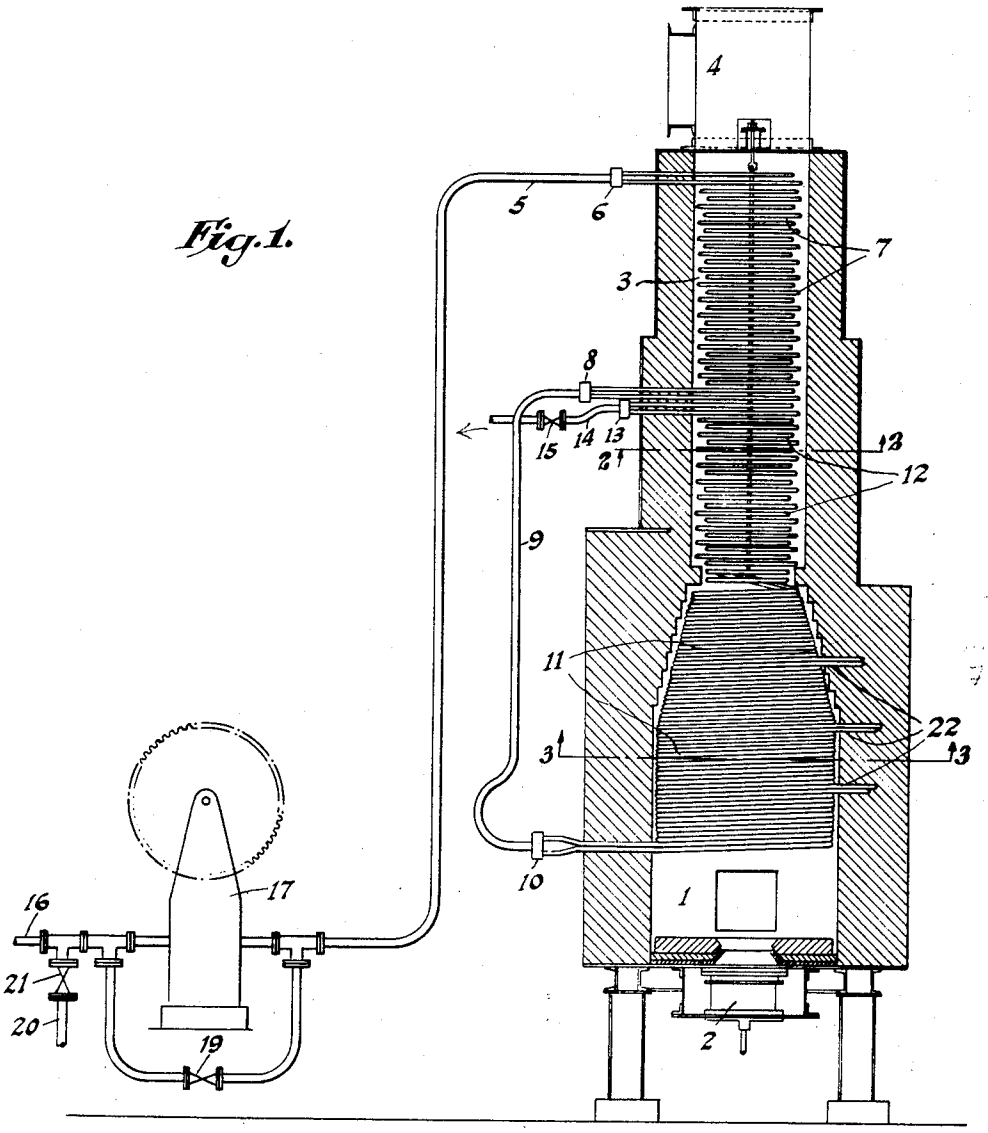
March 9, 1937. H. J. KERR 2,072,887

FORCED FLOW GENERATOR AND METHOD OF OPERATING SAME

Original Filed May 7, 1930 3 Sheets-Sheet 1

Fig. 1.



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122. LIQUID HEATERS
& VAPORIZERS.
250

Examiner

March 9, 1937. H. J. KERR 2,072,887

FORCED FLOW GENERATOR AND METHOD OF OPERATING SAME

Original Filed May 7, 1930 3 Sheets-Sheet 2

Fig. 2.

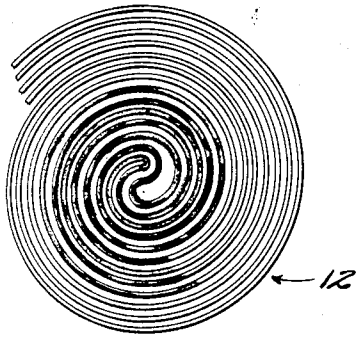
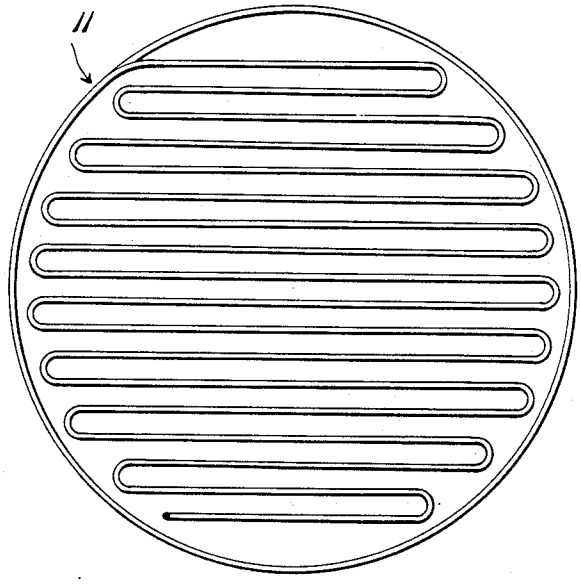


Fig. 3.



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122 LIQUID HEATERS & VAPORIZERS
250

March 9, 1937. H. J. KERR 2,072,887

FORCED FLOW GENERATOR AND METHOD OF OPERATING SAME

Original Filed May 7, 1930 3 Sheets-Sheet 3

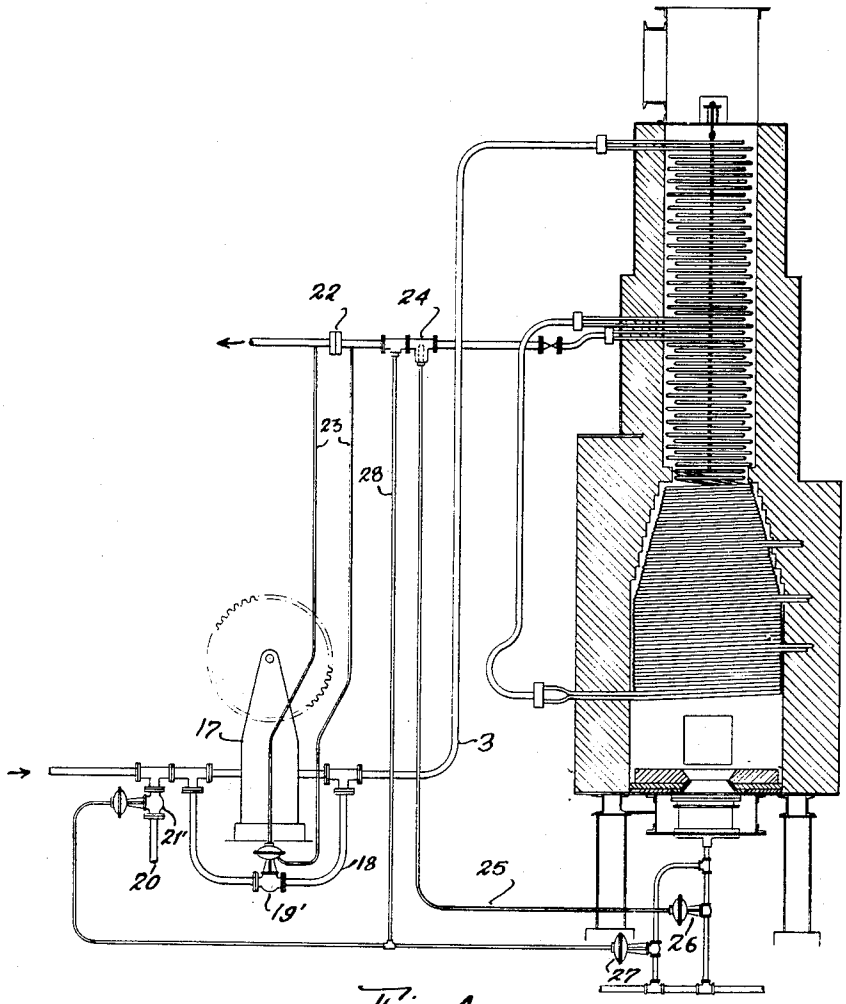


Fig. 4.

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22. LIQUID HEATERS & VAPORIZERS,
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2,072,887

FORCED FLOW GENERATOR AND METHOD OF OPERATING SAME

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Abandoned.

Continuation of application Serial No. 450,348, May 7, 1930. This application July 22, 1932, Serial No. 623,983

10 Claims. (Cl. 122—250)

This invention relates to a method of generating superheated vapors in a vapor generator of the type in which a liquid enters at one end of a tube and emerges from the other end as a vapor or gas; this present application being a continuation of my previous application filed May 7, 1930, Serial Number 450,348.

The present invention, however, is distinguished from the well known flash or semi-flash generator methods in that it comprises utilizing a path, or paths, of extreme length and small bore into which liquid distributed at one end, extends therethrough for a preponderance of the length of such path and at regulated locations therein, dependent upon controlled conditions of water feed and combustion, is preheated, vaporized and superheated in the quantity and quality required to meet specific load conditions, all of which is accomplished without interposition of any separation of liquid and vapor in a drum or the like.

Also, a feature of the present invention is the distribution, for the equalization of flow and temperature, of the fluid at one or several points along the flow path as, for instance, bringing the flow from several paths together in a mixing or equalizing header and the redistributing to a multiplicity of paths, such mixing and distribution preferably being carried out at locations where there is no change in the physical state of the fluid, thereby avoiding the difficulties which would be encountered in endeavoring to mix fluids of unlike physical properties as, for instance, steam and water.

In a preferred form the generator for the method of the present invention is typified by a multiplicity of long small-bore fluid-flow conduits arranged in parallel and presenting an uninterrupted state of flow from liquid inlet at one end to vapor outlet at the other, with means incorporated in the flow path intermediate the inlet and outlet for mixing the fluid of the several paths to establish an equilibrium of physical condition, and to then re-apportion the fluid flow through several paths.

The invention particularly relates to a "once through" steam boiler method of operation that can be practiced at very high pressures, up to, or above, the critical pressure of steam. By a "once through" boiler is meant a boiler into which feed water enters and is entirely evaporated to generate steam without any of the water returning to the inlet of the boiler before it is evaporated and the steam passed to a place of use. In this type of boiler the water is forced through the various sections by means of the feed pump.

The boiler is provided with an economizer section where the feed water is heated while it flows in a counter-current direction to the direction of flow of the heating gases to a point beyond which steam is generated. The heated water then passes to the boiler section where all of it is vaporized, the steam then passes to a superheater where it is superheated before it is carried to the place of use.

In order to permit the use of very high pressures, say up to the critical pressure of steam, it is necessary to dispense with cast iron parts in a boiler and to use small tubes, preferably made of seamless wrought steel with the connections between the tubes welded. In order to prevent the frictional resistance through the boiler from becoming too high with the small tubes which are connected in series, it is sometimes necessary to use two or more tubes grouped in parallel, the groups being connected in series.

Also since the demand for steam may vary rapidly, requiring a corresponding rapid variation in the amount of water fed to the boiler and heat transferred to the water, it is desirable to obviate the presence of large masses of material, such as thick refractory furnace walls, for example, where large quantities of heat might become stored and be transmitted to the water when it is not required. For this reason it is desirable to surround the furnace, or a substantial portion thereof, with steam generating tubes of the boiler to absorb the radiant heat of the furnace and prevent the storage of too much heat in parts where it would interfere with the desired change in the rate of steam generation.

In the boiler described in this application the amount of feed water is varied in accordance with the demand for the steam and the firing of the boiler is to be varied so as to keep the outlet temperature of the steam at the desired point. The desired pressure of the steam is maintained by the proper variation of the amount of feed water and fuel.

In the accompanying drawings:

Figure 1 is a vertical sectional view, somewhat diagrammatical of a vaporizer constructed in accordance with the present invention.

Fig. 2 is a transverse section on the line 2—2 of Fig. 1.

Fig. 3 is a transverse section of a modified arrangement of tubes in the plane represented by the line 3—3 of Fig. 1.

Fig. 4 is a somewhat diagrammatic view, similar to Fig. 1, showing the vaporizer partially in

section, and with the controls for water input and elements of combustion.

In the drawings reference character 1 indicates a furnace that may be fired by one or more burners 2 that are shown located at the bottom of the furnace. A flue 3 extends from the upper portion of the furnace to the stack 4.

The feed water pipe 5 enters a distributing and equalizing header 6 near the upper portion of the flue 3. One or more long small bore tubes lead from the header 6 to the economizer section 7 of the boiler that is located in the upper portion of the flue 3. The economizer 7 may consist of coils of small seamless, wrought steel tubes in parallel, or may be made up of parallel tubes subdivided by headers into small groups, the groups being connected in series, and the total series connected group then joined to the header 6, the coils or groups of tubes constituting the economizer are connected so that the water passes through them counter-current to the gases in the flue 3 and the outlet ends of the economizer coils or groups of tubes are connected to a header 8 outside of the flue. The header 8 is connected by means of the pipe 9 to a header 10 located outside of the wall of the furnace 1.

One or more tubes extend from the header 10 to the steam generating tubes or boiler section 11. This section preferably comprises coils or tubes surrounding the furnace 1 to shield the walls thereof from the radiant heat of the furnace and prevent a large amount of heat from being stored in walls of the furnace. In addition to the coils or tubes of the steam generating section which shield the furnace walls form the intense heat, the steam generating or boiler section may comprise additional tubes which extend across the furnace, these tubes also being connected in series or in groups in parallel with the tubes in each group connected in series. The tubes referred to in the steam generating section, in addition to the coils heated by radiant heat, may be arranged across the furnace in the manner shown in Fig. 3, which is representative of a section in any location in the steam generating section similar to the plane represented by the line 3—3 of Fig. 1 from the lowermost portion of the steam generating section 11 to the uppermost portion thereof, if desired, it being obvious that in the case of such an arrangement the lowermost of these transverse coils would be subjected to radiant heat. The vapor or steam generating section 11 is comprised of a plurality of tubes coiled in parallel and each connected at its fluid entrance end to the header 10. The steam and water in the section 11 are shown to flow parallel to the direction of the hot gases, so that if the steaming temperature of the water has not been reached in the economizer section 7, the coolest portions of these tubes are exposed to the hottest gases. This steam generating section is so constructed that there is an upflow of water and steam to obviate any danger of steam pockets forming which might be the case if the water and steam were made to flow downwardly.

The outlet ends of the tubes of the steam generating or boiler section 11 are connected in series to coils or groups of tubes constituting the superheater 12 which is constructed in a manner similar to that described above in connection with the economizer 7. The superheater 12 is located in the flue 3 between the economizer 7 and boiler 11. The steam to be heated in the superheater 12 flows in the same direction as the gases which heat the economizer. The outlet ends of the superheater coils or groups of tubes 12 are connected to the header 13 from which a pipe 14 provided with a valve 15 leads to a steam main or place of steam consumption. In connection with Fig. 2 and the section line 2—2 of Fig. 1, it is to be understood that, if desirable, all of the coils in this superheater section may be of the type represented in this figure, or that such coils may be located at any suitable zones therein, and it is to be noted that the actual superheating may take place only in the uppermost portion of this section 12 and after the steam becomes dried in the section 12.

A feed water pipe 16 leads from a condenser or hot well (not shown) to the inlet of a feed pump 17 which is preferably a triplex plunger pump driven in any convenient way. The pipe 5 leads from the outlet side of the pump 17 to the header 6 of the economizer 7.

A bypass 18 having a valve 19 may be provided around the pump 17, and a make up feed water pipe 20 having a valve 21 may be connected to the pipe 16.

Portions of the coils 11 are extended as shown at 22 to enter the setting of the steam generator and thereby form supports.

In Fig. 4 an orifice or similar element is located between the flanges 22, creating a pressure differential bearing a known relation to rate of vapor outflow. Such pressure differential is effective, through pipes 23, to continuously position a regulating valve 19' in the by-pass 18, thereby automatically regulating liquid supply in accordance with the demand upon the generator. A bulb 24, sensitive to vapor outflow temperature, forms part of a thermostat system of which 25 indicates the connecting capillary continuously positioning the fuel regulating valve 26 to maintain desired vapor outflow temperature. Should vapor outflow pressure depart from desired value, a readjustment of liquid inflow and of fuel supply rate is automatically accomplished in the desired direction and amount, through the agency of regulating valves 21' and 27, both positioned directly by such pressure effective through the pipe 28.

When the demand upon the generator increases, the increased rate of vapor outflow causes a throttling of valve 19', with consequent increase in rate of liquid inflow. Should the temperature of the vapor fall below desired value, the valve 26 will be opened proportionately to increase the heating; while if vapor pressure at the same time decreases below desired value the auxiliary fuel supply valve 27 will be positioned in an opening direction and the supplementary liquid supply valve 21' will be positioned in necessary direction and amount to cause the pressure to return to normal. These various regulations are quite independent in action and may act in sequence or simultaneously, to correct the variables under control.

While a specific construction of a once-through boiler has been illustrated and described in connection with the method of the present invention, it will be understood that other constructions employing the same method of operation come within the scope of this invention. Also while different portions of the boiler have been described as economizer, boiler, and superheater sections, it will be clear that the lines of demarcation between these various sections are not definitely fixed, but will vary depending upon the operation of the boiler, but in all cases the feed water will enter the economizer and after

122, LIQUID HEATERS
& VAPORIZERS,
250
Examiner

passing through the "once-through" sections in series will leave the last, or super-heater section, as superheated steam.

I claim—

1. A method of generating superheated vapor in a vaporizer including a furnace and a flow path continuous from fluid inlet to superheated vapor outlet and composed of a plurality of long, small-bore fluid flow conduit portions arranged for flow in parallel, said path including a steam generating and a superheating portion, said vaporizer having fluid forced therethrough from liquid inlet to superheated vapor outlet, which comprises supplying working medium to the vaporizer at a pressure substantially higher than the desired working pressure of the superheated vapor, utilizing the difference between supply and working pressures to force said working medium through the vaporizer with continuously decreasing pressure from inlet to outlet, said flow path having an extremely large ratio of surface to cross-section, releasing heat by combustion of fuel in the furnace and passing the gaseous products in heat transfer relation to said flow path at heat release rate and gas flow rate sufficiently high in relation to the ratio of surface to cross-section of said flow path to evaporate and superheat said working medium in said flow path before it issues from the end thereof, and equalizing the heat content per pound of working medium entering the several conduit portions in parallel intermediate the vaporizer inlet and outlet with respect to following conduit portions and at a location in advance of the superheating portion of the flow path.

2. A method of generating superheated vapor in a vaporizer including a furnace and a flow path continuous from fluid inlet to superheated vapor outlet and composed of a plurality of long, small-bore fluid flow conduit portions arranged for flow in parallel, said path including a steam generating and a superheating portion, said vaporizer having fluid forced therethrough from liquid inlet to superheated vapor outlet, which comprises supplying working medium to the vaporizer at a pressure below critical and substantially higher than the desired working pressure of the superheated vapor, utilizing the difference between supply and working pressures to force said working medium through the vaporizer with continuously decreasing pressure from inlet to outlet, said flow path having an extremely large ratio of surface to cross-section, releasing heat by combustion of fuel in the furnace and passing the gaseous products in heat transfer relation to said flow path at heat release rate and gas flow rate sufficiently high in relation to the ratio of surface to cross-section of said flow path to evaporate and superheat said working medium in said flow path before it issues from the end thereof, and equalizing the heat content per pound of working medium entering the several conduit portions in parallel intermediate the vaporizer inlet and outlet with respect to following conduit portions and at a location in advance of the superheating portion of the flow path.

3. A method of generating superheated vapor in a vaporizer including a furnace and a flow path continuous from fluid inlet to superheated vapor outlet and composed of a plurality of long, small-bore fluid flow conduit portions arranged for flow in parallel, said path including a steam generating and a superheating portion, said vaporizer having fluid forced therethrough from liquid inlet to superheated vapor outlet of the vaporizer, which comprises supplying working medium to the vaporizer at a pressure substantially higher than the desired working pressure of the superheated vapor, utilizing the difference between supply and working pressures to force said working medium through the vaporizer with continuously decreasing pressure from inlet to outlet, said flow path having an extremely large ratio of surface to cross-section, releasing heat by combustion of fuel in the furnace and passing the gaseous products in heat transfer relation to said flow path at heat release rate and gas flow rate sufficiently high in relation to the ratio of surface to cross-section of said flow path to evaporate and superheat said working medium in said flow path before it issues from the end thereof, and equalizing the heat content per pound of working medium entering the several conduit portions in parallel intermediate the vaporizer inlet and outlet with respect to following conduit portions and at a location in advance of the superheating portion of the flow path and outside of the heating zone.

4. A method of operating a vaporizer to generate superheated vapor, said vaporizer including a fuel fired furnace and a flow path continuous from liquid inlet to superheated vapor outlet and composed of a plurality of long small-bore fluid flow conduit portions arranged for flow in parallel and having an extremely large ratio of heat absorbing surface to cross-section, said path including vapor generating and superheating portions, and having fluid forced therethrough from liquid inlet to superheated vapor outlet by a positive displacement pump means, which comprises operating the pump means to positively displace a supply of working medium to the vaporizer at a pressure substantially higher than the desired working pressure of the superheated vapor, utilizing the difference between supply and working pressures to force said working medium through the vaporizer with continuously decreasing pressure from inlet to outlet of said flow path, releasing heat by combustion of fuel in the furnace without a solid fuel bed, passing the gaseous products in heat transfer relation to said flow path at heat release rate and gas flow rate sufficiently high in relation to the ratio of surface to cross-section of said flow path to evaporate and superheat the working medium passing from the outlet of the superheater portion of the flow path, equalizing the heat content per pound of working medium entering the several conduit portions in parallel intermediate the vaporizer inlet and outlet and at a location in advance of the superheating portion of the flow path, and controlling the quantity of liquid delivered to the flow path independent of the rate of displacement of the aforesaid pump means.

5. A method of operating a vaporizer to generate superheated vapor, said vaporizer including a fuel fired furnace and a flow path continuous from liquid inlet to superheated vapor outlet and composed of a plurality of long small-bore fluid flow conduit portions arranged for flow in parallel and having an extremely large ratio of heat absorbing surface to cross-section, said path including vapor generating and superheating portions, and having fluid forced therethrough from liquid inlet to superheated vapor outlet by a positive displacement pump means, which comprises operating the pump means to positively displace a supply of working medium to the va-

porizer at a pressure substantially higher than the desired working pressure of the superheated vapor, utilizing the difference between supply and working pressures to force said working medium through the vaporizer with continuously decreasing pressure from inlet to outlet of said flow path, releasing heat by combustion of fuel in the furnace without a solid fuel bed, passing the gaseous products in heat transfer relation to said flow path at heat release rate and gas flow rate sufficiently high in relation to the ratio of surface to cross-section of said flow path to evaporate and superheat the working medium passing from the outlet of the superheater portion of the flow path, equalizing the heat content per pound of working medium entering the several conduit portions in parallel intermediate the vaporizer inlet and outlet and at a location in advance of the superheating portion of the flow path and remote from the heat of the combustion gases, and controlling the quantity of liquid delivered to the flow path independent of the rate of displacement of the aforesaid pump means.

6. A vapor generator comprising a furnace, a fluid flow passage continuous from liquid inlet to superheated vapor outlet and composed of a plurality of long small-bore fluid flow conduit portions arranged for flow in parallel and having an extremely large ratio of heat absorbing surface to cross-section, said path including vapor generating and superheating portions, means firing the furnace with elements of combustion in a manner incapable of forming a substantial fuel bed and operable at a heat release rate and gas flow rate sufficiently high in relation to the ratio of surface to cross-section of said flow passage to evaporate and superheat the fluid before passing from the superheater outlet, means at a location in advance of the superheating portion of the flow path and combining the fluid flow from a plurality of conduit portions for equalization of the heat content per pound of working fluid, displacement pump means arranged to supply liquid positively to the generator at a pressure substantially higher than the desired working pressure of the superheated vapor whereby the difference between supply and working pressures forces the fluid through the fluid flow passage with a continuously decreasing pressure from liquid inlet to vapor outlet and with the pressure quantity relation of the liquid supply normally unaffected by a change in pressure in the flow path, and means for varying the quantity of liquid delivered to the flow passage independent of the rate of displacement of said pump means.

7. A vapor generator comprising a furnace, a fluid flow passage continuous from liquid inlet to superheated vapor outlet and composed of a plurality of long small-bore fluid flow conduit portions arranged for flow in parallel and having an extremely large ratio of heat absorbing surface to cross-section, said path including vapor generating and superheating portions, means firing the furnace with elements of combustion in a manner incapable of forming a substantial fuel bed and operable at a heat release rate and gas flow rate sufficiently high in relation to the ratio of surface to cross-section of said flow passage to evaporate and superheat the fluid before passing from the superheater outlet, means at a location remote from the heat of the combustion gases and in advance of the superheating portion of the flow path and combining the fluid flow from a plurality of conduit portions for equalization of the heat content per pound of working fluid, displacement pump means arranged to supply liquid positively to the generator at a pressure substantially higher than the desired working pressure of the superheated vapor whereby the difference between supply and working pressures forces the fluid through the fluid flow passage with a continuously decreasing pressure from liquid inlet to vapor outlet and with the pressure quantity relation of the liquid supply normally unaffected by a change in pressure in the flow path, and means for varying the quantity of liquid delivered to the flow passage independent of the rate of displacement of said pump means.

8. A vapor generator comprising a furnace, a fluid flow passage continuous from liquid inlet to superheated vapor outlet and composed of a plurality of long small-bore fluid flow conduit portions arranged for flow in parallel and having an extremely large ratio of heat absorbing surface to cross-section, said path including vapor generating and superheating portions, means firing the furnace with elements of combustion in a manner incapable of forming a substantial fuel bed and operable at a heat release rate and gas flow rate sufficiently high in relation to the ratio of surface to cross section of said flow passage to evaporate and superheat the fluid before passing from the superheater outlet, means at a location in advance of the superheating portion of the flow path and combining the fluid flow from a plurality of conduit portions for equalization of the heat content per pound of working fluid, displacement pump means arranged to supply liquid positively to the generator at a pressure substantially higher than the desired working pressure of the superheated vapor whereby the difference between supply and working pressures forces the fluid through the fluid flow passage with a continuously decreasing pressure from liquid inlet to vapor outlet and with the pressure quantity relation of the liquid supply normally unaffected by a change in pressure in the flow path, and means for varying the quantity of liquid delivered to the flow passage independent of the rate of displacement of said pump means, a portion of the heat absorbing surface of said flow path presenting a substantially continuous heat absorbing wall area within the zone of radiant heat to reduce to a minimum the heat storage capacity of the furnace structure.

9. A method of generating superheated vapor in a vaporizer including a furnace and a flow path continuous from fluid inlet to superheated vapor outlet and composed of a plurality of long, small-bore fluid flow conduit portions arranged for flow in parallel, said path including a steam generating and a superheating portion, said vaporizer having fluid forced therethrough from liquid inlet to superheated vapor outlet, which comprises supplying working medium to the vaporizer at a pressure substantially higher than the desired working pressure of the superheated vapor, utilizing the difference between supply and working pressures to force said working medium through the vaporizer with continuously decreasing pressure from inlet to outlet, said flow path having an extremely large ratio of surface to cross-section, releasing heat by combustion of fuel in the furnace and passing the gaseous products in heat transfer relation to said flow path at heat release rate and gas flow rate sufficiently high in relation to the ratio of surface to cross-section of said flow path to evaporate and superheat said working medium in said flow path before it issues from the end

122. LIQUID HEATERS
& VAPORIZERS,
250

Examiner

thereof, equalizing the heat content per pound of working medium entering the several conduit portions in parallel at a location in advance of the superheating portion of the flow path, operating the fluid forcing means to provide a continuous supply of working medium at a rate at least equal to and a pressure greater than the desired demand rate and pressure of superheated steam, and controlling the rate of working medium delivery to the flow path independent of the continuously imposed supply rate.

10. A method of generating superheated vapor in a vaporizer including a furnace and a flow path continuous from fluid inlet to superheated vapor outlet and composed of a plurality of long, small-bore fluid flow conduit portions arranged for flow in parallel, said path including a steam generating and a superheating portion, said vaporizer having fluid forced therethrough from liquid inlet to superheated vapor outlet, which comprises supplying working medium to the vaporizer at a pressure substantially higher than the desired working pressure of the superheated vapor, utilizing the difference between supply and working pressure to force said working medium through the vaporizer with continuously decreasing pressure from inlet to outlet, said flow path having an extremely large ratio of surface to cross-section, releasing heat by combustion of fuel in the furnace and passing the gaseous products in heat transfer relation to said flow path at heat release rate and gas flow rate sufficiently high in relation to the ratio of surface to cross-section of said flow path to evaporate and superheat said working medium in said flow path before it issues from the end thereof, and equalizing the temperature of the working medium entering the several conduit portions at a location in advance of the superheating portion of the flow path, operating the fluid forcing means to provide a continuous supply of working medium at a rate at least equal to and a pressure greater than the desired demand rate and pressure of superheated steam, and controlling the rate of working medium delivery to the flow path independent of the continuously imposed supply rate.

HOWARD J. KERR.