



**Aug. 5, 1941.**

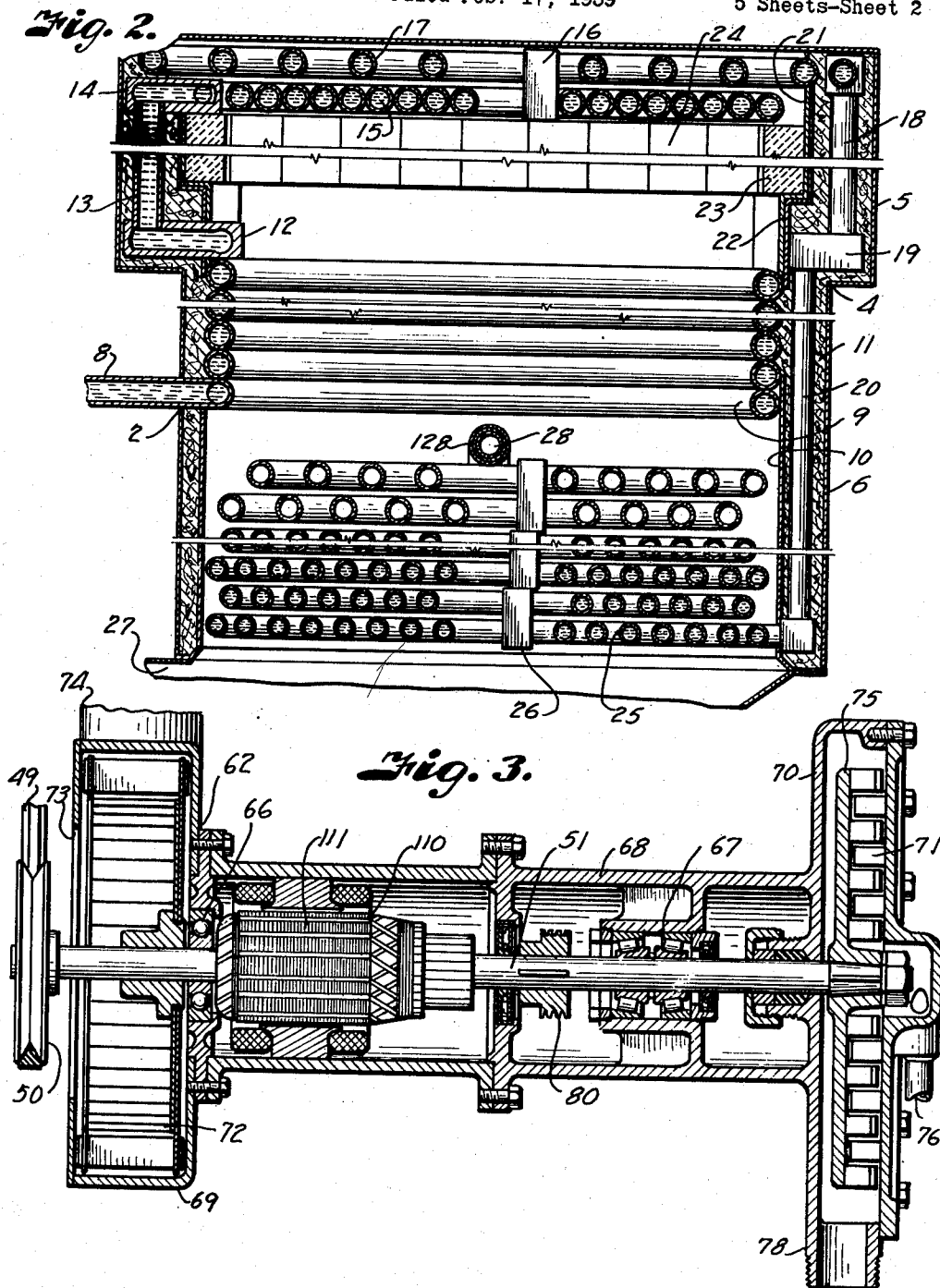
**F. S. THOMAS**

**2,251,383**

## STEAM GENERATING SYSTEM

Filed Feb. 17, 1939

5 Sheets-Sheet 2



**Aug. 5, 1941.**

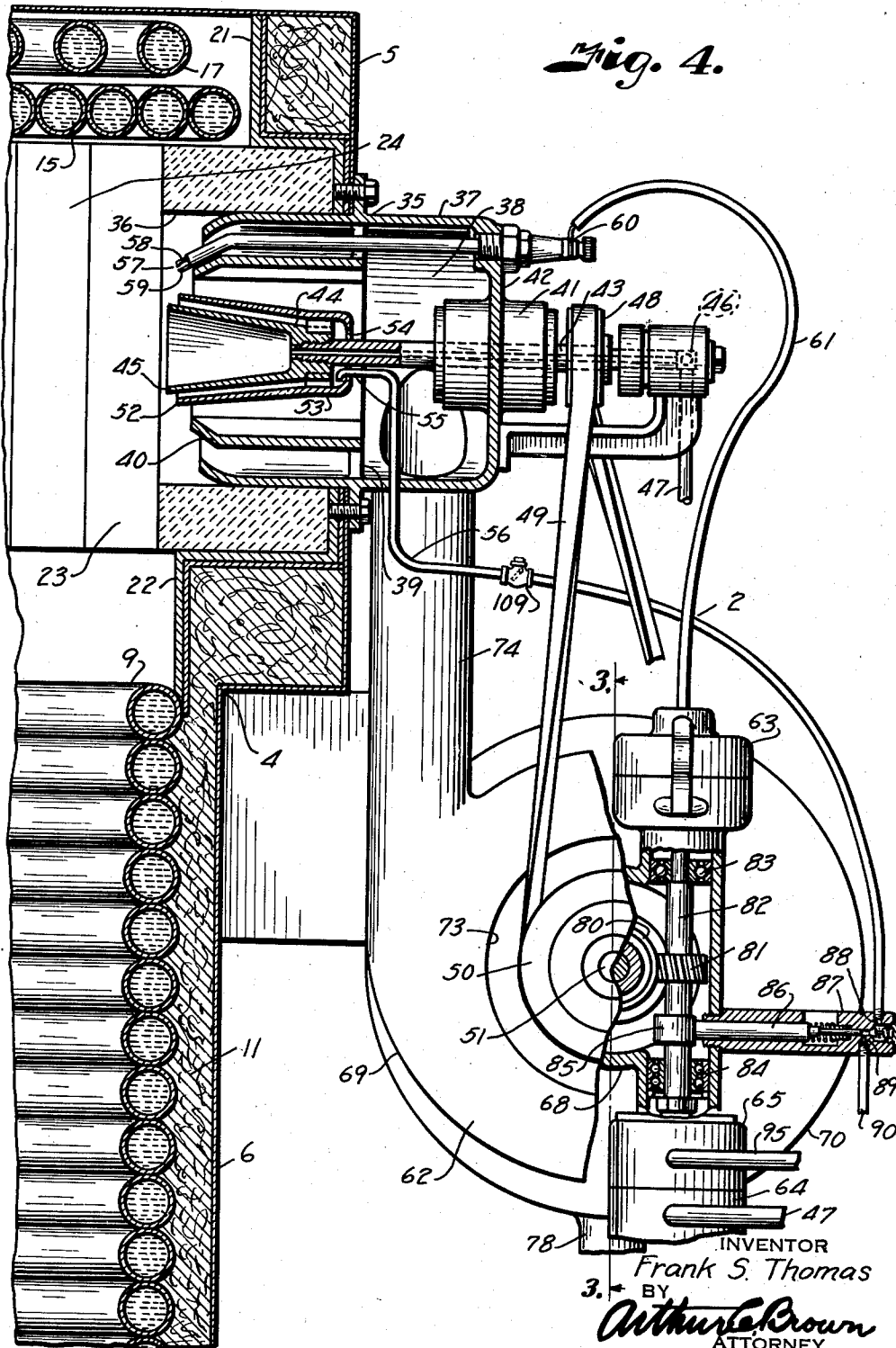
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# STEAM GENERATING SYSTEM

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STEAM GENERATING SYSTEM

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*Fig. 5.*

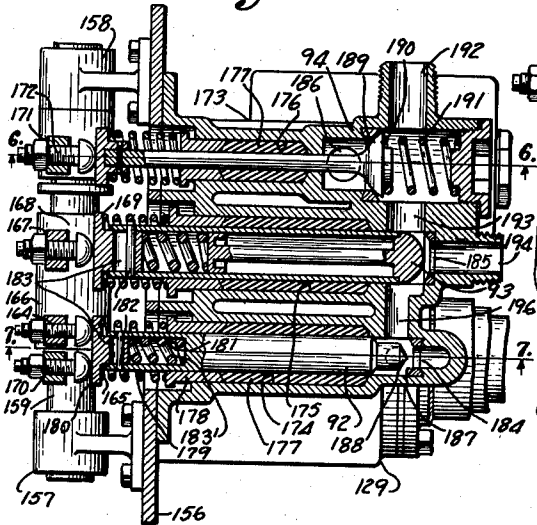


*Fig. 6.*

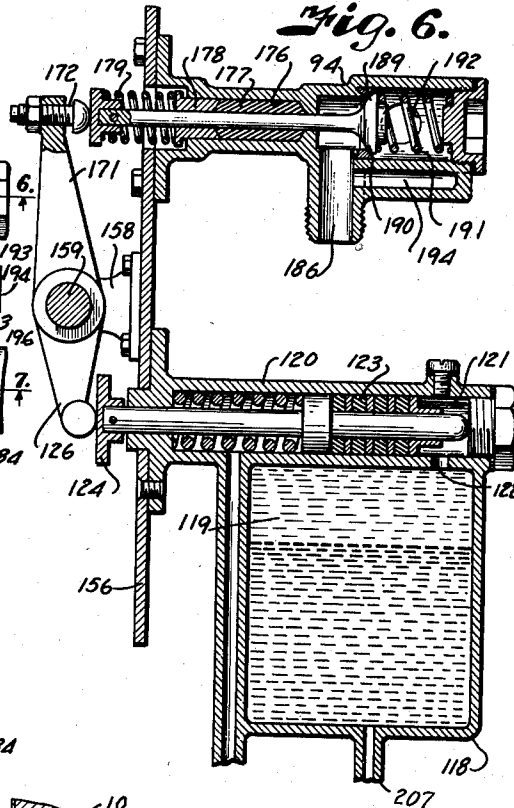
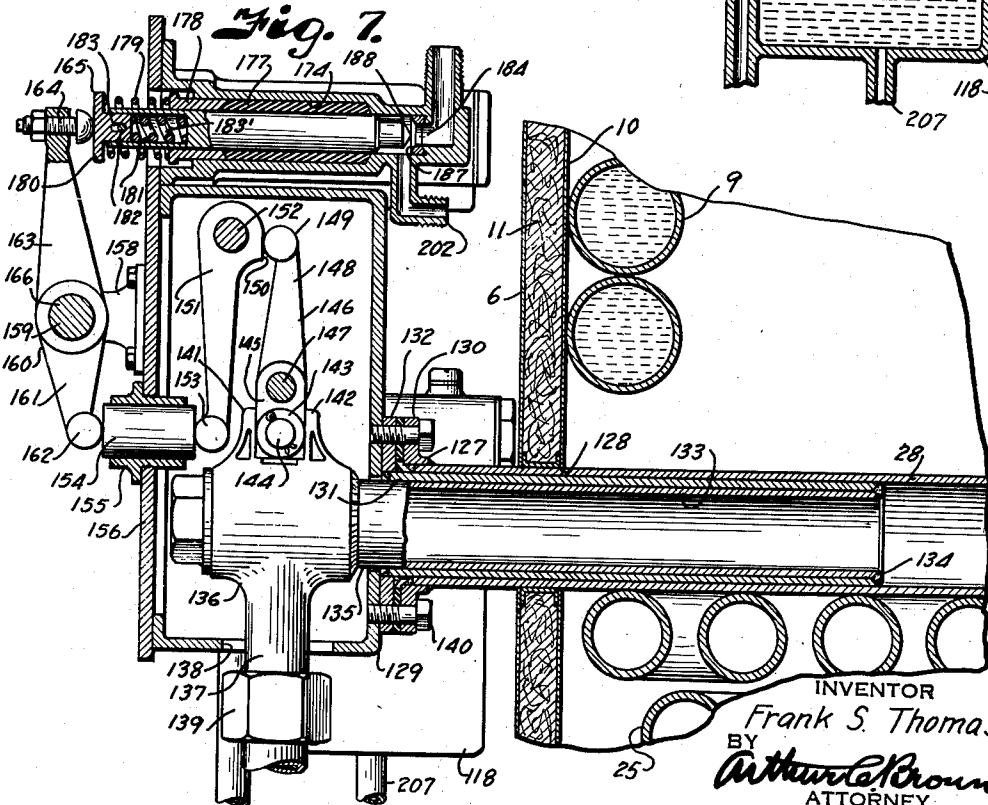


*Fig. 7.*



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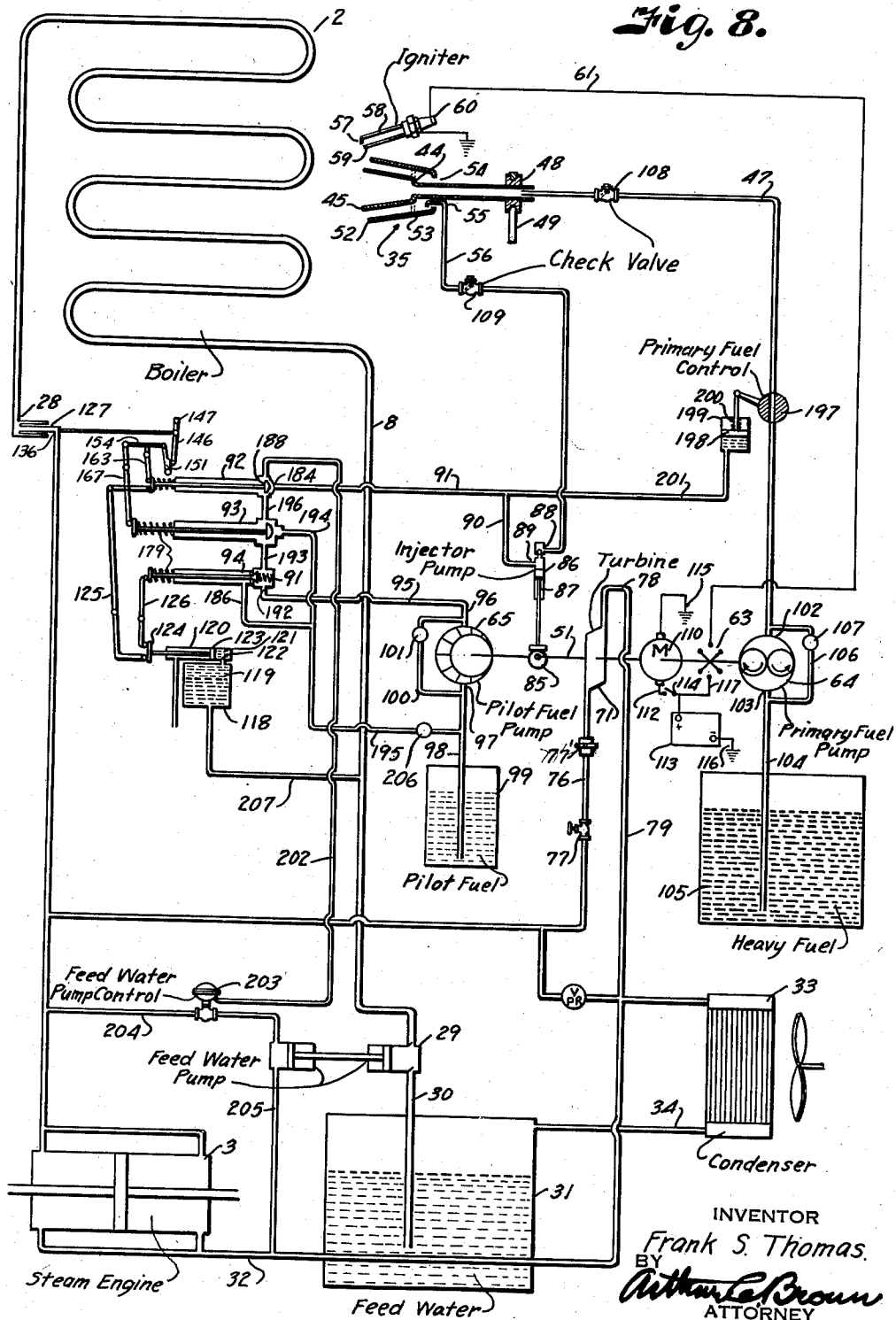
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5 Sheets-Sheet 5

Fig. 8.



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## UNITED STATES PATENT OFFICE

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## STEAM GENERATING SYSTEM

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Application February 17, 1939, Serial No. 256,920

20 Claims. (Cl. 122-448)

This invention relates to steam generating systems, and has for its principal object to provide a compact unit of light weight and high generating capacity.

Other objects of the invention are to provide a generating system that is safe and dependable in operation; and to provide a generating system equipped with full automatic controls.

Further objects of the invention are to provide an intermittently fired generator utilizing a low grade inexpensive fuel; to provide for ignition or kindling of such fuel with a volatile, readily combustible pilot fuel; to provide the system with controls adapted for hydraulic operation responsive to pressure of the volatile fuel; to provide for shutting off fuel supplies and/or water when the generator has reached maximum temperature or pressure conditions; and to provide for shutting off the fuel supplied to the generator in case of failure or depletion of the water supply, or either of the fuel supplies.

A further object of the invention is to provide forced movement of the feed water in contraflow relatively to the hot gases of combustion, thereby promoting rapidity of heat transfer which results in quicker steam generation.

In accomplishing these and other objects of the invention, as hereinafter described, I have provided improved details of structure, the preferred form of which is illustrated in the accompanying drawings, wherein:

Fig. 1 is a side elevational view of a steam generating unit constructed in accordance with the present invention.

Fig. 2 is a vertical section through the generator, particularly illustrating the coil arrangement therein.

Fig. 3 is an enlarged section through the turbine and motor drive assembly for the fuel pumps and the blower for supplying combustion supporting air to the burner, the section being taken on the line 3-3 of Fig. 4.

Fig. 4 is an enlarged section through the generator, particularly illustrating the construction and mounting of the fuel burner.

Fig. 5 is an enlarged detail section through the control valves on the line 5-5 of Fig. 1.

Fig. 6 is a section through the fuel shut-off valve actuated responsive to a maximum steam pressure in the generator, the section being taken on the line 6-6 of Fig. 5.

Fig. 7 is an enlarged section through the thermostatically operated valve for shutting off the fuel supply when the generator has reached a predetermined maximum temperature, the section being taken on the line 7-7 of Fig. 1.

Fig. 8 is a schematic diagram of the steam generating system.

Referring more in detail to the drawings:

1 designates a steam generating system em-

bodying the features of the present invention, and which includes a steam generator 2 adapted for furnishing steam to a steam actuated mechanism, such as a steam engine 3. The generator 2 includes a cylindrical casing 4 having an upper section 5 of larger diameter than a lower section 6. Extending through the side wall of the lower section 6, about midway of the height thereof, is a feed water supply line 8 terminating in a series of upwardly extending, closely wound tubular coils 9 that are spaced inwardly from the wall of the casing 4 to cooperate with an inner casing 10 in retaining an insulation material 11.

The terminal of the upper coil 9 connects with a header 12, which in turn is connected by a pipe 13 with a header 14. The header 14 is connected to the outer terminal of a spirally wound coil 15, the convolutions of which are closely wound and substantially cover the upper portion of the combustion chamber. The terminal of the inner convolution connects with a header block 16 connected with the inner convolution of a superimposed, spirally wound coil 17, the convolutions of which are spaced apart, and the outer terminal connects with a pipe 18 leading downwardly to connect by a header block 19 with a pipe 20. Spaced inwardly from the outer wall of the upper section is an inner wall 21 having an inset lower portion 22 substantially aligning with the inner casing 10, the offset portion forming an annular shoulder for seating refractories 23 encircling the combustion space 24 between the helical wound coils 9 and the upper spirally wound coils 15 and 17. The space between the outer wall of the upper section and the inner wall 21 is also filled with insulating material to retard heat losses through the generator casing. The pipe 20 extends to the bottom of the lower section and connects with the outer convolution of the lowermost of a superimposed series of spirally wound coils 25. The coils 25 are arranged in pairs with their inner convolutions connected by header blocks 26 and the upper set of coils of each pair is connected with the lower set of the next upper pair to provide a continuous passageway for the flow of water and steam, as later described. The coils in one series are preferably staggered with relation to the coils of the adjacent series so as to form a tortuous outlet for the products of combustion traveling from the combustion chamber to a bottom flue outlet 27. The upper series of coils is preferably of greater capacity to provide a larger reserve steam space having outlet through the side of the generator through a steam line 28 leading to the steam engine 3.

Feed water is supplied to the pipe 8 under pressure of a pump 29 having its inlet connected by a pipe 30 with a feed water supply tank 31. The steam discharge pipe 32 for the steam en-

line 3 is connected with a condenser 33 whereby the steam is condensed and returned to the feed water tank through a pipe 34. It is thus obvious that the feed water is withdrawn from the tank by the pump 29 and discharged into the generator through the pipe 8 to circulate upwardly through the coils 9, header block 12, pipe 13, header block 14, and then spirally toward the center of the generator through the coil 15, thence through the header block 16 and through the upper spirals 17. Upon flowing from the upper coils, the feed water moves downwardly through the pipes 18 and 20 to the lower series of coils, and thence upwardly and outwardly through one set, and inwardly through the next set, and so on to the steam storage coils for discharge through the outlet pipe 28 to the intake connections of the steam engine.

Fuel is admitted to the upper section of the generator, and at the upper end of the combustion chamber, through a burner 35, having a nozzle extending tangentially through an opening 36 formed in the refractories 23, as best shown in Fig. 4. The hot products of combustion from the burner are thus caused to swirl circumferentially about the inner wall of the combustion chamber and to move downwardly in sweeping contact with the coils 9 for passage between the convolutions of the lower sets of coils for discharge through the flue 27. The hot products of combustion therefore move in counterflow with respect to the water so as to promote rapidity of heat transfer and thereby increase the rate at which the steam is generated. The water is also caused to pulsate and move through the coils at high velocity. With this arrangement every atom of water contained within the generator is forced to move, and is kept in maximum contact with the heated surfaces of the coils which also promotes rapid steam generation. The water contained in the set of coils nearest the fire source, having absorbed a greater amount of heat, explodes into steam, and the steam passes through the subsequent coils to the point of exit, picking up additional heat so that it is kept in superheated state. The water level or point of vaporization within the coils varies with the load, that is, the greater the load, the higher the water level or point of vaporization will become, and the higher the water level or point of vaporization, the greater is the evaporative capacity of the generator due to the water being forced into closer proximity to the fire. The continuous or forced flow also prevents accumulation of scale, mud, and other foreign substances. Under certain conditions of extreme demands, the water and steam may move at the rate of 6,000 feet per minute or more. This velocity and turbulence of flow carries the solids and foreign matter in suspension and they do not have time to settle out and become attached to any portion of the coils. The small amount of lubricating oil which is usually present in the fast moving stream nullifies corrosion and further prevents lime formations.

The burner 35 is designed to operate on the less expensive hydrocarbons which have high B. t. u. content but are usually of viscous character and difficult to ignite and maintain in combustion, particularly in intermittently operated systems wherein the steam is generated in accordance with the demand. I therefore design the burner to also use a substantially non-viscous, readily combustible pilot fuel to ignite and maintain

combustion of the primary fuel, thereby assuring positive operation of the burner and promoting efficiency of the main fuel. The burner, therefore, includes an outer casing 37 having an air inlet chamber 38 separated from the nozzle portion of the burner by a spider 39 carrying an inner air directing nozzle 40. Rotatably mounted in a bearing 41 carried by the rear wall 42 of the burner housing is a tubular shaft 43 carrying a substantially truncated conical cup 44, having the inner surface thereof flaring outwardly in the direction of the combustion chamber and terminating in a circumferential discharge lip 45. Connected with the outer end of the tubular shaft 43 is an inlet fitting 46, having connection with a supply pipe 47 through which the primary fuel is admitted to the bore of the tubular shaft 43 for discharge into the cup. In the illustrated instance, the shaft is rotated by a pulley 48 that is driven by a belt 49 from a pulley 50 on a counter-shaft 51, later described. The heavy primary fuel is, therefore, discharged circumferentially of the lip 45 in a cone-like spray so that it is thoroughly atomized and conditioned for ready combustion by the more readily combustible fuel. This fuel is similarly discharged from the annular lip 52 of an outer, concentrically positioned cup 53, substantially conforming to the inner cup, and which is fixed thereon so that it is also rotated by the shaft 43. The rear end of the outer cup is open circumferentially and concentrically of the shaft, as at 54, to accommodate the terminal end 55 of a supply pipe 56 through which the readily combustible fuel is delivered to the burner. The lip 52 of the outer cup terminates slightly short of the lip 45 of the inner cup so that the lighter fuel is discharged in a cone-like spray spaced slightly from the spray discharged from the inner cup, to prevent intermingling thereof prior to ignition of the outer spray issuing from the cup lip 52.

Ignition of the outer spray is maintained by means of an ignition device 57 including spaced electrodes 58 and 59 terminating in close relation with the outer spray. One of the terminals is grounded and the other is connected through a suitable insulated connector 60 with an electrical conductor 61.

Air is delivered tangentially of the chamber 38 and is discharged circumferentially of the air directing nozzle 40 and about the periphery of the outer cup to support combustion of the fuels. A portion of this air is discharged through the opening 54 to supply primary air to the readily combustible fuel so that it is in condition to be ignited immediately upon discharge from the lip 52 by means of a spark passed across the terminals of the electrodes. Discharge of the lighter fuel slightly to the rear of the discharge of the heavy fuel allows for combustion thereof, so that it is in thoroughly burning condition prior to contact of the flame with the less readily combustible primary fuel discharged from the lip 45. The proportion of light fuel is relatively small to the consumption of the heavy fuel, in that it is fed at a rate only sufficient to effect and maintain combustion thereof so that when the control mechanisms function to start the burner the fuel is quickly ignited and burned efficiently, thereby facilitating the rapidity with which steam is generated in the coils.

In order to supply combustion supporting air, a suitable spark for effecting ignition of the fuel, and the respective fuels under pressure, the shaft

51 actuates a blower 62, an electrical sparking device 63, and fuel pumps 64 and 65. The shaft 51 is rotatably mounted in antifriction bearings 66 and 67, carried within a tubular housing 68, to the respective ends of which are connected a housing 69 of the blower 62 and a housing 70 of a steam turbine 71. Fixed in the housing 69, on the end of the shaft which carries the pulley 50, is an air propeller 72 for drawing air through an opening 73 in the side of the housing 69 and discharging it under pressure through a conduit 74 leading to the air inlet chamber of the burner. Fixed to the opposite end of the shaft, within the housing 70, is the rotor 75 of the turbine which functions to actuate the shaft. Steam is supplied to the turbine through a pipe 76 having connection with the main steam line 28, flow through the pipe being controlled by a manually operated valve 77. In order to maintain a constantly uniform supply of steam to the turbine, regardless of the degree of valve opening, the pipe 76 includes a flow control orifice 77' so that the counter-shaft is driven at a constant predetermined speed. The spent steam, after passing through the turbine, is discharged through an outlet 78 having connection by a pipe 79 with the line 32 leading to the condenser 33. Fixed on the shaft 51 is a worm 80 which meshes with the worm gear 81 on a transverse shaft 82. The shaft 82 is rotatably mounted in suitable bearings 83 and 84 carried by lateral extensions of the housing 68 through which the sparking device 63 and fuel pumps 64 and 65 are respectively supported, as best shown in Fig. 4. Also fixed to the shaft 82 is a cam 85 arranged to operate a spring pressed plunger 86 of an injector pump 87, having its discharge port 88 connected with a pipe 56, previously referred to.

The inlet 89 of the injector pump is connected by a pipe 90 with a fuel line 91 having connection through control valves 92, 93 and 94, later described, with a pipe 95 connected with the outlet 96 of the fuel pump 65. The inlet 97 of the fuel pump is connected by a pipe 98 with the fuel supply tank 99. Connecting the outlet 96 of the pump with the inlet 97 is a by-pass 100 having a regulating valve 101 therein so that when the pressure in the pipe 95 reaches a predetermined amount, for example 16 pounds, the regulator 101 is opened to allow by-pass of excess fuel, as later described.

The pipe 47 is connected with the outlet 102 of the pump 64, and the inlet 103 of the pump is connected by a pipe 104 leading to a supply tank 105 containing the primary fuel. The pump 64 is also provided with a by-pass 106 having a regulating valve 107 set to by-pass the heavy fuel under conditions later described. The pipes 47 and 56 leading to the burner are provided with check valves 108 and 109.

When the system is to be initially started, or is out of operation, with insufficient steam stored in the coils to actuate the turbine, the shaft 51 is operated by an electrical motor 110 built into the tubular housing 68, and which has its armature 111 mounted directly on the shaft. The motor is energized through a conductor 112 having connection with a battery 113 through a manually operated switch 114, the other terminal of the battery being grounded, as at 115, to cooperate with a ground connection 116 of the motor to complete the circuit when the switch 114 is closed. The battery 113 also provides a source of current supply to the sparking device 63 through a branch conductor 117.

The system described is adapted for automatic control so as to build up and maintain the necessary amount of steam when called upon by the steam actuated mechanism supplied by the generator. It is also essential to provide controls adapted to operate automatically in cases of emergency, as in failure of either one of the fuel supplies, failure of the water supply, or in the instance of excessive temperature and pressure conditions arising in the generator. In the present invention these controls are all effected through the hydraulic action of the pilot fuel oil through the valves 92, 93 and 94, previously mentioned. These control valves are actuated responsive to temperature and pressure conditions within the generator, as now to be described.

Connected with the water line 3, on the pressure side of the feed water pump, is a pressure chamber 118 to which water under hydrostatic pressure of the boiler is supplied for acting on a body of oil 119 which is forced to and from a piston chamber 120 having connection with a chamber 121 through a port 122, the oil acting against the piston 123 to effect movement thereof in one direction when a predetermined maximum pressure rises in the boiler, as when the boiler generates steam to its full capacity. The piston 123 has a head 124 adapted to actuate rocker arms 125 and 126 respectively operating the valves 92 and 94 to effect opening of the valve 94 and closure of the valve 92 when the predetermined maximum pressure is attained in the boiler, and to close the valve 94 and open the valve 92 when the pressure drops below said maximum pressure, which action of the valves controls flow of pilot fuel to the burner, which in turn also controls the delivery of the primary fuel to the burner. The valve 92 is also actuated, together with the valve 93 to control the fuel delivery to the burner responsive to temperature conditions in the boiler under actuation of a thermostat 127.

The thermostat is enclosed in the steam outlet pipe of the generator and is swept by the outgoing steam being delivered to the engine 3. The thermostat is designed so that it is responsive to temperature within the generator, as well as the temperature of the tube 28 (Figs. 2 and 7), so that it is not affected through accumulation of sediment, scale or carbonized tubes. The terminal of the steam coil therefore slidably extends through a collar 128 fixed in the wall of the generator so that it is free to float therein responsive to expansion and contraction. Carried on the terminal end thereof is a housing 129, carrying a compound lever system for actuating the control valve assembly which is also mounted on the housing 129. The housing 129 also carries the pressure chamber 118.

Fixed to the end of the steam tube is a flange 130 and closely slidable therein is a tube 131 having a flange 132 on its outer end. Slidable within the tube 131 is a tube 133, the tubes 131 and 133 being welded together at their inner ends, as indicated at 134. The opposite end of the tube 133 projects through an opening 135 in the housing 129 and carries an L-fitting 136, having a neck 137 extending through a slotted opening 138 in the housing, and which is connected with the steam line by a union 139. The flanges 130 and 132 are clamped together, and to the housing, by fastening devices such as stud bolts 140, having their shanks extending through registering openings in the respective flanges and into threaded

openings in the wall of the housing as clearly shown in Fig. 7, a suitable gasket material being inserted between the flanges to prevent leakage of pressure therethrough. The tubes 131 and 133 are made of material having different coefficients of expansion. For example, the inner tube 133 may be formed of material having a low coefficient of expansion, such as invar, and the tube 131 is formed of material having a greater degree of expansion. Therefore, when the tube 131 expands responsive to heat conditions within the generator, it elongates in the direction of the generator. Since the outer end thereof is connected with the tube 28 through the flanges 130 and 132, and since the inner tube 133 has little or no expansion, it is carried therewith so that the L 136 is shifted within the housing 129. The movement of the L 136 is directly proportional to variations in temperature occurring in the generator, and consequently this movement may be utilized in effecting operation of the controls. The L 136 is, therefore, provided with spaced lugs 141 and 142 which mount a sliding block 143 therebetween. The block 143 is connected by a pin 144 with the arm 145 of a rock lever 146, the rock lever 146 being pivotally mounted on a rod 147 extending through the housing. The other arm 148 of the rock lever 146 is of greater length than the arm 145, and terminates in a head 149 which engages against a bearing face 150 of a lever 151.

The lever 151 is pivoted on a rod 152 also carried by the housing in close relation to the bearing surface 150 so that the effective leverage therebetween is short. The free end of the lever 151 terminates in a head 153, which bears against the inner end of a plunger 154 slidable in a bearing 155 carried by the cover plate 156 of the housing 129. Fixed to the cover plate are spaced bearings 157 and 158 mounting a shaft 159. Pivoted on the shaft 159 is a rocker 160 having an arm 161 provided with a head 162 engaging the outer end of the plunger 154. The rocker also has a longer arm 163 carrying an adjusting screw 164 which engages the stem 165 of the valve 92. The rocker 160 has an extended hub 166 carrying an arm 167, having an adjusting screw 168 in the terminal end thereof for engaging the stem 169 of the valve 93. The rocker arm 125, previously mentioned, is fixed to the shaft 159 and rocks the shaft to operate a lever arm 170 which engages the stem of the valve 92 alongside the rocker 160. The rocker arm 126 is fixed to a hub that is pivotally mounted on the shaft, and has an arm 171 carrying an adjusting screw 172 engageable with the stem of the valve 94. It is thus obvious that when the thermostat expands the lever 146 is shifted on its pivot to rock the lever 151, which in turn moves the plunger to effect rocking of the rocker 160 to close the valves 92 and 93. Likewise when the piston 123 is responsive to pressure in the generator, the rocker arms 126 and 125 are operated to close the valve 92 and open the valve 94, in both instances to cut off the fuel supply to the burner.

The valves 92, 93 and 94 are built within a single valve casing 173, having bores 174, 175 and 176 containing packing rings 177 in which the respective valve stems are slidably sealed. In each instance the packing is compressed about the respective stem by a bushing 178, and which is retained in place by a compression spring 179 having one end bearing against the bushing and the other end against a shoe 180. The shoes 180 for the valves 92 and 93 are loosely mounted

within tubular bores 181 of the respective valve stems, and are retained therein by pins 182 extending through the stems and through registering slots 183 in the shoes. The shoes are normally retained in projected position against the adjusting screws of the rocker arms by coil springs 183' bearing against the shoes and against the bottoms of the bores, as shown in Fig. 5. Provided in the outer ends of the respective valve bores are outlet ports 184, 185 and 186, the ports 184 and 185 being provided with valve seats 187 adapted to be engaged by the valved ends 188 of the respective valves. The bore for the valve 94 has a seat 189 ahead of the seat of the outlet port 186 which is engaged by a mushroom type valving head 190 that is normally retained in seated position by a coil spring 191. When the generator is cold, or is under normal operations, the valves 92 and 93 are normally opened and the valve 94 closed so that liquid is free to flow by way of the pipe 95, and inlet 192, into the valve housing where it flows through a port 193, through the port 185, a connecting duct 194, to a pipe 195 that is connected with the pipe 98, previously described. The liquid is also free to flow through a port 196 connecting the valves 92 and 93, through the port 184, and into the pipe 91 where it is discharged through the pipe 90 into the injector pump, to be injected through the pipe 56 into the outer cup of the burner. Pressure of this fuel is also utilized for controlling a valve 197 connected in the fuel supply line 47, and which is actuated by a piston 198 reciprocable in a pressure cylinder 199 in opposition to a spring 200. The pressure cylinder 199 is connected with the pipe 91 by a branch pipe 201 so that the pressure acts against the piston in opposition to the spring for holding the valve 197 in open position so that the pump 64 is effective in supplying primary fuel to the burner.

The inlet side of the valve 92 is connected by a pipe 202 with a pressure actuated valve 203 located in the steam line 204 which supplies steam to the feed water pump 29, the exhaust steam being discharged from the pump through a pipe 205 that is connected with the line 32, previously mentioned. Connected in the line 195 is a pressure regulating valve 206, similar to the by-pass regulators 101 and 107. Water is supplied under generator pressure to the pressure chamber 118 for actuating the piston 123 by way of a branch pipe 207, connecting the line 8 with the pressure chamber as shown in Fig. 8.

In operating a steam generating system constructed and assembled as described, and assuming that the generator and feed water supply tank 31 are filled to the desired levels, and that the respective fuels have been placed in the respective tanks 99 and 105, the operator will open the valve 77 and close the switch 114 to energize the motor 110 to start rotation of the shaft 51. The pump 65 then becomes effective in drawing pilot fuel from the tank 99 and building up pressure in the hydraulic control system, as set by the pressure regulator 101 in the by-pass 100. Should this pressure tend to rise above the set pressure, for example 16 pounds, then the valve 101 will open to by-pass the excess fuel. Since the system is cold, no steam pressure exists in the generator, and the thermostat is in contracted position. The valves 92 and 93 are therefore open and the valve 94 is closed. In open position of the valve 92, pilot fuel is delivered under pressure through the pipe

91 and pipe 90 to the injector 87, which injector is operating incidental to actuation of the shaft 51. The pilot fuel is, therefore, injected under pressure through the check valve 109, and pipe 56, into the outer cup 53 of the burner. The cup 53, being driven from the shaft 51, is rotated to effect centrifugal discharge of the pilot fuel from the lip 52, with sufficient force and spread to produce thorough atomization thereof. Actuation of the shaft 51 also operates the sparking device 63 so that a current is caused to pass across the terminals of the electrodes 58 and 59 to effect ignition of the pilot fuel. The shaft 51 also operates the propeller 72 so that combustion supporting air is being supplied to the burner for effecting combustion of the fuel. Pressure in the pipe 91 is caused to act upon the piston 198 through the pipe 201 to effect opening of the valve 197 in the primary fuel supply line 47. Prior to opening of the valve 197, the primary fuel was by-passed through the regulator valve 107, but after the valve 197 is opened, the heavy fuel is delivered to the inner cup of the burner, where the fuel is centrifugally discharged concentrically within the pilot fuel spray and is readily ignited thereby and kept in a burning state. Thus the pilot fuel is delivered to the burner and is in a burning state prior to delivery to the burner of the primary fuel.

The burner now being in operation, the flame issuing therefrom is caused to swirl about the interior of the combustion chamber in sweeping contact with the coils 15 and to be forced downwardly in circling spirals over the coils 9, and around the coils 25, before being discharged through the flue 27. The intense flame, acting upon the coils, readily heats the water to the steaming point, with the steam collecting in the upper coils 25. Since the valve 203 is set to open at a higher pressure than the by-pass valves 206 and 101, the feed water pump has not yet been placed in operation, because the temperature conditions in the boiler have not raised sufficiently to require additional water. However, as the water then in the boiler vaporizes the temperature rises to the point where additional water is required. The thermostat then functions to close the valves 92 and 93, shutting off the by-pass through the valve 206 so that the pressure increases in the line 202 an amount sufficient to open the valve 203. Steam is then supplied to the feed water pump to begin operation thereof. With the water pump in operation, additional water is delivered to the generator. Upon this operation the fuel supplies to the burner have been suspended but with the admission of additional water the boiler temperature will have dropped sufficiently to contract the thermostat, thereby permitting the valves 92 and 93 to reopen. The primary fuel is then effective to reestablish the fuel supplies as heretofore described, and upon opening of the valve 93, the by-pass 194 is opened so that the excess pilot fuel is discharged through the regulator valve 206. This produces a drop of pressure within the line 202 so that the valve 203 closes, shutting down the feed water pump.

When the initial steam pressure has been built up in the generator, the shaft 51 is operated by the turbine 71. The switch 114 is therefore opened to suspend the current supply to the motor 110. When a desired maximum pressure is reached in the generator, the pressure, acting through the pipe 207 on the body of oil 119, 75

causes movement of the piston 123 to effect actuation of the rock levers 125 and 126, thereby closing the valve 92 to shut off flow of pilot fuel to the injector pump and to the actuating mechanism operating the primary fuel control valve 197 so that the spring 200 is effective in closing the fuel control valve 197, to shut off the primary fuel. The pilot fuel displaced by the piston 198, on the return stroke, is delivered to the injector so that the primary fuel remaining in the burner is therefore burned so as to prevent smoking and fuming thereof when the burner is again operated. The shaft 51, however, will continue to operate under the power of the turbine to actuate the fuel pumps 64 and 65. The pilot fuel discharged from the pump 65 then flows through the opened valve 94, outlet 186 and pipe 195, to the regulating valve 206, back to the pilot fuel supply tank, the valve 206 being set at a lower pressure than the regulating valve 101. Upon opening of the valve 94 pressure drops in the line 202 so that the control valve 203 closes to shut off steam supply to the feed water pump. As the steam is consumed and the pressure begins to drop in the boiler, the valve 94 is closed under spring pressure and the valve 92 opened so that the pilot fuel pump is again effective in supplying pilot oil to the line 91 for feed to the burner, and in opening of the primary fuel control valve 197 to reestablish flow of primary fuel to the burner, the pilot fuel being ignited as previously described. It is thus obvious that the system will operate intermittently in accordance with the generator pressures which, of course, vary with demands of the steam consuming device, such as the engine 3.

The system is provided with safety features besides the customary safety valve which automatically operate in emergency situations and conditions. For example, should the pilot fuel oil supply become exhausted, the system is immediately shut down for the reason that the pilot fuel is itself the control medium regulating the water and primary fuel supplies. When this occurs, pressure in the line 95 drops to zero, allowing the feed water pump control valve to close, shutting off steam to the feed water pump, thereby stopping further delivery of water to the generator. The pressure drop also allows the spring 200 to become effective in closing the primary fuel control valve 197, thereby shutting off the primary fuel supply which is then by-passed back to the supply tank 105. This control is an important feature since the heavy fuel is not readily combustible without the aid of the pilot fuel, and the system would not operate efficiently. The steam pressure then falls due to absence of fire and water until the generator becomes cold, the turbine stopping at the predetermined steam pressure setting therefor so as to stop further actuation of the shaft 51 and the elements driven thereby.

In the event that the water supply becomes exhausted, the generator will operate at predetermined pressure and temperature until the water contained in the generator tubes is about evaporated. As this condition occurs and is gradually approached, the pressure will fall until the turbine stops at the predetermined setting thereby cutting the entire burning system as well as the controls out of operation. The generator pressure and temperature will, in this case, continue to recede until it becomes cold through radiation losses.

In the event the primary fuel oil becomes

exhausted, the pilot fuel cannot maintain the required heat and the steam temperature will gradually drop in the generator to the point where the turbine will fail to operate, stopping operation of the respective pumps.

It is, therefore, evident that running out of primary fuel, pilot fuel, or water, with the system in operation, creates no emergency condition or danger arising from too high pressure or temperature in the generator.

From the foregoing it is obvious that I have provided a steam generating system which is completely automatic and capable of maintaining an adequate steam supply in accordance with variable demands of the steam consuming apparatus.

What I claim and desire to secure by Letters Patent is:

1. In an apparatus of the character described, a generator, a fuel burner for the generator, a pilot fuel supply, means connecting the pilot fuel supply with the burner, a primary fuel supply separate from the pilot fuel supply, means connecting the primary fuel supply with the burner, means responsive to pressure of the pilot fuel independently of the primary fuel pressure for controlling delivery of the primary fuel to the burner, and means responsive to temperature in the generator for suspending delivery of pilot fuel to the burner.

2. In an apparatus of the character described, a generator, a fuel burner for the generator, a pilot fuel supply, means connecting the pilot fuel supply with the burner, a primary fuel supply separate from the pilot fuel supply, means connecting the primary fuel supply with the burner, means responsive to pressure of the pilot fuel independently of the primary fuel for controlling delivery of the primary fuel to the burner, and means responsive to pressure in the generator for suspending delivery of pilot fuel to the burner.

3. In an apparatus of the character described, a steam generator, a fuel burner for the generator, means supplying a pilot fuel to the burner, means supplying a primary fuel to the burner, means supplying water to the generator, means responsive to pressure of the pilot fuel for controlling delivery of the primary fuel to the burner, and means responsive to said pilot fuel for controlling delivery of water to the generator.

4. In an apparatus of the character described, a generator, a fuel burner for the generator, means supplying a pilot fuel to the burner, means supplying a primary fuel to the burner, means responsive to pressure of the pilot fuel for controlling delivery of the primary fuel to the burner, means responsive to pressure in the generator for suspending delivery of pilot fuel to the generator, and separate means responsive to temperature in the generator for suspending delivery of the pilot fuel.

5. In an apparatus of the character described, a steam generator, a fuel burner for the generator, means supplying a pilot fuel to the burner, means supplying a primary fuel to the burner, means responsive to pressure of the pilot fuel for controlling delivery of the primary fuel to the burner, means for delivering water to the generator, and means responsive to pressure of the pilot fuel for controlling said water delivery means.

6. An apparatus of the character described including a steam generator, a burner for the generator, a source of readily combustible pilot fuel

supply, a separate source of less readily combustible primary fuel supply, separate pumps for moving said fuels to the burner, common means for actuating said pumps, means responsive to pressure of the pilot fuel for controlling flow of the primary fuel, and means responsive to temperature and pressure conditions in the steam generator for suspending the pilot fuel supply.

7. An apparatus of the character described including a generator, a burner for the generator, a source of readily combustible pilot fuel supply, a separate source of less readily combustible primary fuel supply, separate pumps for moving said fuels to the burner, a motor for initially operating said pumps, a turbine having connection with said generator for operating the pumps when a sufficient steam supply is created in said generator, a pressure actuated valve in the primary fuel supply, and means connecting the pilot fuel supply with the pressure actuated valve to maintain said primary fuel supply responsive to the pilot fuel supply, said valve being arranged to close upon failure in said pilot fuel supply to suspend flow of the primary fuel to the burner of the generator.

8. An apparatus of the character described including a steam generator, a burner for the generator, a source of readily combustible pilot fuel supply, a separate source of less readily combustible primary fuel supply, separate pumps for moving said fuels to the burner, common means for actuating said pumps, means responsive to pressure of the pilot fuel for controlling flow of the primary fuel, a turbine having driving connection with said pumps, a steam supply line connecting said generator with the turbine, and means responsive to temperature and pressure conditions in the steam generator for suspending the pilot fuel supply.

9. An apparatus of the character described including a steam generator, a burner for the generator, a source of pilot fuel supply, a separate source of primary fuel supply, separate pumps for moving said fuels to the burner, means responsive to pressure of the pilot fuel for controlling flow of the primary fuel, a turbine having driving connection with said pumps, a steam supply line connecting the generator with said turbine whereby the turbine actuates said pumps to maintain pressure on said pilot fuel, and driving means connected with the pumps for initially building up said pressure.

10. An apparatus of the character described including a generator, a burner for the generator, a source of pilot fuel supply, a source of primary fuel supply, separate pumps for moving said fuels to the burner, a drive shaft, a driving connection between the drive shaft and the pumps, a motor connected with the drive shaft for initially operating said pumps, a turbine having connection with said generator for operating the pumps when a sufficient steam supply is created in said generator, and spark producing means operatively connected with said shaft for igniting said fuels.

11. An apparatus of the character described including a steam generator, a burner for the generator, a pilot fuel supply line connected with the burner for delivering a readily combustible fuel of low viscosity, a primary fuel line connected with the burner for delivering a less readily combustible fuel of higher viscosity, a valve in the primary fuel line, pressure actuated means connected with the valve, a duct connecting the pilot fuel line with said valve actuating means

whereby pressure of said pilot fuel is effective in opening said valve to flow of the primary fuel, separate pumps in said lines for separately moving said fuels to the burner, a motor for initially operating said pumps, and a turbine having connection with said generator for operating the pumps when a sufficient steam supply is created in said generator.

12. In an apparatus of the character described, a steam generator, a fuel burner for heating the generator, means for supplying a pilot fuel to the burner under pressure, means for supplying water to the generator, pilot fuel actuated means controlling the water supply to the generator, valve mechanism controlling the pilot fuel supply to the control means, and temperature responsive means in the generator for actuating said valve mechanism whereby water is admitted to the generator responsive to temperature conditions in the generator and when pressure is being maintained on the pilot fuel.

13. In an apparatus of the character described, a steam generator, a fuel burner for heating the generator, means for supplying a pilot fuel to the burner under pressure, means for supplying water to the generator, pilot fuel actuated means controlling the water supply to the generator, valve mechanism controlling the pilot fuel supply to the control means, temperature responsive means in the generator for actuating said valve mechanism whereby water is admitted to the generator responsive to temperature conditions in the generator and when pressure is being maintained on the pilot fuel, and means having connection with the water supply and responsive to hydrostatic head in the generator for controlling the pilot fuel supply.

14. In an apparatus of the character described, a steam generator, a fuel burner for heating the generator, means for supplying a pilot fuel to the burner under pressure, means for supplying water to the generator, pilot fuel actuated means controlling the water supply to the generator, valve mechanism controlling the pilot fuel supply to the control means, temperature responsive means in the generator for actuating said valve mechanism whereby water is admitted to the generator responsive to temperature conditions in the generator and when pressure is being maintained on the pilot fuel, means having connection with the water supply and responsive to hydrostatic head in the generator for controlling the pilot fuel supply, a primary fuel supply for the burner, a control valve for regulating the primary fuel and having connection with the pilot fuel supply through said valve mechanism, and a connection between said last named means and the valve mechanism for controlling supply of primary fuel to the burner responsive to said hydrostatic head.

15. In an apparatus of the character described, a generator, a fuel burner for the generator, a readily combustible pilot fuel supply, means connecting the readily combustible pilot fuel supply with the burner, a less readily combustible main fuel supply separate from the pilot fuel supply, means connecting the main fuel supply with the burner, and means responsive to pressure of the readily combustible pilot fuel independently of pressure of the less readily combustible main fuel for controlling delivery of the less readily combustible main fuel supply to the burner.

16. In an apparatus of the character described, a generator, a fuel burner for the generator, means supplying a main fuel to the burner for heating the generator, hydraulic means for controlling delivery of said main fuel to the burner, means for delivering feed water to the generator, hydraulic means controlling said water supply means, means conducting a pilot fuel for said burner to said hydraulic means for actuating the hydraulic means to render said main fuel supply to the burner effective, and means in said conducting means responsive to temperature in the generator for controlling said pilot fuel supply to the hydraulic means.

17. An apparatus of the character described including, a steam generator, a burner for the generator, a source of pilot fuel supply, a separate source of primary fuel supply, means responsive to pressure of the pilot fuel for controlling flow of the primary fuel to the burner, a valve in the pilot fuel supply, means responsive to temperature and pressure in the steam generator for actuating said valve, and a by-pass connected with said valve for returning pilot fuel to the source of supply when said valve is closed.

18. An apparatus of the character described including, a steam generator, a burner for the generator, a source of pilot fuel supply, a separate source of primary fuel supply, means responsive to pressure of the pilot fuel for controlling flow of the primary fuel to the burner, a valve in the pilot fuel supply, means responsive to temperature and pressure in the steam generator for actuating said valve, a by-pass connected with said valve for returning pilot fuel to the source of supply when said valve is closed, a valve in said by-pass, and means responsive to pressure in the steam generator for controlling the by-pass valve.

19. An apparatus of the character described including, a steam generator, a burner for the generator, a source of pilot fuel supply, a separate source of primary fuel supply, means responsive to pressure of the pilot fuel for controlling flow of the primary fuel to the burner, a valve in the pilot fuel supply, means responsive to temperature and pressure in the steam generator for actuating said valve, a by-pass connected with said valve for returning pilot fuel to the source of supply when said valve is closed, a valve in said by-pass, means responsive to pressure in the steam generator for controlling the by-pass valve, a second valve connected with said by-pass, and means responsive to temperature in the steam generator for controlling said second by-pass valve.

20. An apparatus of the character described including, a steam generator, a burner for the generator, a source of pilot fuel supply, a separate source of primary fuel supply, means responsive to pressure of the pilot fuel for controlling flow of the primary fuel to the burner, a valve in the pilot fuel supply, means responsive to temperature and pressure in the steam generator for actuating said valve, a by-pass connected with said valve for returning pilot fuel to the source of supply when said valve is closed, a valve in said by-pass, and means responsive to temperature in the steam generator for controlling the by-pass valve.

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