Jan. 14, 1936. A. LIEBERHERR 2,027,443

STEAM GENERATOR OF THE WATER TUBE TYPE

Original Filed Dec. 23, 1930

Fig. 1.

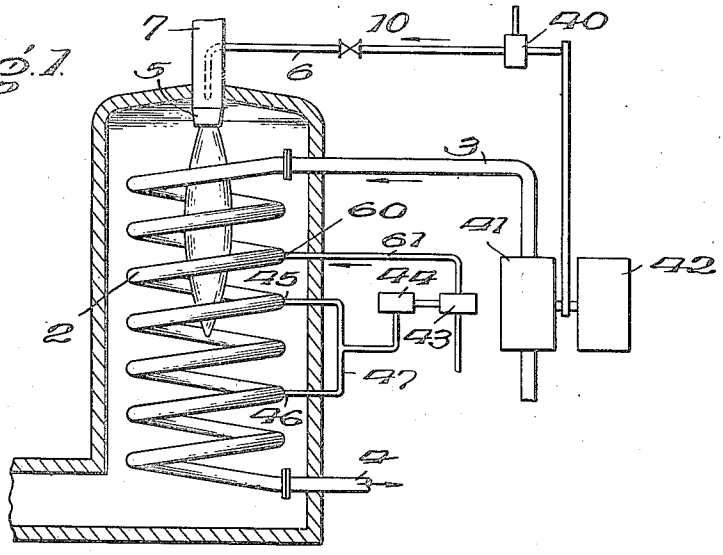


Fig. 2.

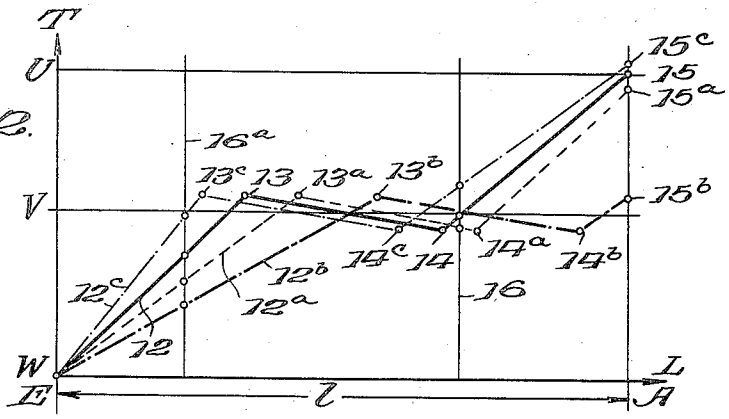
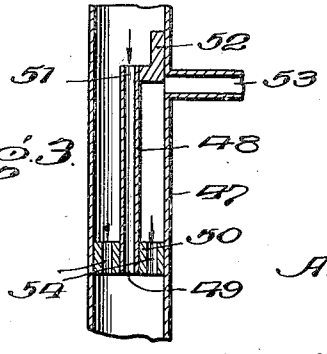


Fig. 3.



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Patented Jan. 14, 1936 2,027,443

UNITED STATES PATENT OFFICE

2,027,443

STEAM GENERATOR OF THE WATER TUBE TYPE

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Original application December 23, 1930, Serial No. 504,261. Divided and this application August 29, 1935, Serial No. 38,456

4 Claims. (Cl. 122—448)

This invention relates to steam generators of the water tube type in which the working medium—which need not necessarily be water—is converted into steam or other vapor in a system of tubes, the amount of fuel and water or other working medium supplied being regulated in accordance with the temperature at which the vapor escapes from the outlet end of the tube system.

Such methods of control have not proved satisfactory as the temperature of the steam or the like at the outlet end of the tube system does not quickly respond to changes which take place in the tubes themselves, i. e. there is a considerable lag due to the heat stored in the wall of the tube system itself and as a result of this lag it is impossible to avoid marked fluctuations in the condition of the steam delivered by the generator.

To meet this difficulty proposals have already been made to vary the supply of feed water in accordance with the temperature of the liquid in the generator prior to its conversion into steam, but this method of regulation prevents compensation for temperature fluctuations due to irregular firing; or variations in the temperature, and the rate of evaporation in that part of the tube system where the liquid is converted into steam, so that the steam discharged is still subject to temperature fluctuations.

The object of the present invention is to prevent the lag to which the temperature of the outlet steam is at present subject owing to the heat stored in the wall of the tubes.

According to this invention the supply of some of the working medium delivered to the generator is regulated in accordance with the temperature of the working medium at or about that point in the length of the tube system where the working medium is converted from saturated into superheated steam or vapor.

The invention is diagrammatically illustrated by way of example in the accompanying drawing, in which

Fig. 1 shows a steam generator in which an additional quantity of the working medium is regulated in accordance with the temperature of the working medium in the tube system,

Fig. 2 is a diagram showing the temperature curve in the tube system under different working conditions, and

Fig. 3 shows a thermostatic device for regulating the feed pump.

The working medium, for example water, is supplied to the system of tubes **2** within the combustion chamber through a pipe **3** and the steam generated in the tubes is conveyed to the points of consumption through the main steam delivery pipe **4**.

Fuel is supplied to the burner **5** through a pipe **6**, the air to support combustion being delivered though a pipe **7**. A valve **10** is provided to regulate the supply of fuel and steam delivered to the main supply pipe **4** is regulated in any desired manner.

The working of the generator will be best seen from the diagram illustrated in Figure 2, in which the length **l** of the system of tubes is plotted horizontally between the inlet end E and the outlet end A, the temperatures of the working medium at the various points in the system of tubes being plotted vertically.

The curve **12** shown in full lines represents the normal state in the system of tubes. First the working medium which is still in the liquid state is heated to the temperature of evaporation V between the inlet point E and the point **13**. Thereafter to the point **14** it is converted into saturated steam containing no unevaporated liquid. At this stage there will be a small drop in the temperature of the steam in accordance with the fall of pressure, and subsequently this saturated steam is superheated to the temperature U between the point **14** and the point of discharge **15** from the system of tubes.

In undergoing the change of state between the inlet and outlet ends of the tube system as shown in Fig. 2 a quantity of heat is distributed approximately as to three-tenths for the heating of the liquid medium six-tenths for evaporation and one-tenth for superheating.

When it is desired to increase the output of the boiler i. e. when the quantity of feed liquid is increased, the temperature of the working medium in the system of tubes **2** will change in the manner indicated by the curve **12***a*. The beginning of evaporation of the working medium is shifted from the original point **13** to a later point **13***a*. As before, the original point **14** at which the working medium was evaporated is now shifted to point **14***a*. The quantity of heat required for superheating the working medium is so small relatively to the quantity of heat required to effect evaporation, that the heat stored in the wall of the tube system is enough for superheating to the temperature U until the discharge point **15***a* is reached.

Consequently, although for the increased output more feed water or other working medium has been supplied, the change in temperature at the point of discharge will be only very small

owing to the heat stored in the tubes and the small amount of heat required for superheating. Within the tube system, however, considerable fluctuations in temperature will occur and these will continue until the increased quantity of working medium has been continuously supplied for a considerable period, by which time the heat stored in the tubes will be used up between the points 14 and 15 with the result that there will be a sudden drop in the temperature of the steam delivered at the outlet end from that of superheated to saturated steam.

The new curve of temperatures of working medium within the tube system will in this case be that represented by the curve 12*b*. The point 13 where evaporation begins and the point 14 where it is completed are shifted still further towards the outlet end of the system to the points 13*b* and 14*b*. The liquid working medium and the mixture of liquid and steam between the points 13*b* and 14*b* absorb from the wall of the tubes so much of the heat stored in this wall that there is insufficient heat left in the tubes to superheat the steam after the point 14*b* has been reached. The sudden change in the temperature of the steam at the outlet from the points 15*a* to 15*b* cannot be avoided so that either saturated steam or steam containing liquid particles will be delivered instead of superheated steam.

This sudden fall of temperature has many drawbacks. For example, engines driven by this steam are liable to be damaged owing to the priming caused by the rapid fall of temperature. Further, the material from which the generator itself is formed will be adversely affected by these rapid falls in temperature either through changes in the inner structure of the material itself or through temperature stresses produced.

When the output of the generator is reduced, less feed liquid is supplied to it. The smaller quantity so supplied will be heated more quickly in accordance with the curve illustrated at 12*c*, the evaporation point at the start being shifted from the original point 13 to the new point 13*c* and the point 14 where evaporation was completed to the point 14*c*. The small amount of heat transmitted to and absorbed by the steam from the tubes between the points 14*c* and 15*c* is unable to effect any appreciable change in the temperature of the tube wall, so that the temperature of the steam at the point of discharge will only be raised to a negligible extent, that is from the point 15 to the new point 15*c*.

Only after a considerable time will a change in temperature at the outlet end of the tube system be perceptible, as in the case when the load is increased, but then this change will take place rapidly and the temperature will quickly rise to a dangerous extent. Such fluctuations lead to irregular working of the engine or apparatus driven by the engine.

According to the invention both the working medium and the fuel are regulated in accordance with the temperature of the working medium at a point in front of the outlet end of the tubes. In Figure 2 this point is indicated at 16. As will be seen from the diagram, the point at which the temperature-responsive device is placed is preferably behind the point at which the steam is completely evaporated in the tubes, at which point large changes of temperature take place in the tube system directly upon any alteration occurring in the load, thus enabling a quick and effective regulation of the generator to be obtained. Such a method avoids the drawbacks of existing steam generators in which evaporation takes place in a system of tubes and regulation is effected in accordance with the temperature of the steam delivered, for in such existing arrangements, owing to lag, the whole process of regulation is exposed to such fluctuations that effective working is almost impossible. As compared with such existing methods the regulation in accordance with the present invention enables fluctuations in the temperature of the steam generated to be practically eliminated and the improved regulating means can be readily set or adjusted.

Referring more in detail to the construction shown in Figure 1, fuel is supplied to the burner 5 by means of a pump 40 through the pipe 6, and the main supply of feed water or other working medium is delivered to the tubes by means of a pump 41 through the main supply pipe 3. Both pumps 40 and 41 are driven from a common engine 42 so that the quantities delivered by them are always in a fixed ratio to one another. Further, an additional supply of feed water or like working medium is introduced into the system of tubes by means of an auxiliary pump 43, this pump being driven by a separate motor or engine 44 controlled by the temperature of the evaporated working medium in the tube system in advance of the outlet end of the tubes so that when the temperature of the working medium in the tube system rises, this pump delivers a greater quantity, and conversely a smaller quantity of additional working medium when the temperature drops.

The approximate regulation of this steam generator is effected by a change in the number of revolutions of the engine 42 which drives the main fuel and feed water pumps. Fine adjustment to maintain constant steam temperature at the outlet end of the generator is effected by interposing between the points 45 and 46 of the tube system a branch pipe 47 in which a temperature-regulating device, such as that illustrated in Figure 3, can be provided. Within the pipe 47 a second length of pipe 48 of some different material and of reduced cross-section, is so mounted that its end 49 is firmly secured to the pipe 47, as by means of the perforated plug 50, whilst its other end is secured to a sliding member 52. The pipes 47 and 48 are formed of different material, for example brass and iron having different coefficients of expansion, so that when the temperature of the working medium flowing through the pipe 48 and perforations 54 rises, the length of the pipe 48 will increase relatively to that of the pipe 47, and conversely, when the temperature of the working medium drops, the pipe 48 will be reduced in length, a sliding block 52 moves over the inner wall of the branch pipe 47 and when the pipe 48 is shortened, shuts off the branch outlet 53 but opens this branch if the pipe 48 increases in length relatively to the pipe 47.

The auxiliary feed pump 43 is driven by an engine supplied with steam through the branch 53 from the branch or by-pass pipe 47. When the temperature of the working medium in the branch pipe 47 rises, the engine 44 will therefore receive more steam, so that its speed will increase and consequently the pump 43 will deliver more feed liquid to the tube system. Similarly, when the temperature in the branch pipe 47 sinks, the number of revolutions of the pump 43 will fall so that a smaller additional quantity of feed liquid will be delivered to the tube system.

With the above arrangement, regulation to obtain steam at constant temperature at the outlet A is effected by varying the additional amount of feed liquid delivered by the pump 43 in accordance with the thermostatic devices 47, 48, 52, regulation to meet changes of load on the steam generator being produced by varying the main supply of feed liquid delivered by the pump 41 and the supply of fuel delivered by the fuel pump 40.

Regulation can also be effected by setting or adjusting the quantity delivered by the pump 41 for delivering the main feed water supply to suit a given load, for example, in accordance with the smallest load, whilst if fluctuations of load occur regulation will be effected by varying the additional supply of feed liquid.

The additional or auxiliary amount of feed liquid is introduced into the system of tubes at a point between the main inlet and the point where additional liquid is normally introduced, e. g. at the point 60, an additional pipe being provided for that purpose. Such an arrangement is quite accurate and gives quick regulation.

It will be understood that instead of depending on the temperature at the point 16 (Figure 2) where evaporation of the working medium has already been completed, an additional heat-responsive element may be introduced say at the point 16a (Figure 2) where the working medium is still liquid, it being essential that this additional temperature-responsive point should be in advance of the outlet where the temperature retardation has only a minor effect on the degree of regulation.

It will also be understood that the invention can be carried into practice without necessarily adopting any of the particular constructions above described, and that instead of the thermo-elements or thermostatic devices specified, any other known suitable device may be employed. The number of revolutions of the pumps may be used to regulate the quantity delivered, or the stroke or clearance, or by-pass or throttle valves may be used for this purpose.

The steam generator may be supplied with solid, pulverized, gaseous or liquid fuel, the regulation of which can be effected in any convenient manner, and any working medium which lends itself to evaporation may be used without departing from the invention.

This application is a division of my application for Steam generators of the water tube type, Serial No. 504,261, filed December 23, 1930.

I claim:

1. A steam generator, comprising at least one tube for the working medium, means for heating said tube, a pump for supplying fuel to said heating means, a pump for supplying working medium to said tube, the two pumps being driven by the same means, and a pump for supplying auxiliary working medium to said tube on occasion, and a single instrumentality for controlling, independently of vaporization zones, the speed of said auxiliary pump by the temperature, only, at that point in the tube system where under normal conditions the working medium first begins to change from saturated to superheated steam.

2. A steam generator, comprising at least one tube for the working medium, means for heating said tube, a pump for supplying fuel to said heating means, a pump for supplying working medium to said tube, and a pump for supplying auxiliary working medium to said tube on occasion, and means for regulating the speed of said auxiliary pump in accordance with the temperature at that point in the tube system where under normal conditions the working medium first begins to change from saturated to superheated steam, said main pump for supplying working medium to said tube being independent of conditions in the tube to deliver a constant quantity, and said auxiliary pump being connected to said tube to be varied by the temperature at said point in the length of the tube to automatically deliver a variable quantity to take care of the respective variations in the load on the generator.

3. A steam generator, comprising at least one tube for the working medium, means for heating said tube, a pump for supplying fuel to said heating means, a pump for supplying working medium to said tube, a pump for supplying auxiliary working medium to said tube on occasion, and means for regulating the speed of said auxiliary pump to effectuate fine adjustments in the tube, said means being actuated solely by the temperature at that point in the tube system where under normal conditions the working medium first begins to change from saturated to superheated steam and consisting of a heat-responsive device, adapted to maintain constant the temperature of the steam at the outlet end of the tube, extraordinarily large changes in the load on the generator being accommodated by varying the speed of the first two pumps.

4. A steam generator comprising at least one tube for the working medium, means for heating said tube, a pump for supplying fuel to said heating means, a pump for supplying working medium to said tube, a pump for supplying auxiliary working medium to said tube on occasion, the inlet thereof to said tube being located nearer the tube outlet than is the main inlet, the quantity of fluid fed being regulated by the speed of said auxiliary pump, said speed being regulated by the temperature at that point in the system where under normal conditions the working medium first begins to change from saturated to superheated steam.

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