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VAPOR GENERATING PLANT

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This invention relates to the construction and operation of vapor generating power installations comprising a vapor generating unit designed to produce superheated vapor under high pressures and high superheat temperatures. Such pressure and temperature requirements complicate the fluid circulation system of the unit and necessitate a superheater location close to the furnace chamber where the superheater tubes are subjected to substantial furnace radiation and high temperature gases.

This problem is particularly present in vapor generators of the drumless forced flow type having a flow path for the liquid to be vaporized including one or more long small-bore tubes receiving liquid under pressure at one end and discharging liquid and vapor into a separator at the other end, from which the vapor is passed to a superheater. Vapor generators of this type are particularly designed for high pressure high superheat temperature operation and in view of their ability to economically handle practically instantaneous load changes of a substantial amount are especially suitable for operating conditions such as marine service, where load variations are of a wide range and are required to be met substantially instantaneously.

In installations of the character described, it is usual to supply the steam for the steam driven auxiliaries of the vapor generating unit, such as fuel and water pumps, circulating fans, etc. from the forced circulation vapor generating unit being served. However, the auxiliaries can be driven by steam from other sources, such as a relatively low pressure steam boiler delivering saturated or superheated steam to the auxiliaries. This means that with the high pressure high superheat vapor generator under standby conditions, there will be no steam flow through the superheater of that unit and thus inadequate protection of the superheater tubes from overheating and burning out.

Furthermore, when a vapor generating unit is started up from a cold condition or rapidly changed from a banked condition to a high load condition, the fluid in the generating circuits rapidly changes from a high to a low percentage of liquid by volume. This change in liquid volume causes a surge in liquid level in the vapor and liquid separating chamber which may cause the superheater to be flooded and slugs of water to enter the high pressure turbine. The surge must be disposed of or the supply of incoming liquid temporarily stopped. If however, the vapor generator is maintained in a vaporizing condition, the amount of surge on sudden increases in load will be substantially reduced and eliminated as a factor limiting the rate of load change. Operation at a vaporizing minimum load is particularly desirable for forced circula-

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tion units, as it is preferable from an efficiency standpoint to have all of the fuel burners thereof in operation at all times rather than turning them on or off as the load demand changes.

The main object of our invention is the provision of an improved construction and mode of operation of a vapor generating plant of the general character described. A further and more specific object is the provision of an interconnection between a high pressure high superheat vapor generator and a relatively low pressure vapor generator in an installation of the character described which permits continuous operation of the high pressure unit under vaporizing conditions and consequently a vapor flow through the superheater section at all times.

The various features of novelty which characterize our invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawing and descriptive matter in which we have illustrated and described a preferred embodiment of our invention.

The single figure of the drawing is a partly diagrammatic illustration of a portion of a vapor generating power plant incorporating a high pressure high superheat forced circulation steam generator and a relatively low pressure natural circulation steam generator constructed and operating in accordance with our invention.

In the drawing we have diagrammatically illustrated a portion of a two pressure marine power plant constructed and operating in accordance with our invention and embodying a high pressure high superheat forced circulation steam boiler 10 and a relatively low pressure natural circulation steam boiler 11. As illustrated, the unit has a middle furnace section 12 fired by fuel burners 13 in its top wall. The products of combustion are variably divided between upflow gas passes 14 and 15 at opposite sides of the furnace chamber, the pass 14 containing a primary economizer section 16 and main steam generating section 17, while the pass 15 contains a tubular air heater 18, a secondary economizer section 19, a primary superheater section 20, and secondary superheater section 21. The gas flow through the gas passes is proportioned by dampers 22 located at the outlet ends thereof. A portion of the steam generating surface is formed by water tubes 23 lining the walls of the furnace chamber and walls below the gas passes 14 and 15 and a convection heated section 24 in the lower part of the gas pass 15 below the second superheater section 21. The usual auxiliaries, such as the water pump, air blower and fuel pump for the unit, are preferably driven on a single shaft

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by an auxiliary steam turbine (not shown). The forced circulation unit described is designed for the production of steam at high pressures and high superheat temperatures, as for example, 1200 p. s. i. and 900° F. The high superheat temperature requirements necessitate a location for the primary and secondary superheater sections close to the furnace chamber and separated therefrom by only the relatively few rows of convection heated steam generating tubes 24.

The natural circulating steam generating unit illustrated is of the separately fired superheater furnace single uptake type disclosed in a co-pending application of E. J. Rooney, Serial No. 228,734, filed September 7, 1938, now U. S. Patent No. 2,332,534, and comprises an upper steam and water drum 30, a laterally offset lower water drum 31, a main bank of inclined steam generating tubes 32 connecting the drums 30 and 31, a vertical bank of generating tubes 33 extending from the drum 30 to a second lower water drum 38 and spaced to enclose a group of steam heating tubes 34. A main furnace chamber 35 is located between the tube banks 32 and 33 and a separately fired auxiliary furnace chamber 36 located at the opposite side of the tube bank 33. A common heating gas outlet 37 for both furnaces insures passage of the heating gases from the auxiliary furnace over the steam heating tubes 34, generating tube banks 33 and 32. In the installation illustrated the boiler 11 is designed to produce saturated steam at 415 p. s. i. or superheated steam at 400 p. s. i. and 850° F. with a maximum steaming capacity of approximately 54,000 lbs. of steam per hour.

The high and low pressure generating units are designed for complete automatic control. The high pressure steam will be maintained at the desired superheat temperature by control of the gas dampers 22 in the gas passes 14 and 15. The temperature of the low pressure steam will be maintained at the desired value by varying the rate of firing in the auxiliary or superheater furnace 36 of that unit.

When the high pressure generating unit is operated at its designed rate, the steam generated is passed to the high pressure steam line 40 incorporating a throttle valve 41 and leading to a high pressure steam turbine 42 and low pressure turbine 52. When the steam is to be reheated prior to entering the low pressure turbine, the steam heating tubes 34 of the low pressure boiler are used as a reheater and the auxiliary furnace fired accordingly. The valves 43 and 44 in the steam line 45 are opened and the valve 46 in the saturated steam line 47 to the tubes 34 closed. The valve 48 in the steam discharge line 49 is opened, the stop valve 50 in the turbine steam line 51 being closed. The reheated steam is then passed to the low pressure turbine 52.

In a two-pressure installation of the character described, the forced circulation unit can be shut down and all of the steam generated by the natural circulation unit. In this case the tubes 34 are used for superheating the saturated steam leaving the drum 30 through the steam line 47. The superheated steam passes through the steam line 49 and control valve 55 to the inlet end of the high pressure turbine 42. The valve 55 is closed when the turbines are driven from the high pressure unit.

In accordance with our invention, the high and low pressure generating units are interconnected by an automatically controlled steam line system in such a manner as to allow a flow of steam

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from the high pressure unit to the low pressure unit and thereby maintain a flow of steam through the superheater sections 20 and 21 sufficient to protect the same during standby operation and other operating conditions of the high pressure unit. The provisions for this purpose comprise a high pressure steam overflow valve 60 in a branch steam line 61 leading from the high pressure main 40 to the water drum 31 of the low pressure unit. The line 61 also includes a pressure reducing valve 62 of any suitable type and stop valves 63 and 64.

The steam overflow valve 60 is a diaphragm operated valve controlled by an air loaded standardizing relay 65 of the type shown in Gorrie U. S. Patent 2,098,914. The relay 65 is actuated by a pressure responsive device having a Bourdon tube 65^a positioning a movable valve member of a pilot valve 65^b of the type shown in Johnson U. S. Patent 2,054,464 in response to steam pressure variations in the high pressure main 40. The relay 65 is also actuated by a flow measuring device 65^c through a second pilot valve 65^b. With this arrangement the relay 65 will be responsive both to steam pressure and steam flow in the high pressure main 40. The valve 60 is normally closed and opens automatically under either of two operating conditions of the high pressure unit, i. e. when the steam pressure in the high pressure unit exceeds a predetermined value, the valve will open to relieve the excess boiler pressure, and secondly, when the firing rate and thereby the steam flow from the high pressure unit falls below a predetermined minimum value. By way of example and not of limitation, in one arrangement of the character described the high pressure unit has a normal generating capacity of 168,000 lbs. of steam per hr. and the valve 60 is arranged to open when the steam flow drops to 16,000 lbs. steam per hr.

When the valve 60 opens, high pressure steam flows from the main 40 through the steam line 61 and valves 60 and 62, the stop valves 63 and 64 being normally open. The reducing valve is set for a pressure reduction to slightly above the operating pressure of the natural circulation unit. The steam line 61 terminates in one or more coils 66 submerged in the water drum 31. The use of the submerged coil 66 is advantageous to partially desuperheat the steam before emerging into the water. This reduces the noise of the entering steam as well as any tendency to torch through the water against the drum shell. In case the natural circulation unit is down for repairs, the valve 63 is closed and the steam passed into a steam line 70 controlled by a stop valve 71 leading to a desuperheater 72. The desuperheated steam passes into the saturated steam main 74 for the generating unit auxiliaries and other saturated steam consuming devices. Likewise the steam entering the water drum 31 is desuperheated and passes through the tube bank 32 to the drum 30, from which it can pass to either the saturated steam main 74 or superheater tubes 34 or both, depending upon the load on the installation.

With the described interconnection between the units, the high pressure unit can be maintained in a standby condition or predetermined minimum operating capacity without fear of endangering the superheater thereof. Due to the flow of some steam from this unit under such conditions, the amount of surge is greatly reduced on increases in load thereon. Changes in load on the high pressure unit can be more

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rapidly and reliably effected because the burners thereof can be kept lit at all times, avoiding any necessity of turning burners on or off as the load changes. It is thus possible to maintain a reasonable burning rate or base load and improved efficiency even when the forced circulation unit is idling. The overall efficiency of the installation is increased due to the fact that the fuel is burned in only one generating unit most of the operating period. The passage of the steam from the high pressure unit through the natural circulation boiler maintains the low pressure unit in a banked condition without the necessity of having any of the burners thereon lit, reducing the surge in that unit on sudden load increases.

While in accordance with the provisions of the statutes we have illustrated and described herein the best form of the invention now known to us, those skilled in the art will understand that changes may be made in the form of the apparatus disclosed without departing from the spirit of the invention covered by our claims, and that certain features of our invention may sometimes be used to advantage without a corresponding use of other features.

We claim:

1. In a vapor generating plant, in combination, a high pressure vapor generator having a vapor superheater positioned in a high temperature zone, a relatively low pressure vapor generator, a superheated vapor connection between said superheater and said low pressure generator, a valve arranged to control the flow of vapor through said vapor connection, and flow and pressure responsive control means connected to said valve and communicating with said vapor connection, said control means being operative to open said valve in response to a rate of superheated vapor flow in said vapor connection less than a predetermined minimum value and in response to a vapor pressure in said vapor connection above a predetermined value.

2. In a vapor generating plant, in combination, a high pressure forced circulation vapor generator having a vapor superheater positioned in a high temperature zone, a relatively low pressure natural circulation vapor generator, a superheated vapor connection between said superheater and said low pressure generator, a valve arranged to control the flow of vapor through said vapor connection, and flow and pressure responsive control means connected to said valve and communicating with said vapor connection, said control means being operative to open said valve in response to a rate of superheated vapor flow in said vapor connection less than a predetermined minimum value and in response to a vapor pressure in said vapor connection above a predetermined value.

3. In a vapor generating plant, in combination, a high pressure forced circulation vapor generator having a vapor superheater positioned in a high temperature zone, a relatively low pressure natural circulation vapor generator having an upper liquid and vapor drum, a lower liquid drum, and a bank of vapor generating tubes connecting said drums, a vapor desuperheater tube positioned in and discharging to said lower liquid drum at a point aiding a normal natural circulation in said tube bank, a superheated vapor connection between said superheater and said desuperheater tube, a valve arranged to control the flow of vapor through said vapor connection, and control means responsive to changes in a variable

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operating condition in said high pressure generator arranged to automatically operate said valve.

4. In a vapor generating plant comprising a high pressure vapor generator having a vapor superheater positioned in a high temperature zone in combination with a relatively low pressure natural circulation vapor generator, the method of operation which comprises passing superheated vapor from said high pressure generator at a reduced pressure into the liquid space of said low pressure generator whenever the superheated vapor demand on said high pressure generator falls below a predetermined minimum value and whenever the vapor pressure in said high pressure generator exceeds a predetermined value, and desuperheating the superheated vapor so passed in the liquid space of said low pressure generator before directly mixing with the liquid therein.

5. In a vapor generating plant comprising a high pressure forced circulation vapor generator having a vapor superheater positioned in a high temperature zone in combination with a relatively low pressure natural circulation vapor generator, the method of maintaining said generators in a standby condition which comprises reducing the firing rate on said high pressure generator, passing superheated vapor from said high pressure generator at a reduced pressure into the lower part of the liquid space of said low pressure generator at a point aiding a normal natural circulation in said tube bank, discontinuing the firing of said low pressure generator, and supplying the vapor generated in said low pressure generator by said superheated vapor to the vapor driven auxiliaries of said high pressure generator.

6. In a vapor generating plant comprising a high pressure vapor generator having a vapor superheater positioned in a high temperature zone in combination with a relatively low pressure vapor generator, the method of protecting the superheater during low load periods which comprises passing superheated vapor from the high pressure generator at a reduced pressure into the low pressure generator whenever the vapor pressure in said high pressure generator exceeds a predetermined value and whenever the superheated vapor flows from said high pressure generator drops below a predetermined minimum value.

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