Oct. 30, 1962 R. CUNNINGHAM, JR., ETAL 3,060,905

STEAM GENERATOR

Filed Sept. 24, 1957 6 Sheets-Sheet 1

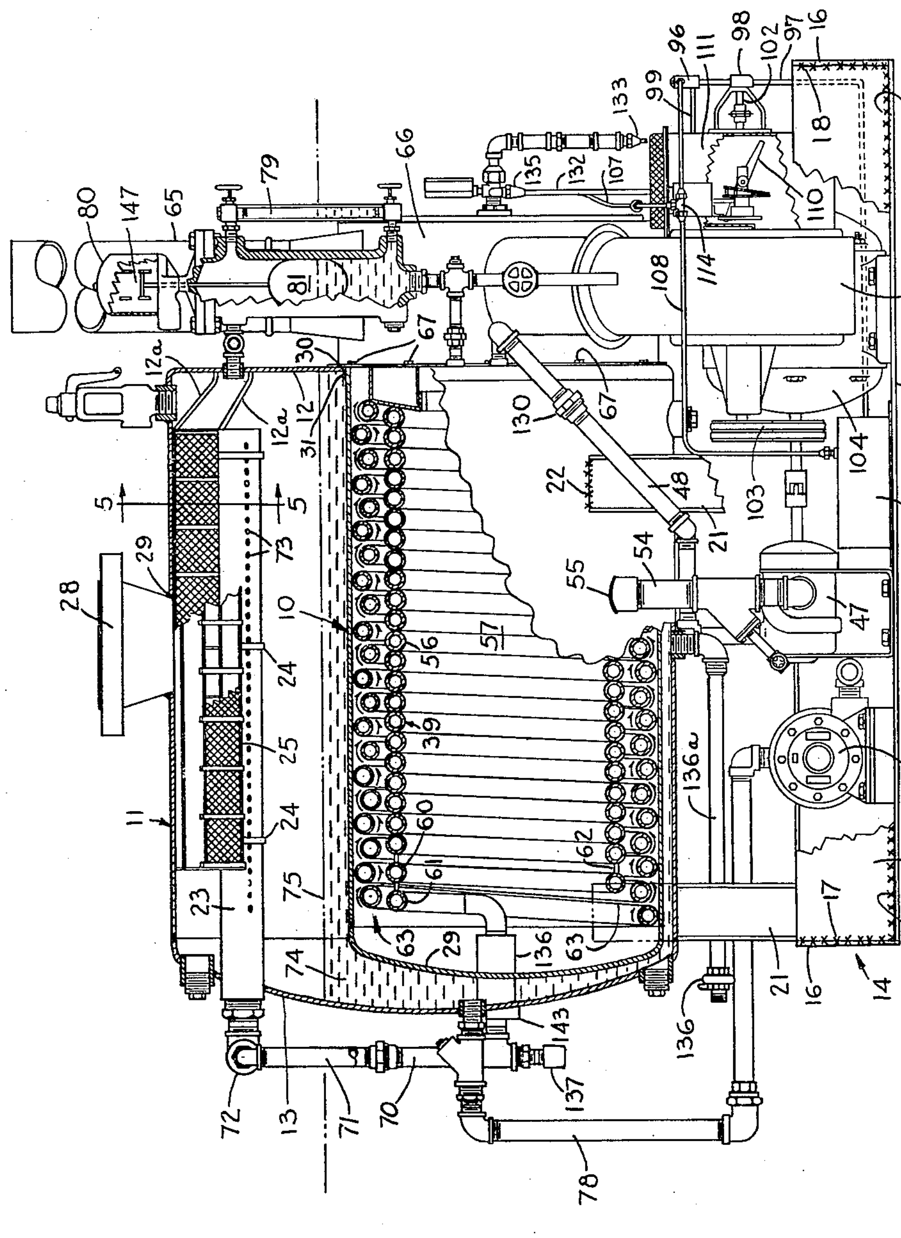

Fig. 1

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STEAM GENERATOR

Filed Sept. 24, 1957 6 Sheets-Sheet 2

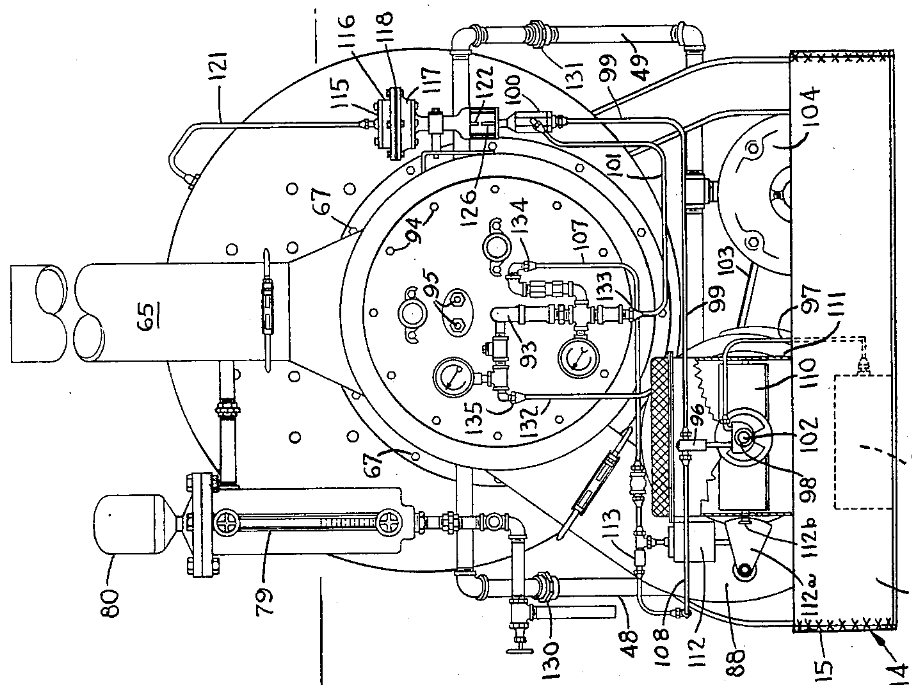

Fig. 3

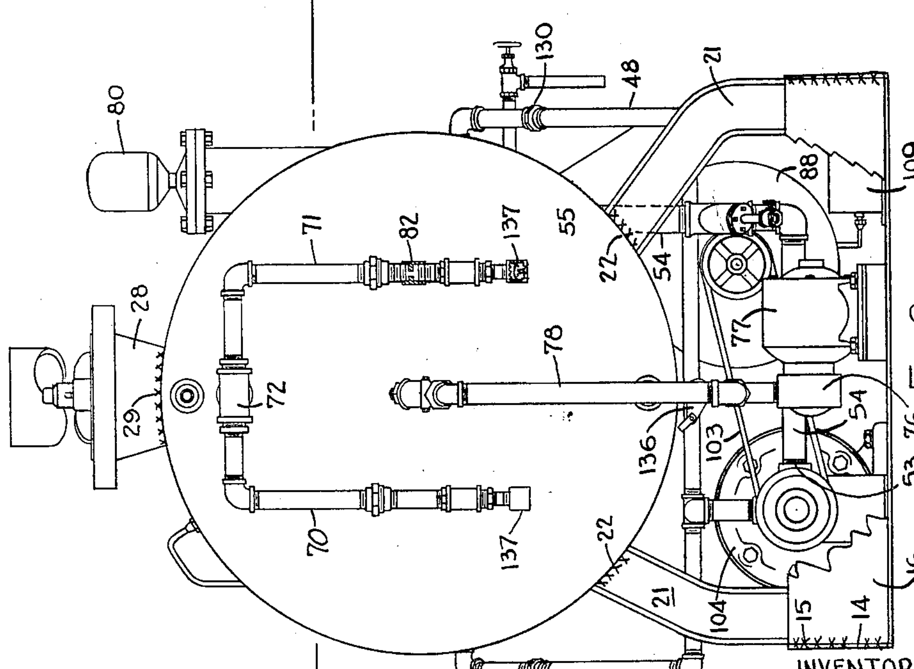

Fig. 2

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STEAM GENERATOR

Filed Sept. 24, 1957 6 Sheets-Sheet 3

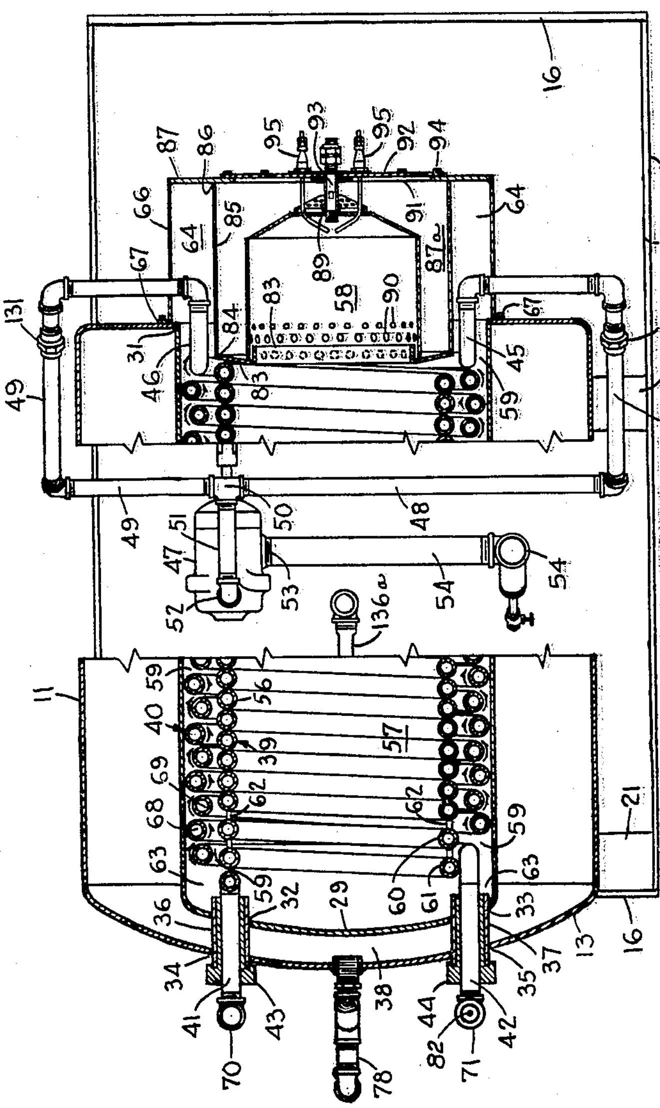

Fig. 4

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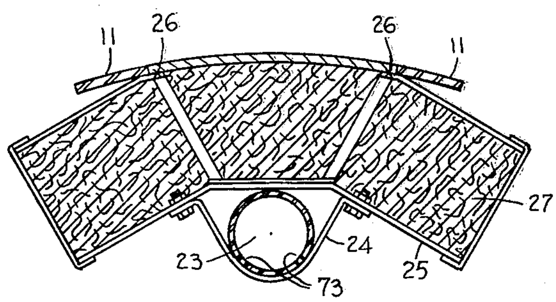

Fig. 5

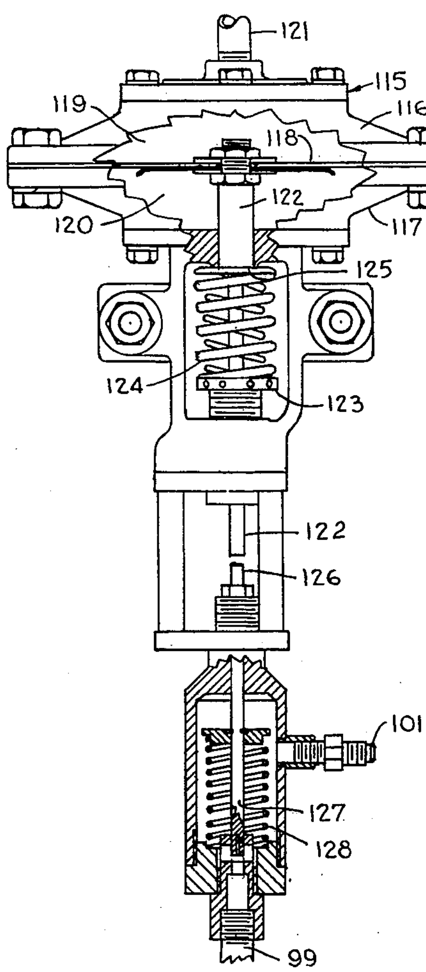

Fig. 6

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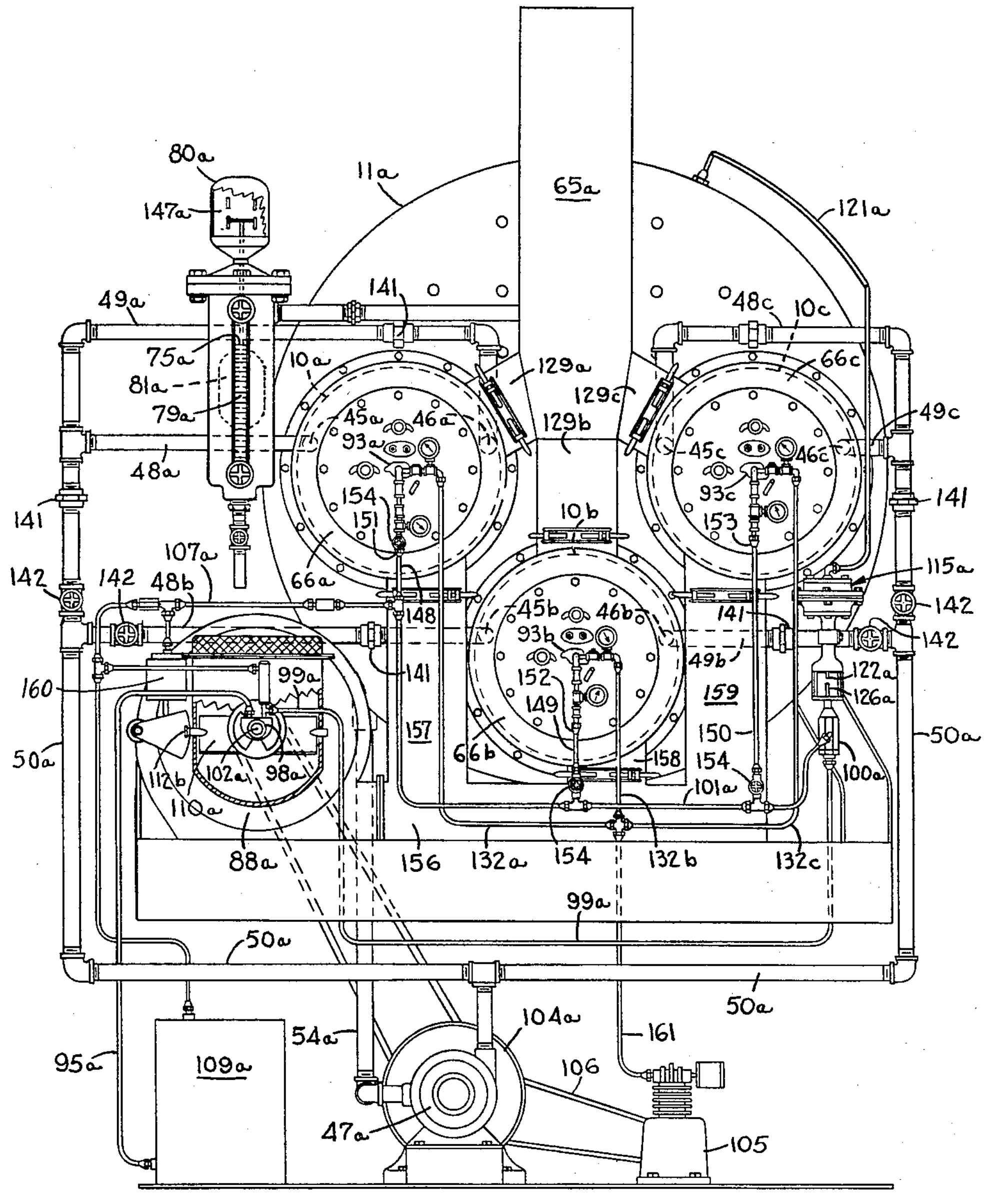

Fig. 7

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STEAM GENERATOR

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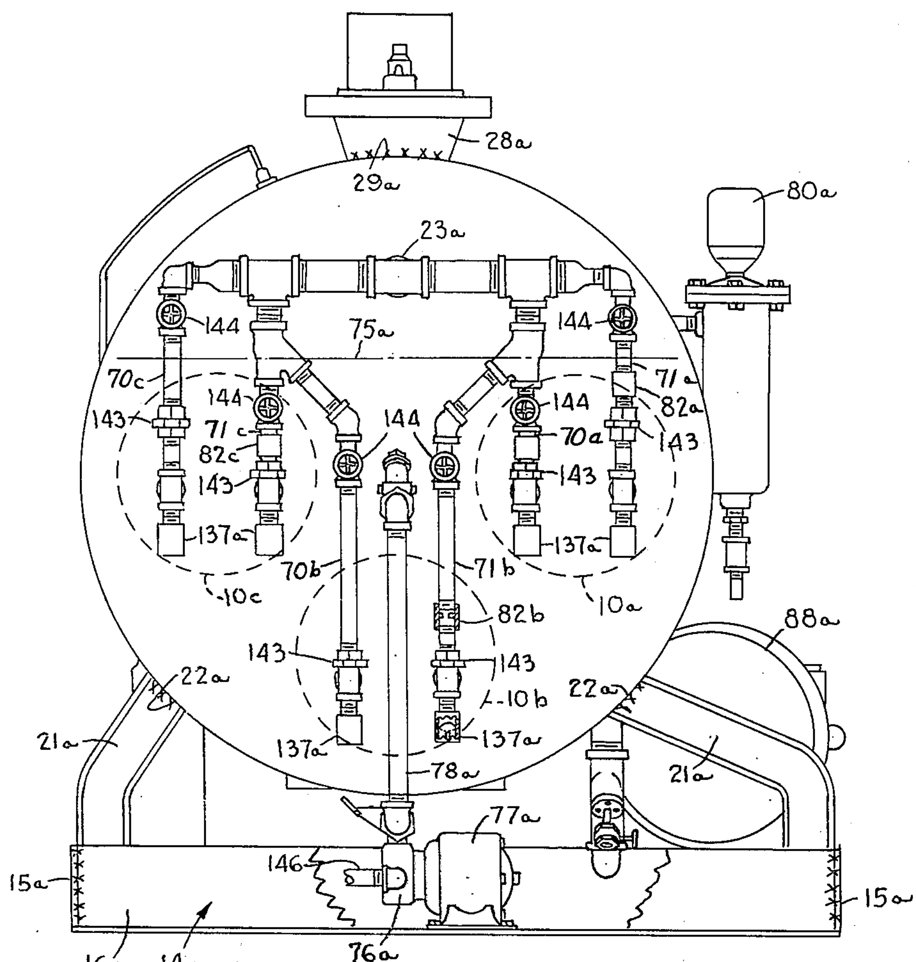

Fig. 8

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United States Patent Office

3,060,905

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3,060,905
STEAM GENERATOR

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Filed Sept. 24, 1957, Ser. No. 685,923
8 Claims. (Cl. 122—448)

This invention relates to steam generators of the water tube class wherein the water to be converted into steam is forced in a continuous stream through one or more heating coils.

In the above class of generators, as heretofore constructed, a portion of the water is converted into steam within the heating coils and is discharged therefrom as a mixture of steam and hot water into a steam separator wherein the water separates from the steam by gravity, while the steam is discharged from the separator through a main steam pipe. Such generators have not been entirely satisfactory, since the generation of steam takes place within the coils and therefore requires the coils to be maintained at high temperatures. These high temperatures cause rapid deterioration of the coils and therefore result in high maintenance cost in connection with the repair and the replacement of the overheated coils. The said generators usually include some provision for reclaiming a portion of the heat contained in the hot water separated from the steam, but these provisions have been inadequate to effect substantial economies, since the volume of hot water returned to the generator as make-up water is usually quite small in relation to the volume of unheated water pumped into the heating coils. Consequently, the feed water, as a whole, is preheated within the coils of the generator.

One of the principal objects of the present invention is to provide a steam generator of the above general class which is constructed to operate on a principle which avoids the above mentioned and other objectionable features embodied in water coil steam generators as heretofore constructed. In this connection, our improved generator is so constructed that a substantial pressure drop exists between the pressure maintained in the water heating coils and the pressure maintained in the steam separating chamber, whereby a portion of the high temperature water discharged from the high pressure of the heating coils into the lower pressure of the steam separating chamber will flash into steam within the separating chamber. The other portion of the water falls by gravity to the lower portion of the separating chamber wherein it receives additional heat by virture of its direct contact with the walls of the heating chamber and is thereafter recirculated through the water heating coils.

Another object is to provide a structure which will maintain the water at high temperatures, but which may be so operated as to avoid overheating of the coils. In this connection the heating chamber is arranged within the steam separating chamber so that the water separated from the steam, together with additional feed water delivered into the separating chamber, completely surrounds the heating chamber casing, it being by this arrangement that additional heat is added to the water within the separating chamber. A quantity of this water, in excess of that which is necessary to safeguard the coil structure from destruction by overheating is circulated through the heating coils. The volume of water thus circulated through the coils is approximately three or four times that which is necessary to prevent said overheating. The large body of water thus maintained in the steam separating chamber eliminates the need for minutely controlling the water delivered to the heating coils during variations in the volume of steam produced. The high volume of

water pumped through said coils also functions to stabilize the operation of the generator by preventing pressure surging effects within the generator during abrupt changes in the demand for steam.

Another object is to provide the improved generator with compact and simplified construction which presents heat transfer surfaces adapted to be wiped by hot gases of combustion, which surfaces are larger than those of other generator constructions of equal size. The compactness of the generator assembly makes it highly suitable for use in situations where conservation of space is an important consideration.

A further important object is to provide novel constructions in a steam generator of the water coil type which makes for ease in the initial assembly of the coils and for removal and replacement thereof. It is also the aim of the invention to provide improved constructions which make it practical to produce a generator assembly having a single heating unit of predetermined capacity or to vary the construction to include a multiple of such heating units when generators of larger capacities are desired.

The above mentioned and other incidental objects of the invention are attained by the novel constructions and arrangements illustrated herein including the provision of a water heating unit comprising one or more tubular coils which are so constructed and arranged within a heating chamber shell that hot combustion gases delivered into the heating chamber will wipe substantially the entire area of the heating coils and also the entire area of the inner surface of the heating chamber shell. The said shell is positioned within an outer casing which functions as a steam separating drum and hot water collector. A spray head is located in the upper portion of the steam separating drum and receives hot water discharged from the heating coils. The spray head is provided with a series of apertures from which the hot water is sprayed under high pressure into the steam separating drum wherein a considerably lower pressure is maintained. As a result of this pressure differential a portion of the water discharged from the spray head flashes into steam. The steam passes upwardly through a mist collector to an outlet pipe, while the other portion of the hot water drops by gravity into the lower portion of the said drum wherein a body of such collected water, together with additional feed water added thereto, surrounds the heating chamber shell as previously indicated and receives heat therefrom by virtue of its direct contact with the outer surface of the heating chamber shell.

The entire assembly thus briefly described is supported on a skid structure which also serves as a suitable mounting for the water feeding and circulating pumps and for a blower for supplying combustion air to the fire chamber. The feed water pump is controlled by a float actuated control means which functions to maintain a predetermined water level in the steam separating drum **11**.

The invention is illustrated in certain preferred embodiments in the accompanying drawings wherein:

FIG. 1 is a side view of one form of steam generator having a single heating unit and showing certain parts thereof in section and other parts in elevation;

FIG. 2 is a rear view in elevation of the assembly shown in FIG. 1;

FIG. 3 is a front view in elevation of the structure shown in FIG. 1;

FIG. 4 is a horizontal sectional view of the generator shown in FIG. 1 with the intermediate portion thereof broken away to better illustrate the location of a water circulating pump and its connections to the inlet ends of the water heating coils;

FIG. 5 is a cross section taken on line **5—5** of FIG. 1;

FIG. 6 is a sectional view of a pressure motor and fuel valve operated by said motor;

FIG. 7 is a front view in elevation of a steam generator composed of a plurality of water heating units corresponding to the units shown in FIG. 1; and

FIG. 8 is a rear view in elevation of the embodiment shown in FIG. 7.

Referring first to FIGS. 1 to 6 inclusive, wherein a steam generator assembly therein shown includes a single water heating unit: This embodiment of the invention comprises a water heating unit including a heating chamber shell **10** positioned to extend into an outer casing **11** which is closed with front and rear end walls **12** and **13** and functions as a steam separating drum and hot water collector. The front end wall **12** of the outer casing **11** is preferably formed with a flat face and is reinforced by a series of stay bolts **12a** located at spaced location to prevent bulging of the end wall when it is subjected to internal pressure. The said drum is supported on a skid **14** comprising a rectangular base composed of side and end sills **15** and **16** suitably welded together as indicated at **17**, **18**. A bottom panel **19** is welded as indicated at **20** to the side and end sills of the skid. Four supporting posts **21**, preferably in the form of vertically extending channels, are securely welded to the base portion of the skid, the upper ends of the post **21** being welded as indicated at **22** to the opposite sides of the steam separating drum **11** near the forward and rear ends thereof.

A spray head **23** is supported in the upper portion of the drum **11** by means of a series of metal straps **24** attached to a frame work **25** welded to the upper portion of the drum **11** as indicated at **26**. The said frame work **25** also serves to support a body of wire mesh **27** which functions to collect the mist held in suspension in the steam as the latter passes through the mist collector to a steam outlet pipe **28**. This pipe is welded as at **29** in an opening formed in the top portion of the drum **11**.

Water Heating Unit

The shell **10** of the water heating unit is closed at its rear end by a wall **29** and open at its forward end. This end fits into an opening **30** formed in the forward end wall **12** of the steam separator drum **11** and is sealed therein by a weld **31**. The rear wall **29** of the shell is formed with a pair of circular openings **32—33** which are aligned with a similar pair of openings **34** and **35** formed in the rear wall **13** of said drum. A pair of short pipe sections **36**, **37** are fitted into the opposing openings **32**, **34** and **33**, **35**, respectively, and are welded therein to bridge the space **38** between the rear wall **29** of the heating chamber shell **10** and the rear wall **13** of the drum **11** and cooperate with the welded connection of the forward end of the shell to the front wall of the drum to support the shell in a fixed horizontal position within the drum.

Water Heating Coils

A pair of concentrically arranged water heating coils **39**, **40** are positioned within the heating chamber shell **10**. The tail ends **41** and **42** of the said coils extend through the bridge conduits **36** and **37** and are clamped therein by sealing plugs **43**, **44**. The inlet ends **45** and **46**, respectively, of the said coils are connected in parallel with the outlet port **52** of a circulating pump **47** by means of piping **48** and **49** leading to a T-fitting **50** and thence by a pipe section **51** to the said outlet port **52** of the pump **47**. The inlet port **53** of the circulating pump is connected by piping **54** communicating with the interior of the steam separating drum **11** at a location **55** (see FIG. 1) positioned a suitable distance above the bottom of the drum so that water withdrawn from the drum, as hereinafter described, for recirculating through the coils **39**, **40** will be free of scale and/or mineral sludge which may collect in the bottom of the drum.

The inner coil **39** includes a series of contiguous convolutions or turns **56** which define a heating chamber **57**, the forward end of which communicates with a fire pot **58**, hereinafter described, which delivers hot combustion gases into the heating chamber to heat the water contained in the coils and to also apply heat to the side and end walls of the heating chamber shell **10**. When the inner coil **39** is in its operative position, it is spaced from the cylindrical side wall of the heating chamber shell **10** so as to define an annular space **59**. The rear end of the coil **39** is provided with spaced apart convolutions **60**, **61** to provide lateral passageways **62** through which hot gases of combustion may pass from the heating chamber **57** into said annular space **59**. The rear end of the inner coil **39** also stops short of the rear end wall **29** of the heating chamber shell and, consequently, provides an additional passageway **63** into the concentric space **59**, whereby the hot gases which impinge against the end wall **29** of the shell **10** will find entrance into the said annular space **59**. These gases will pass through said space to a smoke box chamber **64** and to a smoke stack **65**, the latter being supported on the smoke box chamber housing **66**. The housing is removably attached to the front wall **12** of the drum **11** by means of bolts **67**.

The outer coil **40** is positioned within the said concentric space **59** and is formed throughout its length with spaced apart convolutions **68** and **69**. The convolutions **68** are wound somewhat larger in diameter than the convolutions **69** and are arranged in close relation to the inner surface of the heating chamber shell **10** so that the hot gases of combustion are compelled to follow a circuitous path, as shown by arrows in FIGS. 1 and 4 of the drawings, between the convolutions **68**, **69** and thereby wipe substantially the entire area of these convolutions. The said gases also wipe the inner surface of the heating chamber shell **10** and the undulating outer surface of the inner coil **39**. The undulating outer and inner surfaces of the inner coil **39** promote turbulence in the hot gases, whereby the gases are brought into recurrent wiping contact with the walls and thereby promote high thermal efficiency.

Spray Head and Mist Collector

The tail ends **41** and **42** of the coils **39** and **40** are connected by means of piping **70** and **71**, respectively (shown best in FIG. 2), to a T-fitting **72** leading into the spray head **23**. The spray head is formed with a large number of spray openings **73** arranged in a series of rows lengthwise thereof (see FIGS. 1 and 5). These openings are sufficiently restricted in diameter to maintain a water pressure within the spray head **23** considerably higher than the steam pressure maintained in the separating drum **11**. During normal operations the pressure in the coils **39** and **40** will range between 100 and 120 p.s.i. The pressure in the spray head, under such condition, will be approximately 60 p.s.i. and the pressure within the separating drum will be approximately 15 p.s.i. Consequently, a portion of the high pressure hot water discharged from the spray head **23** into the lower pressure steam separating chamber will flash into steam. The other portion of the water discharged falls into the bottom portion of the drum **11** to assist in forming a large body **74** of water which surrounds the heating chamber shell **10** and is heated by virtue of its direct contact with the outer surface of said shell. Additional water is added to the said body **74** to maintain it at the level indicated at **75** in FIG. 1. This additional water is drawn from a supply source (not shown) by means of a feed pump **76** mounted on the skid **14** and operated by an electric motor **77** or other suitable prime mover. The water is delivered into the drum **11** through the feed pipe **78** and the water level **75** is indicated by a sight glass **79**. This level is automatically maintained by a switch mechanism **147** contained in the housing **80** and actuated by a float **81** to control the operation of the feed pump motor **77**.

Referring again to the heating coils: The inner coil **39**, with its closely wound convolutions, provides the heating chamber 57 of sufficient length to burn the heavier oils as a fuel. It is also desirable, since the inner coil 39 has initial contact with the high temperature flame and hot gases, to force a larger volume of water through this coil than is passed through the outer coil 40, the latter coil being subjected to less intensive heat. Therefore, a flow restricting device 82 is positioned in the piping 71 leading from the discharge end of the outer coil 40 to the spray head 23.

Smoke Box Fire Pot and Plenum Chamber

The fire pot 58 is aligned with the fire chamber 57 and is supported in this position by virtue of its welded attachment to a fire stabilizing ring 83. The said ring is attached by a weld connection 84 to one end of a cylindrical wall 85, which in turn is welded at its other end 86 to the front wall 87 of the smoke box. The cylindrical 85 cooperates with the cylindrical side wall 66 of the smoke box to define the smoke chamber 64 for receiving the spent products of combustion from the annular passage 59. The said cylindrical wall 85 also cooperates with the cylindrical wall of the fire pot 58 to define a plenum chamber 87*a*. Combustion air is delivered into the plenum chamber from a blower 88 located beneath the generator, and the air is directed in part, as primary combustion air, through a hooded central opening 89 leading into the fire pot 58, where initial combustion takes place. Additional secondary combustion air is delivered into the fire pot 58 through a series of apertures 90 formed in the side wall of the fire pot near the fire stabilizing ring 83. The air jets from the said apertures 90 are directed radially inwardly toward the flame and therefore promote turbulence and insure complete combustion of the partially ignited gases as they pass into the heating chamber 57.

The plenum chamber 87*a* has a central opening 91 which is closed by a plate 92 removably secured thereto by bolts 94. A fuel nozzle 93 and a pair of ignition electrodes 95, 95 are secured to the removable plate 92 in a position to project through the hooded opening 89 and into the interior of the fire pot 58.

Fuel Control

Fuel is drawn through a conduit 97 from a fuel reservoir 109 by a pump 98 and is delivered by said pump through conduit 99 to a fuel control valve 100 and thence through conduit 101 to the fuel nozzle 93. The fuel pump 98 is operatively connected to the shaft 102 of the blower 88 which supplies the combustion air to the plenum chamber 87*a*. The said blower is driven through belt connections 103 from the same power source, a motor 104, which operates the circulating pump 47. Consequently, the water circulating pump 47, the blower 88 and the fuel pump 98 are all operated continuously at a fixed rate. When desired, an air compressor 105 (FIG. 7) may also be operated by the said motor 104 by a suitable belt connection 106.

Inasmuch as the fuel pump 98 is operated continuously and the delivery of fuel to the nozzle 93 is varied by the valve 100, a pressure relief fitting 96 is connected in the fuel delivery line 99 at the pump to minimize back pressure. A conduit 108 leading from the pressure relief fitting 96 returns the surplus fuel from the pump back to the fuel supply reservoir 109.

A damper 110 is interposed in an air inlet chamber 111 leading into the blower 88 and is automatically adjustable to vary the delivery of combustion air to the blower and thence into the plenum chamber 87*a* in relation to the oil pressure at the fuel nozzle 93. This result is obtained by means of a pressure motor 112 which is connected in the conduit 107 in advance of an orifice fitting 113. The conduit 107 joins the fuel return line 108 beyond the orifice fitting 113 at T-fitting 114. The pressure of the oil in conduit 107 operates the motor 112 and thereby oscillates a gear segment 112*a*. A pinion 112*b* secured to the damper shaft is rotated by the gear segment 112*a* to alter the position of the damper 110.

Fuel Valve Motor

The position of the fuel valve 100 for varying the delivery of fuel to the nozzle 93 is controlled by a pressure motor 115 which responds to pressure variations within the steam separating drum 11. The pressure motor 115 comprises a casing composed of upper and lower sections 116, 117. A diaphragm 118 separates the casing into upper and lower chambers 119, 120. The upper chamber communicates through a conduit 121 with the interior of the steam separator drum 11 and impresses the pressure therein on the diaphragm 118. A push rod 122 depends from the diaphragm 118 and extends through an adjustable spring seat 123. A spring 124 seats on the spring seat 123 and exerts pressure against an abutment plate 125 secured to the push rod 122 so as to exert spring pressure in opposition to the fluid pressure in the upper chamber 119. The spring pressure exerted can be adjusted by rotating the spring seat 123. The lower end of the push rod 122 is spaced from the upper end of a stem 126 of the fuel valve which stem projects upwardly from the fuel valve casing. This spaced relationship is maintained between the push rod 122 and valve stem 126 until the pressure within the drum 11 reaches a predetermined value as determined by the adjustment of the seat 123. When the pressure within the said drum exceeds said predetermined value the push rod engages the valve stem 126 and moves the stem and its valve in a direction to reduce the delivery of fuel to the nozzle 93. Alternatively any reduction in the steam pressure below the selected value, results in movement of the diaphragm, under the force exerted by spring 124 in a direction to relieve its pressure on the valve element 127 whereupon this element is moved by the force of a spring 128 in a direction to increase the delivery of fuel to the nozzle 93.

Referring again to the smoke box and the purpose of its removable attachment to the steam separating drum 11: The fact that the smoke box is secured to the said drum 11 by means of bolts 67 makes it readily detachable to facilitate insertion of the water heating coils 39 and 40 into the heating chamber shell 10 and also facilitates their removal from said shell. In order to further simplify the insertion and removal of said water coils, the piping leading to the inlet ends 45 and 46 thereof are provided with unions 130 and 131 whereby the water feed piping may be disconnected to facilitate removal and replacement of the coils. In this connection the piping 70 and 71 is provided with similar unions whereby portions of the discharge piping 70, 71 may be disconnected from the water coils per se. The fuel conduits 101 and 107 and the air conduit 132 are also provided with couplings 133, 134 and 135 to facilitate their detachment from the nozzle structure in the event it should be necessary or desirable to remove the nozzle structure. The air pipe 132 supplies compressed air to atomize the fuel. This air may be supplied by the air compressor previously referred to or from any other suitable source.

When it is desired to blow down the steam separator drum to remove any scale or sludge which may have collected in the lower portion thereof a blowdown valve 136 is opened so that the said scale and sludge may be drained through pipe 136*a*.

Summary of Operation

Referring to the drawings and particularly to FIG. 1 thereof, the operation can be briefly described as follows: Before the fuel and air is delivered into the generator the body of water 74 is pumped by the feed pump 76 into the outer drum 11 until the operative level of said water is attained. The operation is then interrupted by stopping the feed water pump. This is accomplished by opening a float operated switch designed to control the operation of the feed pump motor 77. After the proper water level in the drum 11 has been established, the motor 104 is set into operation to operate the fuel pump 98 to deliver fuel to the nozzle 93 and also operate the blower 88 and the water circulating pump 47. The circulating pump 47 withdraws water from the body of water 74, which after the boiler is in operation, has been heated by virtue of its contact with the heating chamber shell 10 and forces this water into the heating coils 39 and 40. The heated water is delivered from the said coils into the spray head 23 from which it is discharged into the upper portion of the drum 11. A portion of the water discharged flashes into steam within the said drum, as previously described, and the remaining water falls by gravity into the body of water 74 for recirculation through the heating coils 39 and 40. A mist collector 27 located in the upper portion of the drum 11 functions to collect the mist contained in the steam and thereby return this condensate to the said body of water 74 while the steam discharges through the main discharge pipe 28.

When the steam within the said drum 11 rises to a predetermined value, the push rod 122 of the fuel valve motor 115 engages the upper end of the valve stem 126. In the event that the steam pressure within the drum 11 continues to rise above said predetermined value, the push rod 122 will depress the valve stem 126 of fuel valve 100 and thereby reduces the delivery of fuel to the nozzle 93.

The temperature of the water discharged from the heating unit may be controlled by means of a pair of temperature responsive switches 137 inserted in the discharge piping 70, 71 leading from the inner and outer terminals 41, 42 of the water heating coils 39, 40. The said switches 137 may be connected in series so that either will function to interrupt the operation of the motor 104 and thereby interrupt the operation of the circulating pump 47, blower 88 and fuel pump 98 so as to cut off the delivery of heat to the heating unit 10. When the temperature of the water recedes to a predetermined low temperature limit, both switches 137 must reclose to activate the motor 104 and thereby re-activate the mechanism for circulating water through the coils 39, 40 and for delivering fuel and air to the fire pot 58. The resultant decrease in the intensity of the heat within the heating chamber 57 is quickly reflected in a decrease of the steam pressure in the drum 11. In such case the motor diaphragm of the valve motor 115 and the push rod 122 will recede toward their normal positions and the spring 128 associated with the fuel valve 127 will move the valve in a direction to increase the delivery of fuel to the nozzle 93. The variation in the delivery of fuel to the nozzle 93 does not result in the development of pressure surges within the drum 11, since the large volume of hot water circulated through the coils 39 and 40 avoids abrupt changes in temperature of the coils so that pressure changes within the drum 11 are brought about gradually.

Modified Generator

Referring now to the modification shown in FIGS. 7 and 8 of the drawings: The modified generator comprises three water heating units 10*a*, 10*b* and 10*c* constructed as illustrated in FIG. 1 and enclosed within a single drum designated 11*a*. Three smoke boxes, one for each water heating unit, are designated 66*a*, 66*b* and 66*c*. Each smoke box corresponds in construction to the smoke box 66 shown in FIG. 1, except that they communicate through separate branch pipes 129*a*, 129*b* and 129*c* with a single smoke stack 65*a*.

Water Circulation for Modified Generator

A water circulating pump 47*a* operated by a prime mover, for example an electric motor 104*a*, withdraws water from the interior of the drum 11*a* through a pipe

54*a* and delivers it into a manifold piping 50*a*. This manifold is connected by branch pipe connections to the inlet ends of the water coils of each of the heating units 10*a*, 10*b*, 10*c*. Branch pipe 48*a* connects the manifold 50*a* with the inlet end 45*a* of the inner coil of the heating unit 10*a*. A branch 48*b* connects the manifold 50*a* with the inlet 45*b* of the inner coil of the heating coil 10*b*; and branch section 48*b* connects the said manifold with the inlet end 45*c* of the inner coil of heating unit 10*c*. The inlet end 46*a* of the outer coil of heating unit 10*a* is connected to the manifold 50*a* by branch piping 49*a*. The inlet end 46*b* of the outer coil of heating unit 10*b* is connected with the manifold 50*a* by a branch 49*b*, and in unit 10*c* the inlet end 46*c* of the outer coil is connected to manifold 50*a* by a branch 49*c*. The branch pipes leading to the inlet ends of the coils embodied in each of the heating units are provided with unions 141 and shut off valves 142 whereby the water coils of any one or more of the heating units 10*a*, 10*b* or 10*c* may be rendered inoperative or may be removed from the general assembly for the purpose of repair or replacement without affecting the operation of the other heating units. The removal of such coils may be accomplished by removing the associated smoke box 66*a*, 66*b*, or 66*c* in the same manner as described in connection with FIGS. 1 to 4, inclusive.

Referring now to FIG. 8: The outlet ends of the coils associated with heating units 10*a*, 10*b* and 10*c* are connected in parallel with a spray head 23*a* by pairs of branch piping 70*a*, 71*a*; 70*b*, 71*b*; and 70*c* and 71*c*. The water thus delivered to the spray head 23*a* is sprayed into the drum 11*a* in the same manner and with the same results as described in connection with FIG. 1. Each pair of said branches 70*a*, 71*a*; 70*b*, 71*b*; and 70*c*, 71*c* have couplings 143 and shut off valves 144 therein to facilitate ready removal of the coils associated with any one or more of the water heating units 10*a*, 10*b*, 10*c*. Identical flow restricting fittings 82*a*, 82*b*, 82*c* are interposed in the pipes 71*a*, 71*b* and 71*c* so that the greater volume of water will flow through the innermost coil of the several heating units 10*a*, 10*b* and 10*c*.

Feed Water Pump Control

Additional make-up water is delivered into the drum 11*a* by means of a feed water pump 76*a*. Said additional water is drawn from a source (not shown) through a pipe 146 and is delivered into the drum 11*a* through pipe 78*a*. The water level 75*a* is maintained substantially constant within the drum 11*a* by means of a switch mechanism 147*a* within the housing 80*a*, the switch being controlled by a float 81*a*. Said switch mechanism 147*a* controls the operation of the feed pump motor 77*a* so that the feed pump 76*a* may be activated and deactivated, as may be required, to maintain the water level 75*a* substantially constant. A sight glass 79*a* indicates the water level 75*a* for the purpose of visual inspection.

Fuel Control for Modified Generator

Fuel is delivered to the several nozzle assemblies 93*a*, 93*b* and 93*c* from a single fuel pump 98*a* which is operatively connected to the shaft 102*a* of a blower 88*a*, the blower being operated by motor 104*a* which also operates the circulating pump 47*a*. The fuel pump 98*a* draws fuel oil from a reservoir 109*a* through conduit 95*a* and delivers it through conduit 99*a* to a control valve 100*a*, and thence into a manifold conduit 101*a*. The manifold conduit 101*a* communicates through branches 148, 149 and 150 to the nozzle assemblies 93*a*, 93*b* and 93*c*, respectively. The said branches are detachably connected to said nozzle assemblies by connectors 151, 152 and 153. They are also provided with shut-off valves 154, whereby the fuel supply to any one or more of the nozzle assemblies 93*a*, 93*b* or 93*c* may be shut off in the event that a nozzle assembly is to be withdrawn from inspection or repair or in the event that it is desired to remove one or more of the smoke boxes **66***a*, **66***b* or **66***c* to permit the withdrawal of the water heating coils from one or more of the heating units **10***a*, **10***b*, **10***c*. The said fuel control valve **100***a* and its pressure operated motor **115***a* are the same in construction and operation as shown and described in connection with FIG. 5. Full pressure in the manifold conduit **101***a* is impressed on the pressure motor **160** by means of the branch conduit **107***a*. Pressure motor **160** adjusts the damper **110***a* so as to vary the delivery of combustion air to the several heating units **10***a*, **10***b* and **10***c* in relation to the fuel pressure delivered to the nozzles in the same manner as described above for the single heating unit. The said air is delivered from the blower **88***a* into a trunk line **156** connected by means of branches **157** and **158** and **159** to the plenum chambers associated with the several heating units **10***a*, **10***b* and **10***c*.

Compressed air for atomizing the fuel is supplied from a suitable source, for example a compressor **105** operated by the motor **104***a*. The compressed air is delivered by the compressor **105** into a manifold supply conduit **161** which is connected by branches **132***a*, **132***b* and **132***c* to the several nozzle assemblies **93***a*, **93***b* and **93***c*.

The temperature of the water discharged from the heating units **10***a*, **10***b* and **10***c* may be controlled by means of temperature responsive switches **137***a* inserted in the discharge piping **70***a*, **71***a*, **70***b*, **71***b*, and **70***c*, **71***c* leading from the inner and outer terminals **41***a*, **42***a*, **41***b*, **42***b*, and **41***c*, **42***c* of the water heating coils. The said switches may be connected in series so that the opening of any one of the switches at a predetermined temperature will interrupt the operation of the motor **104***a* and thereby interrupt the operation of the circulating pump **47***a*, blower **88***a*, fuel pump **98***a* and air compressor **160**. As soon as all of the temperature responsive switches are closed the steam generator will be re-activated.

It will be observed from the above description of the modified generator that the heating coils of any one of the heating units **10***a*, **10***b*, **10***c* can be readily removed from their associated shell for repair and/or replacement without affecting the operation of the steam generator insofar as the other heating units are concerned. It will also be observed that the heating unit shells **10***a*, **10***b*, **10***c*, being welded to the front wall of the drum **11** and being secured to the rear wall by means of the bridge conduits, cooperate with the stay bolts **12***a* to reinforce the front end wall to prevent bulging thereof when it is subjected to internal pressure.

We claim:

1. A steam generator comprising a closed external drum for containing a body of water therein, a fuel burning water heating unit including a heating chamber shell sealed in said drum and completely immersed in and consequently cooled by said body of water, the shell having openings at opposite ends thereof leading to zones externally of the drum, a water heating element insertable into said shell through an opening at one end thereof and having its discharge end projecting through an opening at the other end of the shell and communicating through a spray head with the interior of said drum, a circulating pump for withdrawing water from said body within the drum and forcing it through said heating element and spray head into the said drum at pressures higher than that maintained in the drum whereby a portion of the discharged water flashes into steam within said drum and the remaining portion of the hot water discharged falls into said body of water, and means for delivering hot gases into said heating chamber shell to apply heat to said body of water and to the water in said water heating element.

2. A steam generator according to claim 1 characterized in that a steam discharge pipe communicates with

the upper portion of said drum and a vapor collector comprising a body of wire netting for collecting mist suspended in the steam is positioned in the said drum intermediate said spray head and said steam discharge pipe.

3. A steam generator according to claim 1 characterized by the provision of means defining a smoke box positioned to communicate with the heating chamber shell and is removably attached to the forward end of said drum, and unions interposed in the inlet and discharge piping associated with said water tube coils and cooperating with said removable smoke box to facilitate ready removal and replacement of the water tube coils.

4. A steam generator according to claim 1 characterized by the provision of a nozzle for delivering fuel into said fire pot, a fuel control valve positioned in the flow path of the fuel to the nozzle, and means responsive to pressure changes in the generator for proportionately varying the position of said fuel valve to increase the fuel delivery during a decrease in pressure and to decrease the fuel delivery during an increase in steam pressure.

5. A steam generator according to claim 4, provided with means responsive to the temperature of the water discharged from the water heating unit for increasing the circulation of water through said heating unit during a temperature rise and for controlling the operation of the fuel and combustion air delivery means to decrease the volume of fuel and air delivery.

6. A steam generator according to claim 1 characterized by the provision of a plurality of water heating units positioned in said drum and immersed in the body of water therein.

7. A steam generator according to claim 6 in which separate fuel nozzle assemblies are provided for each heating unit, a fuel pump, a fuel control valve for receiving fuel from said pump, a manifold delivery conduit communicable with said fuel pump, detachable branch conduits leading from the manifold pipe to the several nozzle assemblies, and means responsive to the steam pressure within the generator for adjusting the position of the fuel valve to increase the fuel delivered during a drop in steam pressure within the generator and to decrease the delivery of fuel during an increase in steam pressure.

8. A steam generator according to claim 1 characterized in that the said water heating element includes inner and outer concentrically arranged water tube coils positioned in said heating chamber shell in a position to be wiped by the hot gases delivered into said heating chamber shell, means connecting said inner and outer water tube coils in parallel with said circulating pump, and a flow restricting means positioned in the flow path of the water discharged from the outer coil, whereby a larger volume of water is passed through the inner coil than is passed through the outer coil, so as to avoid overheating of the inner coil and to absorb the greater volume of heat applied thereto.

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