April 15, 1958 E. DURHAM 2,830,440

METHOD OF POWER GENERATION WITH DIVIDED GAS FLOW OVER A SUPERHEATER AND A REHEATER AND APPARATUS THEREFOR

Filed Nov. 29, 1951 4 Sheets-Sheet 1

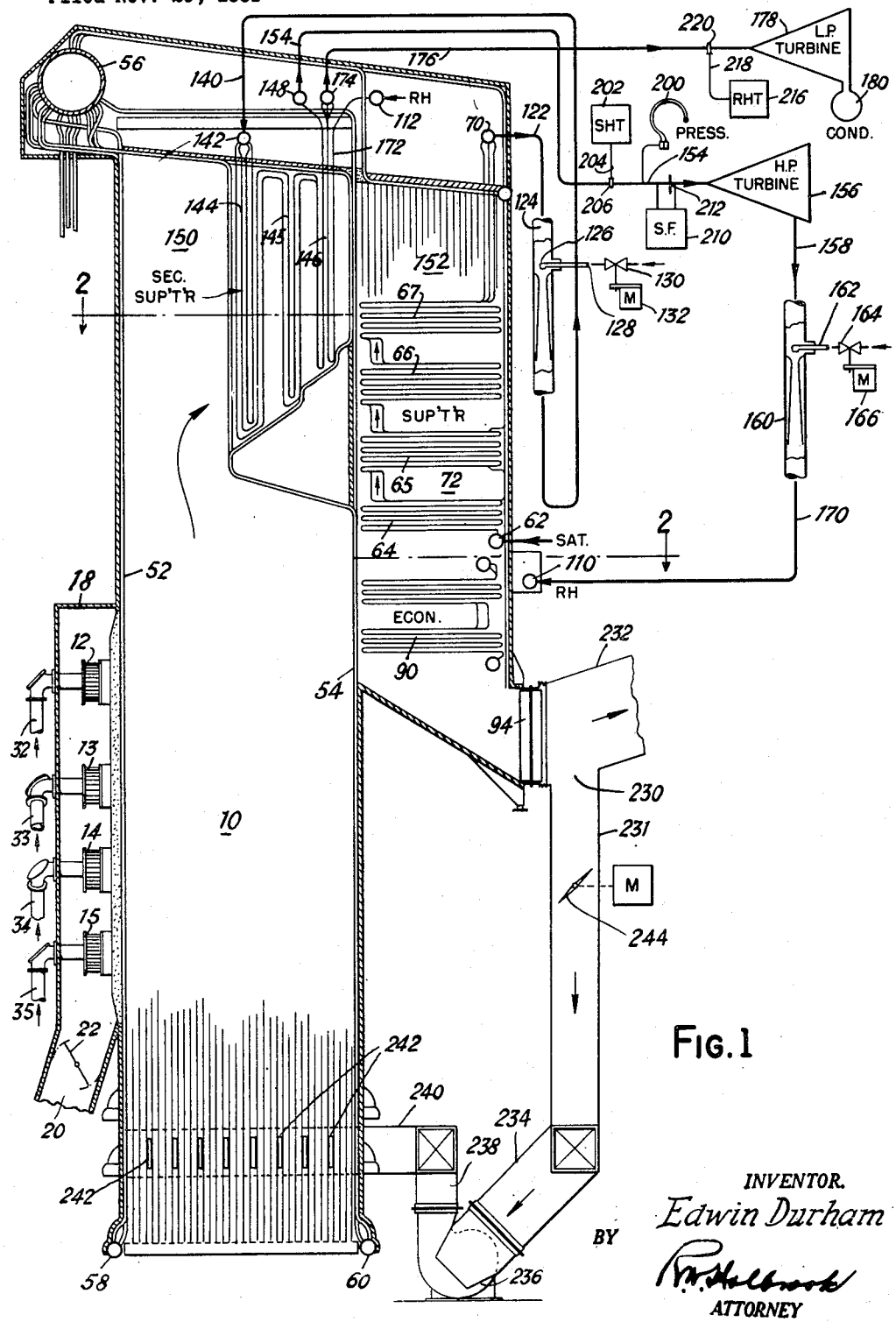


FIG. 1

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Filed Nov. 29, 1951 4 Sheets-Sheet 2

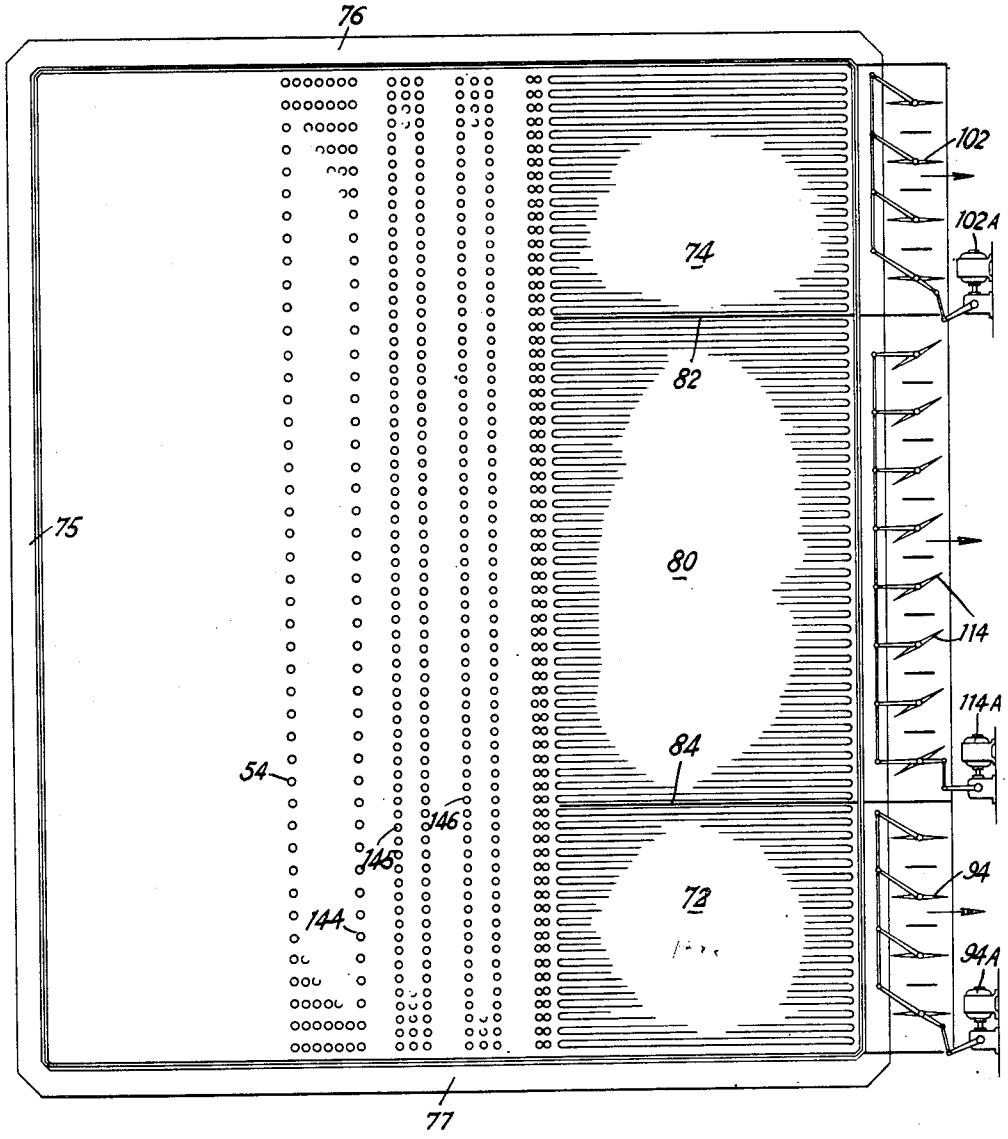


FIG.2

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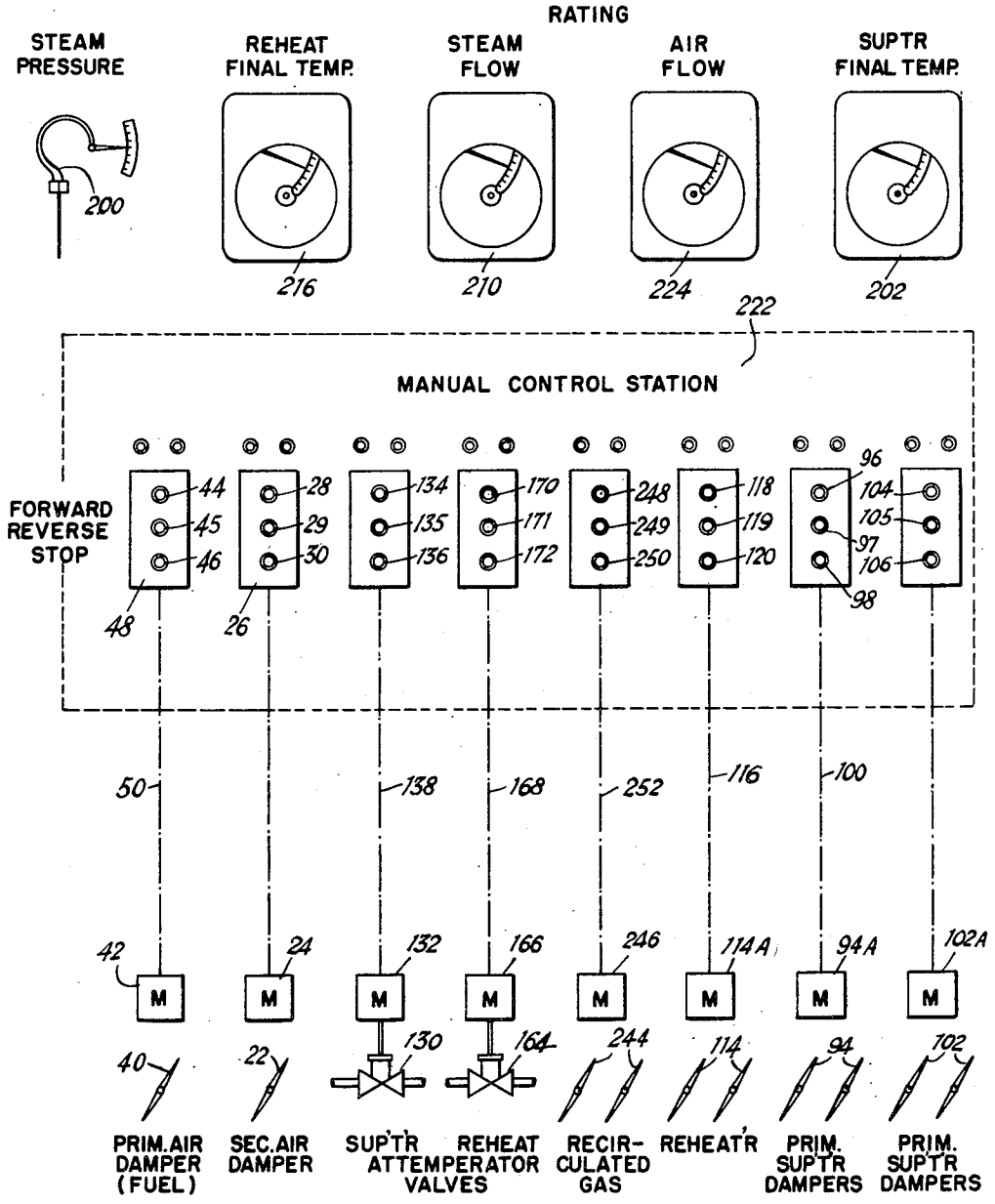


FIG. 3

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METHOD OF POWER GENERATION WITH DIVIDED GAS FLOW OVER A SUPERHEATER AND A REHEATER AND APPARATUS THEREFOR

Filed Nov. 29, 1951 4 Sheets-Sheet 4

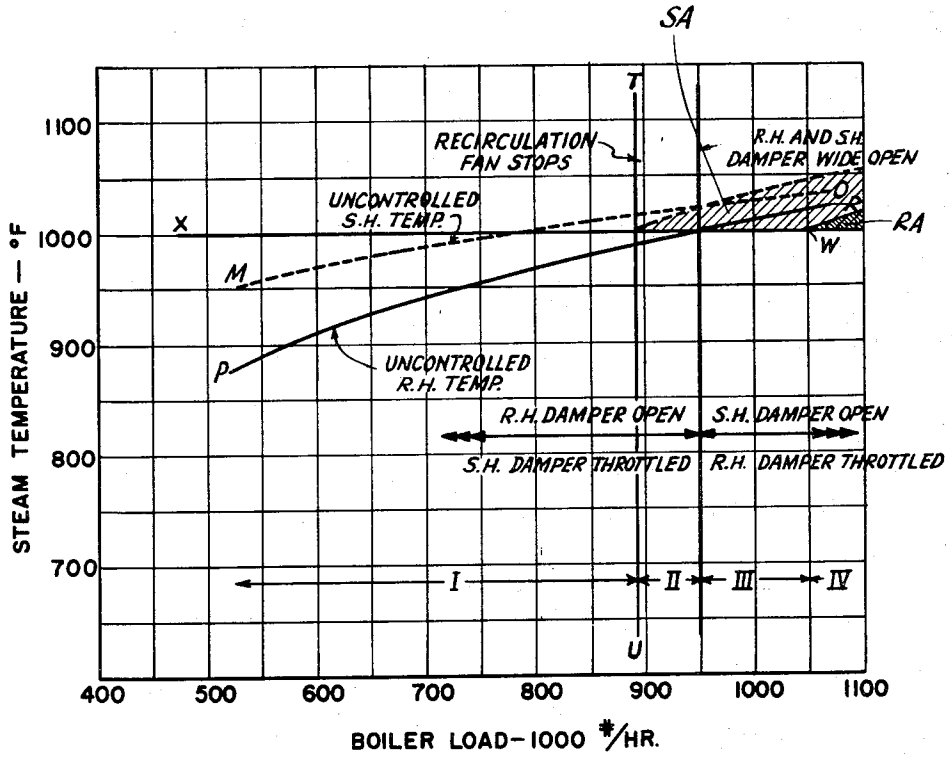


FIG. 4

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United States Patent Office 2,830,440 Patented Apr. 15, 1958

2,830,440

METHOD OF POWER GENERATION WITH DIVIDED GAS FLOW OVER A SUPERHEATER AND A REHEATER AND APPARATUS THEREFOR

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Application November 29, 1951, Serial No. 258,962

13 Claims. (Cl. 60—73)

This invention relates to a superheated steam generating unit in which high temperature heating gases generate and superheat high pressure steam for delivery to a steam turbine, through which it expands while doing useful work, and from which steam at a lowered pressure is returned to the unit for reheating to a high temperature.

More specifically, the invention involves the control of the temperature of the high pressure superheated vapor and the temperature of reheated vapor of a relatively low pressure by spray attemperation of one or both of the streams of superheated and reheated vapor, with concurrent regulation of the heating gas flow over the superheating and reheating heat transfer surfaces.

In the operation of high pressure steam generators delivering superheated steam to a high pressure steam turbine and reheating the relatively low pressure steam from the turbine exhaust for delivery to a low pressure condensing turbine it is advantageous to utilize convection heated steam superheaters and reheaters. However, the temperature-load characteristics of such heaters are such that as customarily designed a deficiency from the optimum vapor temperatures occurs in the lower load range, and some means is usually provided to avoid such a temperature deficiency. The delivery of an adequate hot gas stream to the convection superheater and reheater to attain the optimum steam temperatures therefrom may be effected by any one of several means, such as tilting burners, etc. As the load increases toward a control point load the need of additional gas flow over the superheater decreases until at the control point load, the steam temperature is at an optimum value.

At loads above the control point load, convection superheaters and reheaters naturally tend to effect too high a steam temperature, by absorbing too much heat. By-passing some of the gases about the superheater and/or reheater surfaces could be effected as a means for avoiding such excessive heat absorption. This, however, involves expensive and spacious structural provisions, and the provision of gas flow control dampers which are subject to operating difficulties. This type of correcting measure is also somewhat sluggish in its response to control variables.

Spray attemperation is preferable as a temperature corrective measure because of its simplicity of construction, ease of operation, and low pressure drop. It has, however, had the disadvantage that it had a tendency to effect a loss in overall steam turbine plant cycle efficiency because of the latent heat loss to the condenser of the vapor resulting from the reheat attemperator admixture without the advantage of expansion of that vapor through the high pressure turbine. This invention provides for the spray attemperation of steam, with the minimization, or avoidance of the use of reheater spray attemperation, while effecting optimum concurrent control of both the high pressure superheated steam temperatures and reheated steam temperatures.

The present invention provides for the absorption of heat by the superheater and by the reheater by placing them in separated controlled gas streams arranged for parallel flow. Spray attemperators are arranged in connection with both the superheater and the reheater. At a load where the heat carried by the gases going over the superheating and reheating surfaces is of such an amount as to result in an excessive absorption by the superheating and reheating surfaces, I regulate the gas flow over the reheater so that it will absorb just sufficient heat to bring the final temperature to the desired value. This will result in a gas flow in the other stream over the superheater surface which will raise the superheater absorption such that if uncontrolled it will give a delivered steam temperature in excess of the optimum, but I reduce this excess by spray attemperation in the superheater section.

Inasmuch as spray attemperation in the superheated steam stream does not result in a lowering of the thermal efficiency of the steam turbine plant, I thus attain steam temperature control of both the superheated steam and reheated steam wih unreduced steam turbine plant efficiency.

From an operating standpoint it is undesirable to create too wide an unbalance of gas flow through the reheater and superheater passes, particularly as an attempt to transmit too much heat to the superheater metal may result in its temperature becoming excessive, and it is therefore contemplated that, under some circumstances such as abnormal operating conditions, before maximum overload steam output is reached and for a narrow overload range some degree of spray attemperation may be carried on in connection with the reheater. As the overload range in the normal loading of a steam plant would be incurred infrequently, the effect on the overall plant economy will not amount to much.

The installation of a spray attemperator associated with the reheater with provision to automatically bring it into operation should the temperature become excessive in the reheater outlet, is advantageous from a safety standpoint in giving full protection against high temperatures which might otherwise damage the steam turbine.

Inasmuch as the pressure and heat content per pound of the low pressure steam returned to the reheater from the high pressure turbine exhaust decrease with reduction of load, while the pressure and heat content per pound of the high pressure steam introduced to the superheater remains substantially constant with a corresponding variation in load, the customary installation of convection heated superheater and reheater will give a steam temperature-load graph which will slope downward from maximum load to low load for the resultant delivery temperatures from both the superheater and the reheater, and the outlet temperature-load graph for the reheater will have a greater slope than the corresponding graph of the superheater.

Accordingly in the load range below the control point where gas recirculation is used as a means to raise the proportion of total heat remaining in the gases leaving the furnace, I utilize gas flow control dampers associated with parallel passes containing superheater and reheater surfaces for the purpose of directing an adequate proportion of gas through the reheater pass. This method of damper operation in the low load range below the control point is the reverse of that of the high load range, in that the reheater damper is open and the proportionate gas flow control is by the damper associated with the outlet of the superheater pass.

The invention will be described with reference to the accompanying drawings which diagrammatically illustrate the pertinent type of vapor generating unit and the equipment used in its control.

In the drawings:

Fig. 1 is a diagrammatic illustration of the pertinent vapor generating unit and the prime mover components of the power plant directly associated therewith;

Fig. 2 is a diagrammatic view partly in the nature of a horizontal section on the planes of the line 2—2 of Fig. 1;

Fig. 3 is a schematic illustration including indications of measuring instrumentalities and manually operable means associated with pertinent components applicable to the vapor generating units illustrated in Figs. 1 and 2; and

Fig. 4 is a graph indicating the illustrative mode of operation.

In the vapor generating unit indicated in Fig. 1, steam is generated in wall tubes defining the combustion chamber or furnace **10**. This furnace is fired by horizontal rows of burners **12—15** disposed within a wind-box **18** which is supplied with heated secondary air through a duct **20** controlled by the damper **22**. This damper is operable by a motor diagrammatically indicated at **24** in Fig. 3 as operatively connected with a push button plate **26** in which there are push buttons **28—30** for forward and reverse movements of the motor, and for stopping the motor.

The burners **12—15** are supplied with primary air and pulverized fuel through the conduits **32—35** leading from one or more pulverizers. The flow of primary air and fuel to the conduits **32—35** and thence to the burners **12—15** may be controlled by a damper **40** as indicated in the Fig. 3 schematic drawing, such damper being operated by an appropriate motor **42**, the control of which is effected through the forward, reverse, and stop push buttons **44—46** in the push button plate **48**, these push buttons being appropriately connected by operative lines **50** to the motor.

All walls of the furnace **10** include steam generating tubes such as the wall tubes **52** and **54** connected at their upper ends to the steam and water drum **56**, and at their lower ends to appropriate headers **58** and **60** respectively, the headers having appropriate downcomer connections with the water space of the drum **56**.

Saturated steam passes through appropriate connections from the drum **56** to the inlet header **62** of a primary superheater. This superheater includes series connected banks of return bend tubes **64—67** which are connected to the outlet header **70**. There are two primary superheater sections of this character. One section is disposed in gas pass **72** (Fig. 2), and the other section is disposed in the parallel gas pass **74**, these gas passes being symmetrically arranged with reference to the walls **75—77** of the unit, and also symmetrically arranged with reference to the upright reheater gas pass **80** disposed between the primary superheater gas passes **72** and **74**. A division wall **82** separates the gas passes **74** and **80** and a similar upright wall **84** separates the gas passes **72** and **80**. Beneath each primary superheater section is an economizer **90** and in the outlet of the gas pass **72** there are dampers **94** for control of gas flow, these dampers being operable by a motor **94A** which is subject to push button control from the push buttons **96—98**, having appropriate operative connections with the motor **94A**, as indicated by the line **100**.

Similarly, there are dampers **102** disposed in the outlet of gas pass **74** for the remaining primary superheater section, these dampers being operable by the motor **102A** and the push button controls **104—106**.

In the gas pass **80**, between the gas passes **72** and **74**, there is a convection reheater, including banks of tubes similar to **64—67**. These tubes have their inlets connected to the reheater inlet header **110**, their outlet ends being connected with the reheater outlet header **112**.

The control of gas flow over the reheater is effected by a series of dampers **114** disposed in a position similar to that of the dampers **94** shown in Fig. 1. The dampers **114** are schematically indicated in Fig. 2 as operatively connected to a motor **114A**. These elements are also indicated in the schematic illustration of Fig. 3, the motor being connected by operative lines such as **116** to the forward, reverse, and stop push buttons **118—120**.

Referring again to Fig. 1, steam flows from the primary superheater outlet header **70** through lines **122** to a direct contact or spray attemperator **124** preferably constructed and arranged as indicated in U. S. Patent 2,550,683, May 1, 1951. This attemperator includes a water spray nozzle **126** communicating with a spray water line **128** in which there is a valve **130** operable by a motor **132** through the forward, reverse, and stop push buttons **134—136** appropriately connected to the motor by operative lines such as **138** (Fig. 3).

Attemperated steam from the primary superheaters passes from the attemperator **124** through the line **140** to the inlet header **142** of a secondary superheater including the upright banks of tubes **144—146**, which have their outlet ends connected to the secondary superheater outlet header **148**. These banks of tubes extend entirely across the gas flow from the furnace outlet **150** at the top of the unit to the gas turning space **152** above the reheater and the primary superheater sections.

From the secondary superheater outlet header **148**, steam passes through the line **154** to the inlet of a high pressure turbine **156**. Here, the steam is expanded, in operating the turbine, and it passes from the last stage of the turbine through a line **158** to the reheater attemperator **160**. The spray water line **162** for this attemperator includes a valve **164** operated by a motor **166** controlled by appropriate lines **168** connected to the forward, reverse and stop push buttons **170—172** (Fig. 3).

From the reheater attemperator **160**, steam passes through the line **170** to the reheater inlet header **110**, thence through the tubes of the reheater to the intermediate reheater in pass **80**, header **112**, and thence through other reheater tubes **172** to the reheater outlet header **174**. From this header the steam passes through the line **176** to the inlet of the low pressure turbine **178** which is operatively associated with the condenser **180**. It is to be noted that the heating gases from the furnace **10** pass over the secondary or high temperature superheater including the sections **144—146** in a single and undivided gas pass. Relative to gas flow, the zone of the secondary superheater may be considered as the first superheating zone in spite of the fact that this superheater receives superheated steam through the line **140** from the sections of the primary superheater in the gas passes **72** and **74**.

The manual control station indicated in Fig. 3 is preferably so disposed that the various measuring instrumentalties are visible to the operator from that position. Such instrumentalities include a steam pressure measuring device **200** which, as indicated in Fig. 1 of the drawings, is connected with the steam line **154** conducting superheated steam to the inlet of the high pressure turbine **156**.

Another such measuring instrumentality is the temperature indicator **202** for the final superheat temperature. Such an instrumentality is indicated in Fig. 1 as connected by a line **204** to a temperature responsive element **206** in the steam line **154** leading to the high pressure turbine **156**.

Another instrumentality is the steam flow measuring device **210** which has tubular communications with the steam line **154** on opposite sides of an orifice **212** for utilizing the pressure difference on opposite sides of the orifice as an indication of steam flow.

Final reheat temperature is indicated by the temperature measuring device **216** connected by a line **218** to a temperature responsive element **220** in the reheater steam line **176** leading from the header **174** to the low pressure turbine **178**.

The measuring instrumentalities visible from a control station **222** also includes an air-flow measuring device

224 appropriately connected to measure the total air flow into the furnace 10 (recirculated gas flow not included).

The flow of secondary air is regulated by the push button control (28, 29 and 30) of the secondary air damper 22, for a given steam flow, providing the desired ratio of fuel and air for desired combustion efficiency. Fuel flow is controlled by the operation of damper 40 by the motor 42, effected by push buttons 44—46.

Operation of the illustrative unit is described with reference to a control point load. The control point load considered with respect to steam temperatures for a multiple gas pass unit as exemplified, might be defined as that load at which the gas flow from the furnace, when the fuel burning equipment is operated at optimum efficiency, has the correct total heat content to provide for superheating of the high pressure steam and reheating of the low pressure steam to the optimum predetermined temperatures, there being no operative steps, such as gas recirculation, taken to modify the amount of heat absorption in the furnace. In a multiple pass unit the gas flowing from the furnace is so divided between the passes at the control point load operating rate that the optimum temperature of the superheat and reheat is attained. At loads between this control point load and a predetermined minimum load, the invention involves an increase in the heat content of the gases for maintaining the final superheat temperature, and this reference is to gases which first pass over the secondary superheater and then over both sections of the primary superheater. This increase in heat content is effected by a recirculating gas system extracting heating gas from an opening 230 in the flue 232 leading from the outlet of the gas passes 72, 74 and 80. This system includes the upright duct 231 and associated ductwork 234 connected with the inlet of a fan 236. The outlet of this fan is connected by ductwork 238 and 240 to a series of openings 242 in one or more walls of the furnace 10 and near the bottom of the furnace.

The damper 244 in the upright duct 230 is in a wide open position at a predetermined minimum load, and as the load increases from that point to the control point, the damper 244 is gradually closed by the operation of the motor 246, controlled by the forward, reverse, and stop push buttons 248—250 which are operatively connected to the motor 246 by appropriate lines such as 252. The control of the damper 244 is effected from indications of the final superheat temperature afforded by the instrumentality 202.

As has been above indicated, the heat content of the gases through the superheater is increased by the gas recirculation system in a lower load range. It has also been indicated that the flow of recirculated gases is controlled from the indication of final superheat temperature. This action takes place from a minimum load of the order of 500,000 lbs. of steam per hr. to the recirculation limiting control point, as indicated by line TU in Fig. 4. During this part of the operation, the reheater dampers 114 are wide open, and the primary superheater dampers 94 and 102 are operated concurrently with the regulation of recirculated gas rear damper 244 by the pertinent control elements from a visual indication of the reheat final temperature as indicated by the instrumentality 216. When a point corresponding to the reheater design point (say 950,000 load) is reached, the superheater dampers are wide open and they remain wide open in the load range above or beyond that point.

Above the control point indicated in Fig. 4 by the line TU, superheated steam is attemperated by the spray attemperator 124 to keep the superheated steam temperature at the predetermined value. To accomplish this, the operator observes the final steam temperature as indicated by the instrumentality 202 and accordingly operates the push buttons 134—136 to position the spray water valve 130 to regulate water flow to an amount required to limit the final steam temperature to the desired value.

Through the upper load range (above the reheater design point), the reheater dampers 114 are throttled by the operator by his manual operation of elements 118—120 according to the visual indications of reheat final temperature by the instrumentality 216. Thus, no water for spray attemperation of reheat is required from the control point to a point W which is approximately a load value of the order of 1,050,000 lbs. of steam per hr. Above this load, and in the overload to 1,100,000 lbs. of steam per hr., it may be necessary to use spray water for reheat attemperation depending upon the extent to which it is considered desirable to limit the heat input into the superheater relative to reheater when considering various factors of which superheater metal temperature, superheater steam pressure drop, superheater draft loss, may be mentioned. When some such factor limits the load at which all the attemperation is superheat attemperation then reheat attemperation is initiated for overload conditions. Although a considerable amount of spray water has been used for superheat attemperation between the control point (the line TU) and the point W, such use for superheat attemperation has no such detrimental effect upon the thermodynamic efficiency of the system as would the use of a similar amount of spray water for reheat attemperation.

In the graph of Fig. 4, the line XW from a load value of 550,000 lbs. of steam per hr. to 1,050,000 lbs. of steam per hr. represents the control of steam temperature over that range. The curve MO represents the uncontrolled superheat temperature which would have obtained (with heat absorbing surfaces involved) without the use of the invention, and the line PR represents the uncontrolled reheat temperature which would have obtained without the use of the invention.

The shaded area designated SA (which is inclusive of RA) illustrates the extent of the load range through which superheat attemperation is effected, with the ordinates above line XW indicating the increase in amount of such spray attemperation with increase of load.

The smaller shaded area RA illustrates the extent of the "overload" range through which reheater attemperation is effected and the ordinates above the level of line XW indicate the increase in the amount of spray water so used.

It will be noted that area RA is relatively small as compared to SA and whatever use of spray water in the overload range is necessary will be of minor importance as regards the overall thermal efficiency of the plant which will usually operate below the 1,050,000 lbs. per hour load.

In the contemplated operation of the unit and apparatus exemplified through several phases, each involving a different load range, the following takes place with an increase in load from minimum to maximum.

In phase I, gas recirculation is at its maximum rate and the degree of the superheater pass throttling is greatest at low load, the reheater gas pass being unrestricted. As the load is increased through phase I to the start of phase II, the gas recirculation is reduced to zero, and the throttling of the superheater gas pass is reduced so that when phase II is entered the superheater is still throttled to some extent and the reheater pass is unrestricted. The control point load lies between phases I and II.

In phase II, the reheater gas pass is continued in an unrestricted condition through this phase with further reduction in the restriction of gas flow in the superheater pass and with concurrent introduction and progressive increase in spray attemperation of superheated steam.

There is no restriction to gas flow in the superheater pass in phase III, but the reheater gas pass is progressively restricted and attemperation of the superheater is progressively increased with increases in load.

In phase IV, the overload range, the superheater gas pass is unrestricted, restriction of the gas flow in the reheater gas pass is continued the same as the termination of phase III, while attemperation is progressively increased in the superheater and attemperation of reheated steam is initiated and progressively increased. This is effected by the operation of the push buttons **170—172** (Fig. 3) by the operator, from indications of reheat temperature by the instrumentality **216**.

Whereas in accordance with the revised statutes the invention has been described with reference to certain preferred embodiments; it is to be appreciated that the invention is not limited to all of the details thereof, but that it is rather of a scope corresponding to the scope of the subjoined claims.

I claim:

1. The method of operating a unit generating high pressure steam over a wide load range and having a convection steam superheater and a convection steam reheater disposed respectively in separate and parallel flows of high temperature heating gases; the method including the controlled variation of the heat availability of the heating gases passing through the reheating and superheating zones over a lower part of the controllable load range, limiting by spray attemperation the superheat and reheat temperatures over the upper portion of the controllable load range, and proportioning the total heating as flow between the superheating and reheating zones by variably restricting gas flow through the superheating zone while allowing relatively unrestricted gas flow through the reheating zone through a lower portion of the controllable load range and the variably restricting gas flow through the reheating zone while allowing relatively unrestricted gas flow through the superheating zone during increasing load over the upper portion of the controllable load range whereby reheat temperature is maintained at a predetermined value and spray attemperation predominantly limited to superheat attemperation.

2. The method of operating a unit generating high pressure steam over a wide load range and having a convection steam superheater and a convection steam reheater disposed respectively in separate and parallel flows of high temperature heating gases; the method including the controlled variation of the heat availabililty of the heating gases passing through the reheating and superheating zones over a lower part of the controllable load range, said controlled variation including the withdrawal of heating gases from a position beyond a steam heater and introducing the withdrawn gases into the heating gases before they pass to the reheater and superheater zones, limiting by spray attemperation the superheat and reheat temperatures over the upper portion of the controllable load range, and proportioning the total heating gas flow between the superheating and reheating zones by variably restricting gas flow through the superheating zone while allowing relatively unrestricted gas flow through the reheating zone through a lower portion of the controllable load range and then variably restricting gas flow through the reheating zone while allowing relatively unobstructed gas flow through the superheating zone during increasing load over the upper portion of the controllable load range whereby reheat temperature is maintained at a predetermined value and spray attemperation predominantly limited to superheat attemperation.

3. The method of operating a vapor generating unit having a convection reheater and a convection superheater disposed respectively in divided and separate gas flow paths from the same furnace, the reheater and superheater being subject to such different operative thermal variables that their load range curves have different degrees of slope; the method comprising increasing the heat availability in the gases passing over the superheater and the reheater to maintain superheat and reheat steam temperatures at predetermined values as the load decreases over a load range below a predetermined load constituting a control point, controlling said variation in heat availability in the gases from superheat temperature, regulating superheat and reheat by spray attemperation above the control point, and proportioning total gas flow between the gas flow paths over the reheater and the superheater by progressively decreasing the gas flow over the reheater as the load increases over most of the attemperation load range to maintain reheat at a predetermined value and to closely approach the limiting of spray attemperation to superheat rather than reheat.

4. In a vapor generating unit having a convection superheater and a convection reheater disposed in separate damper controlled gas passes arranged in parallel, a furnace, a damper controlled furnace gas recirculating system with an outlet into the furnace and an inlet beyond the gas inlet of the superheater, a first attemperator for the superheated steam, and a second attemperator for the reheated steam, the method of controlling superheat and reheat temperatures which comprises decreasing the flow of recirculated furnace gases to the furnace to maintain a predetermined superheat temperature as the load increases from a predetermined minimum load until the recirculation of gases is discontinued at a higher load selected as the control point, said decreasing of gas recirculation being effected in accordance with indications of superheat, spray attemperating both superheated steam and reheated steam in load ranges above the control point, said spray attemperation being controlled in accordance with indications of superheat and reheat temperatures, and proportioning the division of gas flow between the reheater and superheater passes to maintain a predetermined reheat temperature below the control point and progressively reduce gas flow over the reheater and thereby minimize reheat attemperation above the control point.

5. In a method of power generation including the expansion of a high pressure vapor in multiple stages, generating high temperature furnace gases, effecting heat transfer between such gases and a vaporizable liquid to generate high pressure vapor, superheating the generated vapor in a convection superheating zone adjacent the zone of vapor generation, dividing the flow of high temperature furnace gases from said superheating zone, reheating a part of the generated vapor returned from an intermediate stage of the vapor expansion by effecting convection heat transfer thereto from the gases in one of said gas divisions, utilizing the remaining gas division for superheating generated steam before that steam passes to the first superheating zone, measuring or determining reheat and superheat temperatures over a wide load range, increasing the heat availability of the gases passing through the first superheating zone, said increasing of the heat availability being effected over a lower load range and controlled from indications of superheated steam temperature over that load range, regulating the degree of final superheat and reheat temperature above a predetermined control point in the load range by direct contact attemperation and thereby limiting superheat and reheat temperatures to predetermined values, said regulating of superheat and reheat temperatures being effected from the measured indications of superheat and reheat, and proportioning the gas flow in said divisions in accordance with the measured indications of reheat, said proportioning being effected both above and below the control point as to substantially reduce in amount the gas division passing through said reheating zone and cause the predominating part of said temperature regulating by direct contact attemperation to be effective only upon superheat.

6. The method of operating a vapor generating unit having a convection reheater and a convection superheater disposed respectively in separate gas passes leading from the same furnace, the reheater and superheater being subject to such different operative thermal variables

that their load range curves have different degrees of slope; the method comprising the recirculating of furnace gases to increase superheat and reheat temperatures at at least to a predetermined value or values over a load range below a predetermined load constituting a control point, increasing and decreasing the amount of gas recirculation as the superheat temperature tends to decrease and increase respectively, regulating superheat and reheat by spray attemperation in load ranges above the control point, and proportioning total gas flow between the gas passes over the reheater and the superheater over a load range overlapping both the gas recirculation and attemperation ranges to maintain reheat at a predetermined value and to closely approach the limiting of spray attemperation to superheat rather than reheat.

7. The method of operating a vapor generating unit having a convection reheater and a convection superheater disposed respectively in separate parallel gas flow paths leading from the same part of the same furnace, the reheater and superheater being subject to such different operative thermal variables that their load range curves have different degrees of slope; the method comprising the recirculating of furnace gases over a load range below a predetermined load constituting a control point, increasing and decreasing the amount of gas recirculation as the superheat temperature tends to decrease and increase respectively, regulating superheat and reheat by spray attemperation in the load range above the control point, and proportioning total gas flow between the gas flow paths over the reheater and the superheater over a load range overlapping both the gas recirculation and attemperation ranges to maintain reheat temperature at a predetermined value and to closely approach the limiting of spray attemperation to superheat rather than reheat.

8. In a vapor generating unit having a furnace, a convection superheater and a convection reheater disposed in separate damper controlled gas passes arranged in parallel as to gas flow from the furnace, a furnace gas recirculaing system with an outlet into the furnace and an inlet beyond the gas inlet of the superheater, a first spray attemperator for the superheated steam, and a second spray attemperator for the reheated steam, the method of controlling superheat and reheat temperatures which comprises decreasing the flow of recirculated furnace gases to the furnace to maintain a predetermined superheat temperature as the load increases from a predetermined minimum load until the recirculation of gases is discontinued at a higher load selected as the control point, said decreasing of gas recirculation being effected in accordance with indications of superheat, spray attemperating both high and low pressure steam above the control point, said spray attemperation being controlled in accordance with steam temperature indications, and proportioning the division of gas flow between the reheater and superheater passes to maintain a predetermined reheat temperature below the control point and to reduce gas flow over the reheater and thereby minimize reheat spray attemperation above the control point.

9. In a method of power generation including the expansion of a high pressure vapor in multiple stages, generating high temperature furnace gases, effecting heat transfer between such gases and a vaporizable liquid to generate high pressure vapor, superheating the generated vapor in a first convection superheating zone adjacent the zone of vapor generation, dividing the flow of high temperature furnace gases from said superheating zone into different gas passes, reheating a part of the generated vapor returned from an intermediate stage of the vapor expansion by effecting convection heat transfer thereto from the gases in one of said gas passes, utilizing the remaining gas pass for superheating generated steam on its way to the first superheating zone, continuously measuring or determining reheat and superheat temperatures over a wide load range, increasing the heat availability of the gases passing to the superheating and reheating zones, said increasing of the heat availability being effected over a lower load range and controlled from indications of superheated steam temperature over that load range, regulating the degree of final superheat and reheat temperature above a predetermined control point in the load range by direct contact attemperation and thereby limiting superheat and reheat temperatures to predetermined values, said attemperation regulating of superheat and reheat temperatures being effected from the measured indications of superheat and reheat, and proportioning the gas flow in said divisions in accordance with the measured indications of reheat temperature, said proportioning being effected both above and below the control point in the load range and also being so effected above that control point as to substantially reduce in amount the gas division passing through said reheating zone and cause the predominating part of said attemperation to be effective only upon superheat.

10. In a method of power generation including the expansion of high pressure steam in multiple stages; generating high temperature furnace gases; transmitting heat from the furnace gases to generate high pressure steam; superheating the generated steam in a first convection superheating zone adjacent the zone of steam generation; dividing the flow of high temperature furnace gases from said superheating zone into different gas passes; reheating a part of the generated steam returned from an intermediate stage of the expansion by effecting convection heat transfer thereto from the gases in one of said gas passes, utilizing the remaining gas pass for superheating the generated steam on its way to said first superheating zone; continuously measuring or determining load, reheat temperature, and superheat temperatures over a wide load range; varying or controlling the heat availability of the gases passing to the first superheating zone and the gas passes; said variation of the heat availability being effected over a lower part of the load range and controlled from indications of superheated steam temperature; the changes in said heat availability having a reverse relation to load changes; regulating superheat and reheat temperatures to predetermined values above a predetermined control point in the load range by limiting superheat and reheat temperatures by spray attemperation; said regulating of superheat and reheat temperatures being effected from the measured indications of superheat and reheat; and proportioning the gas flow between said gas passes in accordance with the measured indications of reheat temperature; said proportioning being so effected above the control point load as to substantially reduce in amount the gas flow passing through the reheater gas pass and cause the predominating part of said spray attemperation to be effective only upon superheat.

11. In a method of power generation including the expansion of high pressure steam in multiple stages; generating high temperature furnace gases; transmitting heat from substantially all of such gases to generate high pressure steam; superheating the generated steam in a first convection superheating zone adjacent the zone of steam generation; said superheating being effected by heat transfer from the furnace gases in a single unitary gas pass; dividing the flow of high temperature furnace gases from said superheating zone into a plurality of parallel gas passes; reheating a part of the generated steam returned from an intermediate stage of the expansion by effecting convection heat transfer thereto from the gases in one of said gas passes, utilizing the remaining gas pass for superheating the generated steam before that steam passes to the first superheating zone; continuously measuring or determining reheat and superheat temperatures over a wide load range; increasing the heat availability of the gases passing to the first superheating zone; said increasing of the heat availability being effected by gas recirculation over a lower load range and controlled from indi-

cations of superheated steam temperature over that load range; regulating superheat and reheat temperatures to predetermined values above a predetermined control point in the load range by limiting superheat and reheat temperatures by spray attemperation; said regulating of superheat and reheat temperatures being effected from the measured indications of superheat and reheat temperature; and proportioning the gas flow between said gas passes in accordance with the measured indications of reheat temperature; said proportioning being so effected above the control point as to substantially reduce in amount the gas flow passing through the reheater gas pass and cause the predominating part of said spray attemperation to be effective only upon superheat.

12. In a high pressure steam generating and superheating unit having a fluid cooled furnace and fuel burning means therein for generating high temperature heating gases, means defining a convection steam superheater zone and a convection steam reheater zone in separate damper controlled heating gas passes arranged in parallel to receive separate streams of heating gases flowing from the furnace, a spray attemperator associated with the convection steam superheater, and a gas recirculating system for drawing gases from beyond the outlet of said gas passes and returning the gases to the furnace; the method of concurrently controlling the temperature of delivered high pressure superheated steam and reheated steam throughout a relatively wide load range of said unit which comprises generating steam by radiant transmission of heat from the burning fuel and gaseous products of combustion, directing the gases in convection heat transmission relation with steam streams in the reheating and superheating zones to reheat and superheat the respective steam streams, over a lower part of the load range recirculating cooled gas from beyond the superheating and reheating zones to the furnace to effect a regulation of the ratio of heat radiantly transmitted by the burning fuel for steam generation to the heat remaining in the products of combustion leaving the furnace, increasing and decreasing the amount of gas recirculation as the superheat temperature tends to decrease and increase respectively, simultaneously proportioning the gas flow between the separated streams by restricting the flow through the superheater zone only to effect an increase in the temperature of the delivered reheated steam to a predetermined degree; and for upper load rates of steam delivery, restricting the gas flow through the reheating zone only in accordance with indications of temperature of the reheated steam stream while permitting unrestricted gas flow through the superheating zone, and spray attemperating the superheated steam stream flowing through the superheating zone to regulate the final temperature of superheated steam.

13. The method of operating a vapor generating unit having a convection superheater and a convection reheater disposed respectively in divided and separate parallel gas flow paths from the same combustion zone, the superheater and reheater having uncontrolled load-temperature characteristic curves with different degrees of slope, which comprises increasing the heat availability of the heating gases passing over the superheater and reheater to increase superheat and reheat temperatures toward a predetermined value over that portion of the controllable load range below the control point load, limiting superheat and reheat temperatures by spray attemperation over that portion of the controllable load range above the control point load, and proportioning total heating gas flow between the parallel paths by variably restricting gas flow over the superheater gas flow path while allowing unrestricted gas flow over the other path through a lower portion of the controllable load range and variably restricting gas flow over the reheater gas flow path while allowing unrestricted gas flow over the superheater gas flow path during increasing load over the remaining upper portion of the controllable load range.

References Cited in the file of this patent

UNITED STATES PATENTS

1,751,004	Kemnal	Mar. 18, 1930
2,229,643	De Baufre	Jan. 28, 1941
2,357,300	Bailey	Sept. 5, 1944
2,416,674	Bailey	Mar. 4, 1947
2,550,683	Fletcher et al.	May 1, 1951
2,579,027	Walter et al.	Dec. 18, 1951
2,590,712	Lacerenza	Mar. 25, 1952
2,628,598	Van Brunt	Feb. 17, 1953
2,649,079	Van Brunt	Aug. 18, 1953

FOREIGN PATENTS

112,287	Australia	Jan. 16, 1941
371,985	Italy	June 12, 1939
481,398	Great Britain	Mar. 10, 1938
504,114	Great Britain	Apr. 14, 1939

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,830,440 April 15, 1958

Edwin Durham

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 11, after "overload" insert -- range --; column 7, line 3, after "as" insert -- at --; column 8, line 66, after "point" insert -- in the load range and also being so effected above that control point --.

Signed and sealed this 12th day of August 1958.

(SEAL)
Attest:
KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents