Aug. 3, 1954 H. J. BLASKOWSKI 2,685,280

SUPERHEATER-REHEATER HEAT EXCHANGER

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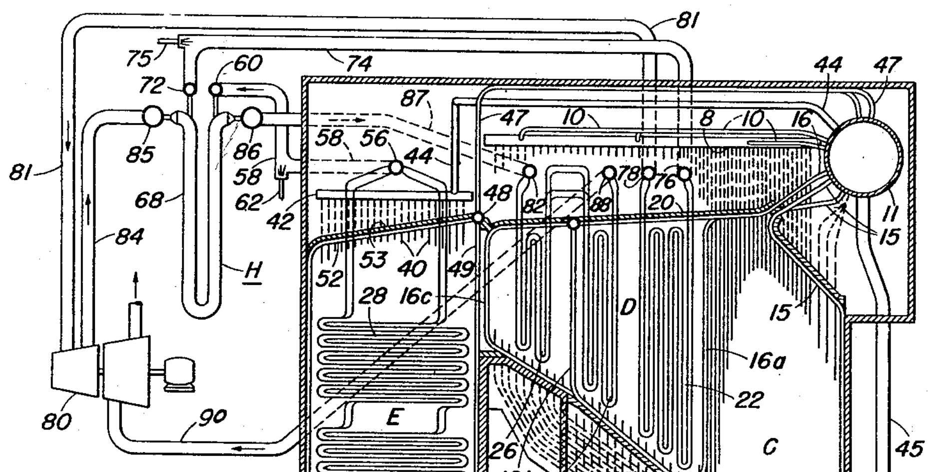

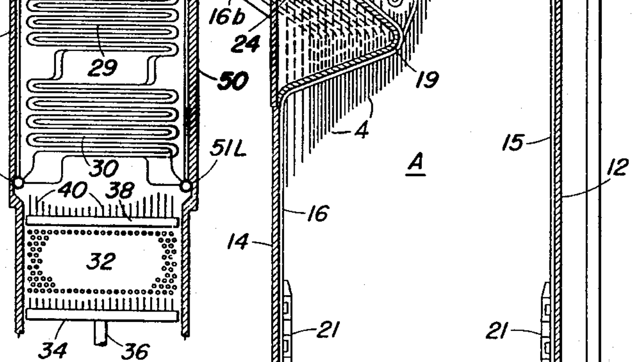

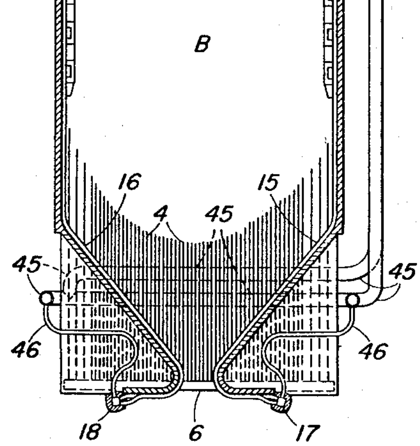

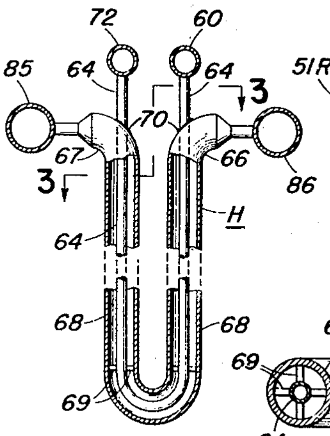

Fig. 2.

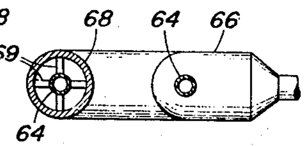

Fig. 3.

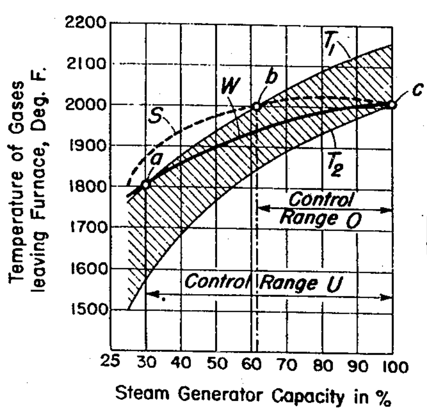

Fig. 4.

Fig. 1.

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SUPERHEATER-REHEATER HEAT EXCHANGER

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This invention relates to vapor power plants in which superheated vapor is generated. More specifically this invention deals with steam generators operating under the reheat cycle in which the superheated steam after having given up part of its energy is reheated in a reheater.

In the operation of modern high pressure, high temperature steam power plants it is essential that the temperature of the steam entering the steam turbine be held at a constant value over a wide range of load.

Moreover, in steam generating stations operating under the reheat cycle it becomes necessary to control not only the temperature of the superheated steam or primary steam but also the temperature of the reheated steam or secondary steam and to maintain these temperatures at a constant value over a wide range of load.

Furthermore in some cases it is desirable to obtain the same temperature for the superheated and the reheated steam or maintain a given relationship therebetween.

It is accordingly the main object of my invention to provide a superior and more efficient method whereby the temperatures of the primary or superheated steam and the secondary or reheated steam are held at constant values.

Another important object of my invention is to greatly extend the capacity range over which the primary and secondary steam temperatures can be controlled.

A further object of my invention is to increase the plant efficiency by eliminating spray type desuperheater devices in the secondary or reheat steam line.

Other objects and advantages of the invention will become apparent from the following description of illustrative embodiments thereof when taken in conjunction with the accompanying drawings wherein:

Fig. 1 is a diagrammatic representation of a power plant operating under the reheat cycle including a steam generator equipped with my inventive improvement.

Fig. 2 is an enlarged elevational view of the superheat-reheat heat exchanger of Fig. 1 with portions shown in section.

Fig. 3 is an enlarged horizontal cross section taken on line 3—3 of Fig. 2.

Fig. 4 is a plot showing graphically how my inventive improvement extends the steam temperature control range of a reheat boiler.

Referring now to Fig. 1, the reference character A indicates the furnace setting which provides a tall, straight chamber, generally rectangular in

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cross section. The lower portion of the space defined by this setting constitutes a fuel firing and combustion chamber B. The upper portion C receives the gaseous products of combustion generated in the combustion chamber B and discharges them into a horizontal furnace offtake D, whence the gases pass through vertical down flow duct E for ultimate delivery to the stack, not shown.

The side walls of the space defined by this setting A are lined with closely spaced, steam generating tubes 4, which rise from supply header 6, of which there is one at each side of the setting. These tubes 4 extend to the delivery header 8 and are subject to radiant and convection heat. Although only a portion of the side walls are shown as being lined with such tubes 4, it will be understood that the entire surface thereof is so lined and that the tubes constitute, in effect a substantially solid water wall. Delivery tubes 10 discharge the mixture of steam and water from the headers 8 into the steam and water drum 11.

The front and rear walls 12 and 14 are lined with tubes 15 and 16 respectively. These are closely spaced in the same manner as tubes 4. The sets of tubes 15 and 16 rise from the front and rear supply headers 17 and 18 respectively, located at the bottom portion of the combustion chamber B. Tubes 15 discharge a mixture of water and steam directly into drum 11.

Tubes 16 rise along the rear wall 14 of the furnace chamber, are bent upwardly and inwardly toward the furnace center, and then upwardly and outwardly to form a nose 19 projecting into the furnace proper. At the tip of the nose 19 some of the tubes 16 extend upwardly to form screen 16*a*, thence continue for a short distance along the roof 20 of the furnace chamber to discharge into drum 11. The remaining tubes line the sloping upper wall of nose 19. Some of these tubes form vertical tube screen 16*b* and others form vertical tube screen 16*c*. All extend upwardly to meet roof 20 of the gas offtake D, thence pass along that roof to discharge into drum 11.

Fuel and air for combustion are discharged into combustion chamber B through burners 21. In the embodiment herein shown, these burners are of the tangentially firing tilting type. The products of combustion pass upwardly through chamber C, thence horizontally through offtake D, thence downwardly through duct E.

Following the flow of gases there is suspended in gas offtake D the high temperature bank 22 of the primary superheater, the high temperature bank 24 of the reheater and the low temperature bank 26 of the reheater.

After leaving horizontal gas offtake D the combustion gases flow downwardly entering vertical pass E wherein is located the low temperature section of the primary superheater which in the illustrative embodiment shown comprises three tube banks 28, 29 and 30. At the lower end of vertical gas pass E there is installed an economizer section 32 which may be followed by other heat recovery surfaces such as an airheater before the gases are discharged into the stack.

In operation feed water from any convenient source enters header 34 through feed pipe 36, passes through economizer 32, thence into outlet header 38, thence through tubes 40 lining the side walls of downflow pass E. These tubes 40 discharge into header 42 located above the roof of downflow pass E. Discharge pipe 44 then delivers the heated feed water into drum 11. There it mixes with the water returned through furnace chamber wall tubes 10, 15 and 16. This water thereupon flows downwardly through pipes 45 passes by way of tubes 46 into headers 17, 18 and 6 and rises along the furnace walls upwardly through tubes 4, 15 and 16 while absorbing heat from the furnace chamber for the generation of steam as hereinbefore described.

As the steam and water mixture enters drum 11, the steam is separated from the water by well known means and passes through tubes 47 into header 48 located in the roof of horizontal gas offtake D. Two rows of steam delivering tubes lead from this header. One row in forming screen 49 passes downwardly to line the inner wall 50 of gas duct E. This row of tubes thereupon enters superheater inlet header 51L. The other row 42 leaves header 48 in a nearly horizontal direction to line the roof 53 and the outer wall 54 of downflow gas pass E before entering superheater inlet header 51R. Thus the steam from the drum 11 enters both inlet headers 51L and 51R to pass upwardly through low temperature superheater banks 30, 29 and 28. There the steam picks up a large portion of the superheat and thereupon discharges into an intermediate header 56 located above the roof of downflow pass E.

This header 56 is connected by way of pipe 58 to a horizontal header 60 which forms part of my inventively new superheat-reheat heat exchanger H. In pipe 58 there is located a desuperheating spray nozzle 62 for controlling the temperature of the superheated steam flowing from the low temperature superheater section 28 before it enters header 60.

Referring now to Fig. 2 which shows an enlarged elevational view of the heat exchanger H, a row of tubes 64 extend from header 60 downwardly into heat exchanger H. Each of these tubes 64 of relatively small diameter such as 2 inches, enters an elbow 66, passes lengthwise through a larger tube 68 of hairpin shape, and leaves through elbow 67. Substantial concentric relationship is established between each of tubes 64 and each tube 68 by placing of spacer member 69 as shown in Figs. 2 and 3. Although both tubes 64 and 68 are shown to form a loop of hairpin shape any desired form or shape can be used in practicing my invention. A pressure tight seal is maintained such as by welding at the points 70 where tube 64 passes through elbow 66 in entering and elbow 67 in leaving tube 68. An outlet header 72 is provided into which the steam is discharged and from which it passes by way of pipe 74 to the inlet header 76 of the high temperature superheater section 22. A second desuperheating spray nozzle 75 is installed in pipe 74 to afford control of the temperature of the steam entering section 22. There the steam is superheated to the desired temperature and passes into header 78 from where the steam is conducted to a steam turbine 80 by way of steam pipe 81.

Having given up some of its energy by passing through the high pressure stage of steam turbine 80 the steam is then returned to the steam generator to be reheated. For this purpose the steam is conducted to the inlet header 82 of the reheater section 26. In accordance with the invention, the reheat or secondary steam before it reaches header 82 passes first through heat exchanger H via pipe 84 which connects the turbine 80 with the inlet header 85. From header 85 the reheat steam flows through elbows 67, tubes 68, elbows 66 into outlet header 86. In the embodiment shown in Figs. 1 and 2 the diameter of one end of each elbow 67 and 66 is reduced to accommodate header 85 and header 86 respectively. The secondary steam by flowing through the heat exchanger by way of tubes 68 enters into a heat exchange relationship with the primary or superheated steam passing through the smaller tubes 64. More or less heat is picked up by the reheat steam depending on the temperature of the partially superheated steam flowing through tube 64. This temperature can be regulated by the amount of water injected into pipe 58 by way of spray nozzle 62. From header 68 the secondary or reheat steam proceeds through pipe 87 to reheater inlet header 82. Having been heated in reheater sections 26 and 24 to a predetermined desired temperature, the reheated steam thereupon leaves by way of outlet header 88 and is conducted through pipe 90 to an intermediate stage of turbine 80. After passage through the turbine the steam is exhausted in any conventional manner.

As earlier herein set forth the designers of reheat steam generating power plants are not only confronted with the problem of controlling the temperature of the primary or superheated steam over a wide range of load but they are also faced with regulating at the same time the temperature of the secondary or reheated steam. This task is especially made difficult since, in giving up heat to both the superheater as well as the reheater control of the volume or temperature of the combustion gases such as by tilting burners, gas recirculation or by gas by-passing effects both the heat transfer to the superheater as well as that to the reheater. Auxiliary devices such as desuperheater sprays must therefore be employed to lower the temperature of either the superheated steam or that of the reheated steam to obtain the steam temperatures desired.

It is a well known fact that, in the operation of reheat steam generating stations, the employment of a spray type desuperheater in connection with the reheated steam lowers the overall efficiency of the power plant. My invention as herein disclosed provides means whereby the use of a desuperheater apparatus in the reheat steam line is eliminated and semi-automatic heat exchange between the superheated steam and the reheat steam is provided. Furthermore, my invention extends the control range of both the superheated and reheated steam temperatures to a degree heretofore only possible with great sacrifice in plant economy.

In Fig. 4 there is shown a plot illustrating the conditions prevailing in the operation of a reheat-superheat steam generator.

Four curves are shown indicating the temperature of gases leaving the upper furnace portion C. They are plotted for various steam generator capacities extending over a load range of 25% to 100%. The steam generating unit for which these curves have been calculated has a maximum steam delivery capacity of approximately one million pounds of steam per hour at a temperature of 1000° F. Steam temperature control is mainly accomplished by means of tilting burners whereby the body of the burning gases is shifted vertically in the furnace chamber. The temperature of the gases leaving the furnace can thereby be raised or lowered within a range of approximately 150° F. This is indicated in Fig. 4 by the two curves of T1 and T2. The upper curve T1 represents furnace outlet gas temperatures obtained by tilting the burners upwardly as far as the tilting mechanism will allow. The lower curve T2 represents the combustion gas temperatures leaving the furnace obtained by tilting the burners downwardly to the maximum position. The area between curves T1 and T2, which is indicated by cross hatching, shows the range of control over the temperature of the gases leaving the furnace that will prevail by tilting the burners from the uppermost position to the lowermost position. This temperature range therefore is available to the designer for determining the heating surfaces of the superheater and of the reheater to attain the desired superheated and reheated steam temperatures of 1000° F.

Without the use of auxiliary steam temperature control equipment, positioning of the tilting burners in such a manner as to maintain a constant superheated steam temperature may result in a reheated steam temperature above or below the desired value. Or, on the other hand, if the tilting burners are positioned to maintain a constant reheated steam temperature, then the superheated steam temperature may be too high. A supplementary temperature controlling device is therefore necessary, such as a desuperheater in both the superheated steam line as well as in the reheat steam line. Employing a desuperheater for both the superheated steam as well as for the reheated steam and proportioning the heating surfaces of the superheater and the reheater in the most economical manner, the designer of the steam generator under discussion has arrived at curve S (see Fig. 4) as being the line of furnace outlet temperatures necessary to obtain 1000° F. superheated steam temperature and 1000° reheated steam temperature. Curve S intersects curve T1 at point *b* and curve T2 at point *c*. These two points *b* and *c* indicate the lower and the upper limits of the temperature control range O obtainable by tilting the burners upwardly or downwardly. It will be noted that this range O extends from 61% to 100% of the maximum capacity of the steam generator.

My invention provides for means whereby to extend the temperature control range a substantial amount. This I accomplish primarily by the use of the superheat-reheat heat exchanger H as hereinabove described. Applying my invention to the illustrative steam generator it is possible to maintain the desired steam temperature of 1000° F. for both the superheated or primary steam as well as the reheated or secondary steam from a high of 100% steaming capacity to a low of 30% steaming capacity. This is indicated by by curve W which intersects curve T1 at a point *a* and curve T2 at point *c*. A control range U from 30% to 100% is thereby established. This advance in control range is made possible by providing a controlled exchange of heat between the superheated steam and the reheat steam by means of heat exchanger H.

For instance, in the operation of a steam generator of the type herein considered and without the benefits of my inventive improvement, it has been found that at all loads, with the tilting burners adjusted to maintain a reheated steam temperature of 1000° F., the superheated steam temperature exceeds considerably the desired value. In such a case the superheated steam temperature must be lowered by means of a desuperheater. In order to maintain the efficiency of the steam generating unit at a reasonable level it becomes necessary to limit the amount of spray water discharged into the superheated steam line for desuperheating thereby limiting the range over which desuperheating is feasible. My invention makes a high degree of spray desuperheating unnecessary, since a large amount of the heat which heretofore has been taken out of the superheated steam by desuperheating now is being transferred to the reheated steam, where it is needed, by way of the herein disclosed heat exchanger H. It accordingly becomes economically practical to extend the control range considerably, such as to the control range U (see Fig. 4), without increasing the degree of desuperheating.

In the embodiment herein disclosed desuperheater spray nozzle **62** functions in controlling the temperature of the partially superheated steam leaving the low temperature superheated sections **28**, **29** and **30** before the steam enters heat exchanger H. By controlling the temperature of the primary steam in this manner the amount of heat which is absorbed by the secondary steam flowing through tubes **68** is also controlled. In some cases it may be more desirable to regulate the temperature of the primary steam being heated in sections **28**, **29** and **30** by providing a gas by-pass around this heating surface instead of desuperheater spray nozzle **62**.

Spray nozzle **75** located in the superheated steam line **74** serves to adjust the temperature of the superheated steam if this should become necessary. By placing the desuperheater nozzle **62**—indirectly controlling the temperature of the reheated steam as hereinabove described—in the superheated steam line **58**, I have eliminated the necessity of a spray desuperheater in the reheat steam line. A lowering of the overall power plant efficiency due to desuperheating the reheated steam is accordingly avoided. Although desuperheaters of the spray type have herein been shown in connection with the preferred embodiment of the invention, other types of desuperheaters such as the non-contact type may be used with comparable benefits in practicing my invention.

In order to control the operation of spray nozzles **62** and **75** or any other convenient type of desuperheater, any conventional control system may be utilized which is actuated by devices responsive to temperature fluctuations of the superheated steam or the reheated steam. Furthermore any conventional control system may be employed which combines the control of the tilting burners with the control of the cooling action of nozzles **62** and **75**, or that of other desuperheating means used instead.

My system of regulating the temperature of the superheated and of the reheated steam can be operated both manually or automatically. In addition, although in the illustrative embodiment herein described steam temperature control by tilting of burners has been used, other control means such as recirculation of gas or bypassing of gas may be employed in conjunction with my invention with comparably beneficial results.

While the illustrative embodiment of my invention has been here shown and described, it will be understood that changes in construction, combination and arrangement of parts may be made without departing from the spirit and scope of the invention as claimed.

I claim:

1. In a steam generating power plant operating under the reheat cycle and under variable load conditions, a steam generator comprising fuel burning means generating products of combustion, a superheater exposed to said products for superheating primary steam, a reheater exposed to said products for reheating secondary steam, a heat exchanger for exchanging heat between the primary steam and the secondary steam, the heat exchange capacity of said heat exchanger being such that the secondary steam receives heat from the primary steam without condensation of the latter, and means for controlling the temperature of the primary steam before entry thereof into said heat exchanger whereby indirectly to control the temperature of said reheated steam.

2. Apparatus as claimed in claim 1 in which said heat exchanger is further characterized by having a primary steam space and a secondary steam space, and in which said temperature control means comprise a conduit communicating with the inlet of said primary steam space and the outlet of said superheater, and a spraying device located in said conduit for spraying water into the primary steam to lower the temperature thereof whereby indirectly to control the temperature of said reheated steam.

3. In a steam heating plant operating under the reheat cycle and under variable load comprising fuel burning means generating products of combustion; a superheater exposed to said products for superheating primary steam and having an inlet for receiving and an outlet for discharging said primary steam to a first point of use; a reheater exposed to said products for reheating secondary steam and having an inlet for receiving steam from a steam source and an outlet for discharging said secondary steam to a second point of use; a heat exchanger having one compartment for flow of primary steam therethrough and having another compartment for flow of secondary steam therethrough, said one compartment and said other compartment organized for heat exchange between the said primary steam and the said secondary steam; the heat exchange capacity of said heat exchanger being such that the secondary steam receives heat from the primary steam without condensation of the latter; a first conduit connecting the outlet of said superheater with the inlet of said one compartment; a second conduit connecting the outlet of said one compartment with said first point of use; a third conduit connecting the inlet to the other or secondary steam compartment of said heat exchanger with said steam source; a fourth conduit connecting the outlet of said other compartment with the inlet of the aforesaid reheater; a fifth conduit connecting the outlet of said reheater with said second point of use; first means for controlling the temperature of said primary steam before entrance thereof into said heat exchanger whereby indirectly to regulate the temperature of said secondary steam flowing through said heat exchanger; and second means for controlling the temperature of said primary steam after exit thereof from said heat exchanger.

4. Apparatus as claimed in claim 3 in which said first means and said second means for controlling the temperature of said primary steam comprise a spray nozzle located in said first conduit and a spray nozzle located in said second conduit, respectively, for injecting cooling water into the stream of primary steam to lower the temperature thereof.

5. A method of controlling the temperatures of the primary steam and of the secondary steam in a steam generator operating under the reheat cycle, which comprises burning fuel at a given combustion rate for production of hot combustion gases; transferring heat from the combustion gases to the primary steam; regulating the temperature of the thus heated primary steam by cooling the said primary steam to a temperature still within the superheated steam temperature range by transfer of heat therefrom to the secondary steam; transferring additional heat from the combustion gases to the secondary steam; controlling the temperature of the secondary steam resulting from said additional heat transfer by regulating the heat absorbed from the combustion gases for said given combustion rate; and further regulating the final temperature of the primary steam by desuperheating.

6. The method of superheating primary vapor and reheating secondary vapor which comprises passing unsuperheated primary vapor from a vapor generating zone to a superheating zone, superheating the primary vapor in the superheating zone, controlling the heat absorbed by the primary vapor to control the temperature of the superheated primary vapor, passing the superheated primary vapor from the superheating zone to a cooling zone, cooling the superheated primary vapor in the cooling zone to a temperature still within the superheated steam temperature range by indirect contact with the secondary unreheated vapor thereby partially heating the secondary vapor in a first secondary vapor heating zone, passing the partially heated secondary vapor from the first heating zone to a second heating zone for final reheating, and controlling the heat absorbed by the secondary vapor in the reheating zone to thereby control the final temperature of the secondary vapor.

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