112 at a point between orifice 126 and the burner. Thus, referring to Figure 4, after the solenoid valve 144 is open, permitting fuel to pass to the igniter and allowing ignition to take place, the main solenoid valve 148 opens and permits fuel to flow through conduit 114 and orifice 124 to conduit 112. All of the fuel then passes through conduit 112 to the burner and is not pre-mixed with the air in conduit 120. In this respect, System No. 3 is similar to System No. 2 (Figure 5). However, in Figure 5 the valve 236 controlling the flow of fuel to the igniter is of the slow opening type, whereas the solenoid valve 144 in Figure 4 is of the rapid opening type. Furthermore, the control of fuel flow in Figure 5, as illustrated, is obtained by a mechanically operated temperature responsive means, as distinguished from the electrically operated temperature responsive control shown in Figure 4 and which is also preferably employed in System No. 3.

It will be apparent that a number of modifications may be made in the various control systems described without departing from the invention. For instance, in Figure 4 instead of the solenoid valves, other types of electrically operated valves may be used. In the ignition control system shown at D in Figure 4 and D' in Figure 5, it has been found advantageous to use mercury switches. These switches may be mounted in well known ways. The induction coils in the ignition systems are preferably of the type having a floating primary coil in order to obtain a constant current.

In Figure 5 the temperature responsive control means, generally illustrated at E', may be so constructed as to operate the fuel flow valve by electrical means rather than mechanical means. It will also be recognized that changes may be made in electrical circuits in ways well known to those skilled in the art.

The combustible fuel is preferably a gaseous fuel, e. g., natural gas, butane, water gas, producer gas, or gas mixtures of the type ordinarily used in household heating and for gas stoves. Instead of gaseous fuels, liquid or powdered fuels may be used, for example, atomized or vaporized oil, gasoline, and the like.

The rate of flow of the fuel may vary widely depending upon many factors, such as the type of fuel, output of the burner, use of the burner, etc. Good results in practice have been obtained with a relatively low rate of flow of the gas to be ignited, preferably not above 125 cubic feet per hour. We have observed a tendency for the flame to pop out if much higher rates of flow are used on ignition. In heating acid pickling baths by our method of submerged combustion, it is preferable to have a minimum gas flow of at least 25 cubic feet per hour because of difficulties in clogging. With other liquids the flow may be lower. The main fuel flow is normally at a much higher rate. For example, good results have been obtained with a total gas flow within the range of 550 to 650 cubic feet per hour. The rate of flow is regulated by the orifices (not shown) in the supply lines, or by the size of the holes in the burner plate, or in any other suitable way.

The apparatus and control systems described are especially desirable because they do not require a large amount of space and are relatively simple to operate. Moreover, by the control system illustrated it is possible to obtain automatic control of submerged combustion while at the same time maintaining constant agitation of the liquid being heated. The ignition system shown and described above is entirely satisfactory for all practical purposes. The igniter is preferably above the liquid level, because although ignition may be obtained with the igniter below the liquid level, the results are not quite so reliable. Hence the liquid level is normally intermediate between the igniter and the burner plate.

The apparatus is especially useful in heating acid pickling baths, in concentrating liquids, and generally in heating liquids including household heating systems. An efficiency of about 95% can be obtained whereas in the conventional steam boiler, an efficiency of 75% is considered very good.

Having thus described the invention, what we claim as new and desire to secure by Letters Patent of the United States is:

1. In a submerged combustion burner control system, the combination of: a submerged combustion burner, means for introducing fuel into the burner, means for introducing air into the burner, ignition control means comprising a mercury ignition switch, a primary and second coil, an igniter element, a bimetallic timing strip, a holding magnet adjacent to the ignition switch and adapted, when energized, to pull the ignition switch to off-position, a pilot solenoid valve controlling the flow of fuel to the burner for the purpose of ignition, a second mercury switch electrically connected to said solenoid valve controlling the flow of fuel to the burner for the purpose of ignition, a second solenoid valve controlling the main flow of fuel to the burner, a third mercury switch connected to said second solenoid valve controlling the main flow of fuel to the burner after ignition and likewise connected to the ignition switch holding magnet, an electrical circuit through the ignition switch to the primary coil whereby, when the ignition switch is closed, a current flows through the primary coil which generates a current in the secondary coil and thereby operates the igniter element and causes the bimetallic strip to bend, which, as it bends, actuates an arm carrying the second and third mercury switches which are mounted in such a way that the third switch closes after the second switch and after a sufficient time has been allowed for ignition.

2. A submerged combustion burner system for directly heating materials in a liquid state comprising, in combination, a burner having a combustion zone for fuel and air positioned in a liquid to be heated, thermal responsive means associated with said liquid and responsive to the temperature of said liquid, pilot fuel supply means associated with said burner, separate pilot air supply means associated with said burner, main fuel supply means associated with said burner, main air supply means associated with said burner, pilot fuel control means associated with said pilot fuel supply means, main fuel control means associated with said main fuel supply means, means associated with said thermal responsive means and said pilot fuel control means to cause the amount of pilot fuel introduced into the burner to be automatically controlled, means associated with said thermal responsive means and said main fuel control means to cause the amount of main fuel supply admitted to the burner to be automatically controlled, pilot fuel ignition means, means associated with said thermal responsive means for energizing and actuating said pilot fuel ignition means, and means associated with said energizing and actuating means for rendering said ignition means inoperative after the pilot fuel has been ignited.

3. A submerged burner system for directly heating materials in a liquid state, comprising, in combination, a burner having a main combustion zone for combustion of fuel and air positioned in a liquid to be heated, a thermal responsive means associated with said liquid, a pilot fuel supply means associated with said burner, a pilot air supply means associated with said burner, a main fuel supply means associated with said burner, a main air supply means associated with said burner, an electrically actuated valve controlling said pilot fuel supply means, an electrically actuated valve controlling said main fuel supply means, an electrical circuit controlling said electrically actuated valve on the pilot fuel supply means and controlled by said thermal responsive means, another electrical circuit controlling said electrically actuated valve on the main fuel supply means and controlled by said thermal responsive means, an electrical pilot fuel ignition means, a third electrical circuit controlling said electrical ignition means and controlled by said thermal responsive means, and a fourth electrical circuit associated with the main fuel control valve circuit and adapted to render the circuit controlling said ignition means inoperative without affecting the circuits controlling the pilot fuel valve and the main fuel valve.

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CERTIFICATE OF CORRECTION.

Patent No. 2,174,533. October 3, 1939.

THEODORE S. SEE, ET AL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, first column, line 41, for the word "is" insert in; page 4, first column, line 34, for "conneted" read connected; and second column, line 57, for "oil" read coil; page 7, first column, line 16, claim 1, for "second" read secondary; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 21st day of November, A. D. 1939.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.

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1. In a submerged combustion burner control system, the combination of: a submerged combustion burner, means for introducing fuel into the burner, means for introducing air into the burner, ignition control means comprising a mercury ignition switch, a primary and second coil, an igniter element, a bimetallic timing strip, a holding magnet adjacent to the ignition switch and adapted, when energized, to pull the ignition switch to off-position, a pilot solenoid valve controlling the flow of fuel to the burner for the purpose of ignition, a second mercury switch electrically connected to said solenoid valve controlling the flow of fuel to the burner for the purpose of ignition, a second solenoid valve controlling the main flow of fuel to the burner, a third mercury switch connected to said second solenoid valve controlling the main flow of fuel to the burner after ignition and likewise connected to the ignition switch holding magnet, an electrical circuit through the ignition switch to the primary coil whereby, when the ignition switch is closed, a current flows through the primary coil which generates a current in the secondary coil and thereby operates the igniter element and causes the bimetallic strip to bend, which, as it bends, actuates an arm carrying the second and third mercury switches which are mounted in such a way that the third switch closes after the second switch and after a sufficient time has been allowed for ignition.

2. A submerged combustion burner system for directly heating materials in a liquid state comprising, in combination, a burner having a combustion zone for fuel and air positioned in a liquid to be heated, thermal responsive means associated with said liquid and responsive to the temperature of said liquid, pilot fuel supply means associated with said burner, separate pilot air supply means associated with said burner, main fuel supply means associated with said burner, main air supply means associated with said burner, pilot fuel control means associated with said pilot fuel supply means, main fuel control means associated with said main fuel supply means, means associated with said thermal responsive means and said pilot fuel control means to cause the amount of pilot fuel introduced into the burner to be automatically controlled, means associated with said thermal responsive means and said main fuel control means to cause the amount of main fuel supply admitted to the burner to be automatically controlled, pilot fuel ignition means, means associated with said thermal responsive means for energizing and actuating said pilot fuel ignition means, and means associated with said energizing and actuating means for rendering said ignition means inoperative after the pilot fuel has been ignited.

3. A submerged burner system for directly heating materials in a liquid state, comprising, in combination, a burner having a main combustion zone for combustion of fuel and air positioned in a liquid to be heated, a thermal responsive means associated with said liquid, a pilot fuel supply means associated with said burner, a pilot air supply means associated with said burner, a main fuel supply means associated with said burner, a main air supply means associated with said burner, an electrically actuated valve controlling said pilot fuel supply means, an electrically actuated valve controlling said main fuel supply means, an electrical circuit controlling said electrically actuated valve on the pilot fuel supply means and controlled by said thermal responsive means, another electrical circuit controlling said electrically actuated valve on the main fuel supply means and controlled by said thermal responsive means, an electrical pilot fuel ignition means, a third electrical circuit controlling said electrical ignition means and controlled by said thermal responsive means, and a fourth electrical circuit associated with the main fuel control valve circuit and adapted to render the circuit controlling said ignition means inoperative without affecting the circuits controlling the pilot fuel valve and the main fuel valve.

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