Oct. 21, 1958 P. H. KOCH 2,856,908

VAPOR GENERATING AND SUPERHEATING UNIT
WITH RECYCLED GAS FLOW

Filed March 27, 1953 3 Sheets-Sheet 1

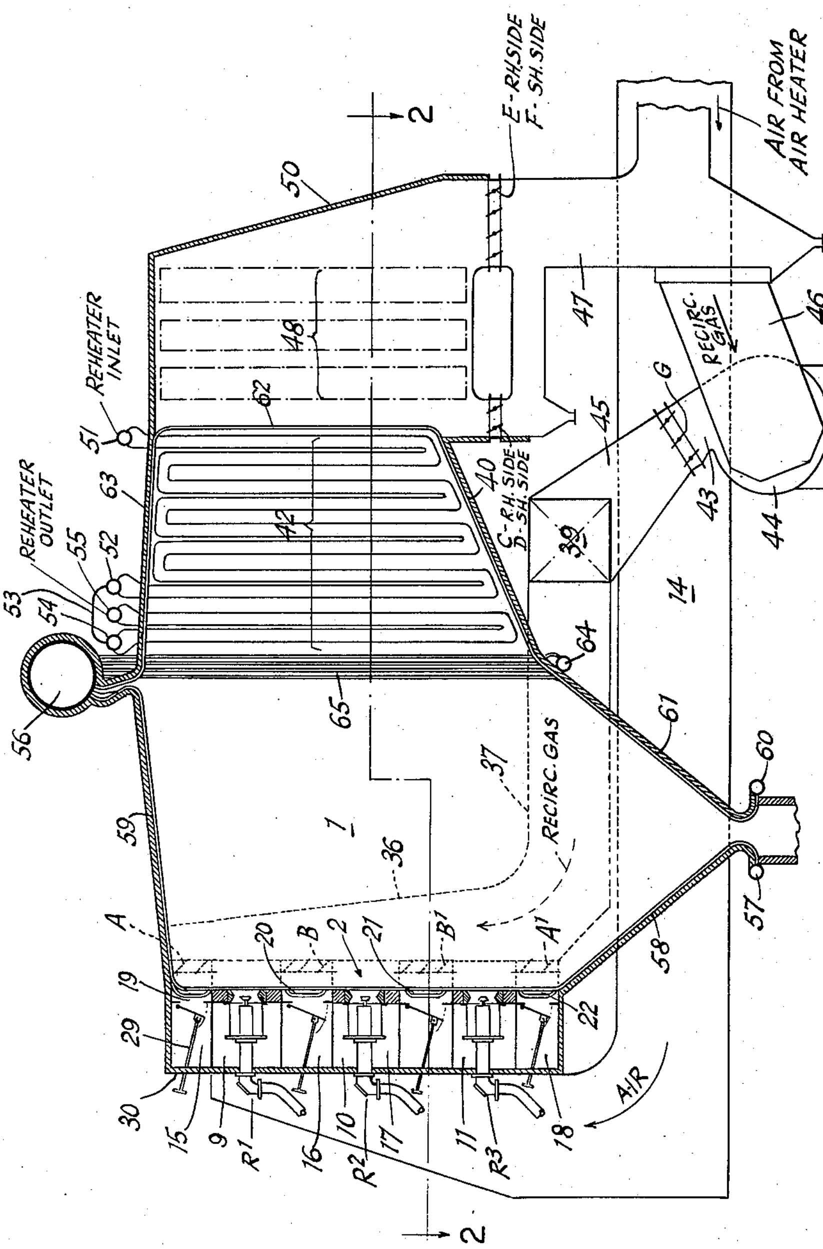

FIG. 1

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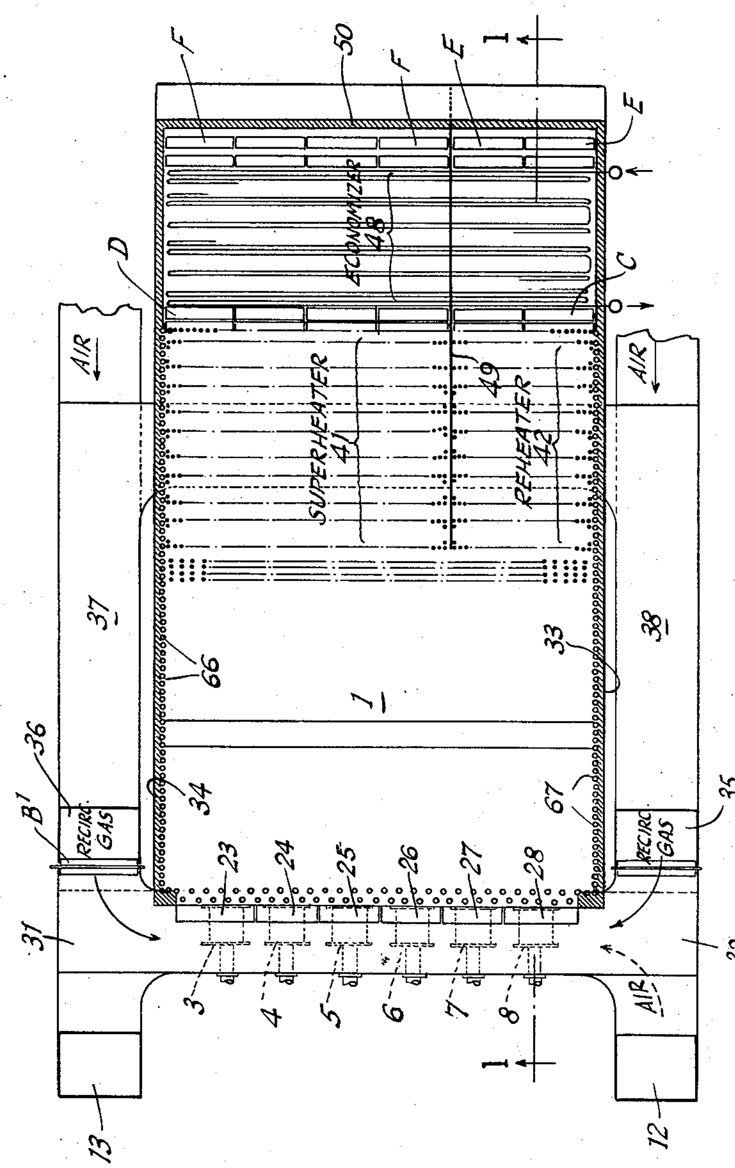

FIG. 2

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VAPOR GENERATING AND SUPERHEATING UNIT WITH RECYCLED GAS FLOW

Filed March 27, 1953 3 Sheets-Sheet 3

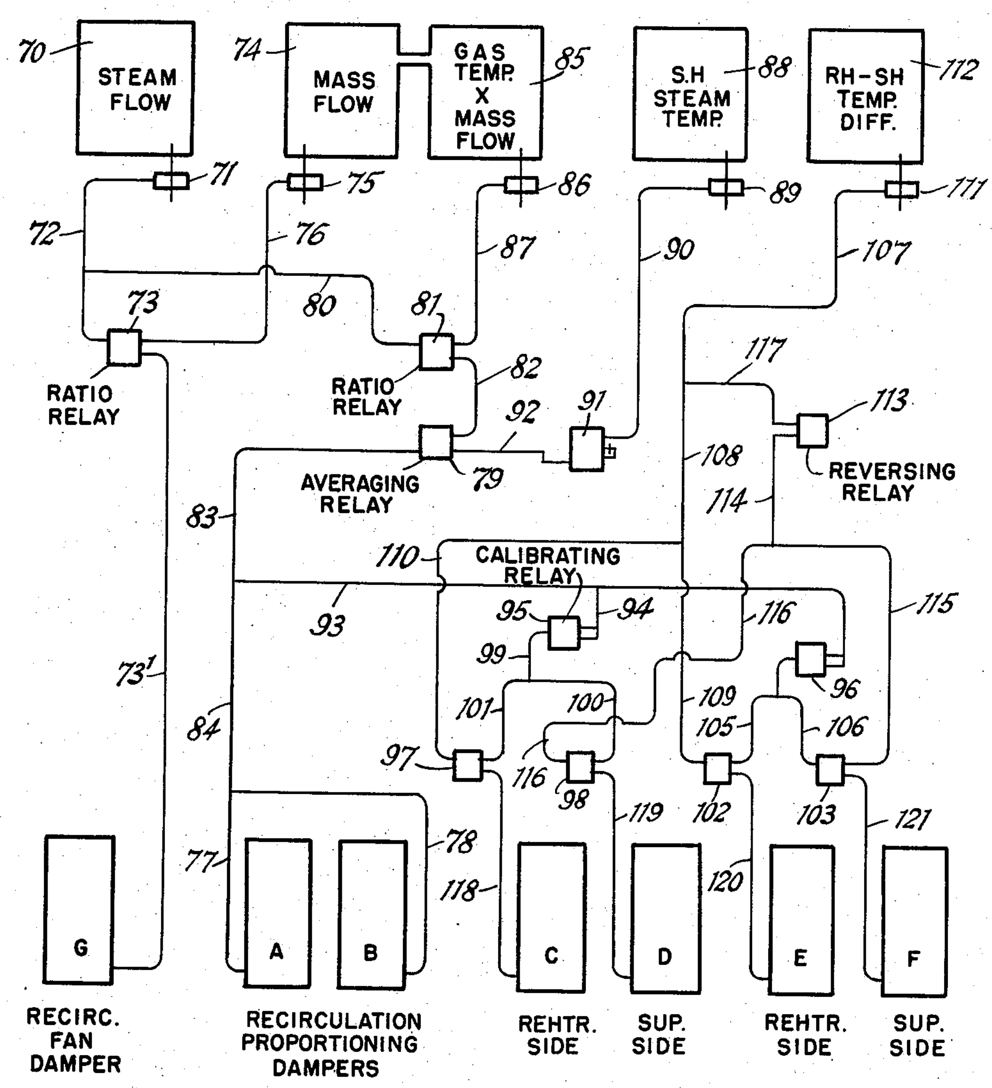

FIG. 3

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United States Patent Office

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VAPOR GENERATING AND SUPERHEATING UNIT WITH RECYCLED GAS FLOW

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Application March 27, 1953, Serial No. 345,092

12 Claims. (Cl. 122—479)

This invention relates to a method of, and a unit for, generating and superheating vapor at high temperatures and pressures, and it provides for a wide range of vapor generating rates with the concurrent maintenance of predetermined high superheat and reheat temperatures over a wide load range. The invention involves the attainment of these results by the burning of fuel in a combustion zone, the radiant transfer of heat from the combustion zone by radiation for vapor generation, the convection absorption of heat for reheating and superheating the generated vapor in a convection zone beyond the combustion zone, the recirculation or recycling of the combustion gases to the combustion zone after the gases have been partially cooled by convection heat absorption, introduction into the combustion zone of the recirculated gases at low velocity and in different relations to the fuel burning and the radiant heat absorption, dependent upon the vapor generating load conditions. In one embodiment of the invention fuel is burned in the combustion zone at highest optimum temperatures and the extent of the area of radiant heat absorption for vapor generation is minimized and the combustion products have their temperature lowered to an allowable range at the gas inlet of the convection zone by the low velocity introduction of the recirculated gases.

In one embodiment of the pertinent method, the convection zone involves the convection absorption of heat by the vaporizable liquid, and the regulation of the amount of such convection absorption of heat by controlling the amount of the combustion gases effecting such heat absorption in accordance with vapor generating load changes. For example, at low vapor generating loads, the percentage of gases effecting convection heat transfer to the vaporizing liquid in the convection zone is decreased by by-passing a controlled proportion of the gases around that part of the convection zone. These by-passed gases are recirculated to the combustion zone, and at increasing by-passing rates the combustion gas temperatures at the outlet of the combustion zone are increased, thus promoting the maintenance of desired high superheat and reheat in the convection zone. This may be augmented by simultaneous increase in the rate of recirculated gas flow so that there is a combined effect of increased mass flow and increased gas temperature to maintain desired superheat and reheat temperatures at low vapor generating loads.

The vapor generating and superheating unit of the invention is characterized by low draft loss through a superheater, a reheater and economizer. The physical arrangement of elements of the unit in one embodiment of the invention is such that the unit is also characterized by low head room requirements, thus, minimizing the high cost of supporting steelwork.

In one embodiment of the invention the elements of the vapor generation section, the superheater, the reheater and the economizer are arranged as upright elements disposed across the straight through horizontal gas flow from fuel burners distributed across an upright furnace wall. The burners are arranged in horizontal rows between which there are recirculated gas inlets parallel to the burner rows. The recirculated gas inlets are provided with segmental or sectionalized gas flow

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control devices which are regulated to vary the relationship of recirculated gas introduction relative to the radiant heat absorbing vapor generating walls of the furnace and relative to the operative burners to promote the optimum ratio coordination of vapor generating absorbed heat and superheater and reheater absorbed heat under varying load conditions. The superheater and reheater are arranged in parallel gas passes with dampers at the gas outlets of those passes for the proportioning of gas flow between the parallel gas passes to effect optimum superheat and reheat. The reheater and superheater may be set for 40% gas recirculation at top load so that the extent of superheater surface, furnace surface, and reheater surface and the cost of such surfaces, are reduced. With this arrangement the percentage of recirculated gas may be increased as the vapor generating load decreases, but this percentage of increase of recirculated gas is minimized at low loads when the combustion gases are caused to by-pass the economizer, but are recirculated to the furnace. This by-passing of economizer causes an increase of the temperature of the recirculated gases entering the furnace.

The invention also involves coordination of selective burner operation and controlled recirculated gas flow to promote the attainment of the optimum superheat and reheat temperatures under decreasing vapor generating load. For example, as load decreases, the lowermost row of burners are first shut off. Secondly, the top row of burners is shut off on further decrease of load, and, thirdly, upon still further decrease of load some of the remaining burners are shut off. Concurrently with this selective burner operation, the position of recirculated gas entry into the furnace is varied and controlled in such a way that the entry of gases take place at different positions relative to the radiant heat absorbing furnace walls, under varying load and particularly in the lower part of the load range. The recirculated gases will be caused to enter the furnace at positions near heat absorbing furnaces, and the number of the points of entry of the recirculated gas may be simultaneously increased to further increase the furnace surface blanketing effect whereby the radiant transmission of heat from the fuel burning zone immediately in front of the burner to the radiant heat absorbing surfaces is further decreased.

The invention also includes apparatus and a method which will afford means for obtaining optimum superheat under heat absorption conditions which may vary as the load remains constant. In other words, the invention is not limited in its advantages to attaining optimum superheat and optimum division of the total absorbed heat between the superheat and vapor generation at varying loads, but it also involves the attainment of the optimum conditions while the load remains constant. This is of considerable advantage for example, when the conditions of heat absorption are changed as a result of the deposits upon the heat absorbing surfaces. For example, with certain fuels, the superheater surfaces may have an increase of deposits thereon while the same load is being maintained, and the extent of these deposits may otherwise vary under the same load. Under these circumstances, the invention provides means for compensating such conditions and bringing up the final steam temperature to the desired value by increasing the amount of heat available to the superheating surfaces. Similar advantages apply under some conditions as to the increase of heat available for vapor generation on furnace surfaces in the event that they should be subject to variable solids deposits at the same load.

Another advantage of the invention is that it affords means for attaining guaranteed or optimum results from a high capacity unit when the engineering calculations have been such that they could not take into account the various effects of all the variables affecting the operation of the pertinent vapor generating and superheating units at all stages in their operative cycles. For example, such pertinent engineering calculations may be such that they are based on such premises that they cannot result in accurate predictions of the effects of all the variables which may cause variation in the ultimate results.

Further, the invention affords means for attaining the optimum results throughout the operating cycle of the unit regardless of changes in the performance as caused by changes in fuel fired, and changes in accumulations of heat barriers on the heat exchange surfaces. In calculating the predicted performance of a high capacity unit the designers must arbitrarily select some point in the operating cycle of the unit to base their predictions. Necessarily, the results of their calculations will not be equaled in actual operation when the unit is clean or immediately prior to unit shut down for periodic cleaning of the heat exchange surfaces.

The invention, with its plurality of operatively controllable factors, provides for the attainment of the optimum results even if the engineering calculations are substantially off in their predictions, and this can be accomplished during operation, and without any substantial operative loss.

When the invention is embodied in a vapor generating and superheating unit having a furnace including a hopper bottom, roof and walls including vapor generating tubes, and when the fuel burners are disposed at the upright wall parallel to the longitudinal axis of the hopper bottom and opposite the furnace gas outlet leading to the convection superheater, the furnace gas temperatures at the furnace outlet are brought within allowable limits, at top load, by introducing the lower temperature recirculated gases in a gas mixing manner. This is exemplified by their introduction within, or substantially centrally of, the fuel burning zone and between positions of fuel and air introduction by the burners. This "coring" manner of introduction and consequent mixing of the recirculated gases with the fresh combustion gases is capable of reducing the exit furnace gas temperatures from a maximum in the range of 2500 to 3000 F. to a value within the range of 2100 F. to 1900 F. at the furnace gas outlet. This action permits a substantial reduction in furnace size, and a corresponding reduction in high cost furnace wall absorption area. It also minimizes superheater costs by reducing or eliminating the necessity of constructing the superheater tubes of high cost high alloy steel, otherwise necessary to withstand the high gas temperatures. It also reduces superheater and/or reheater cost by reduction of the surface required. It also particularly enhances efficient operation of the unit when the furnace is fired with pulverized fuel. The reduction in furnace gas outlet temperatures substantially eliminates slagging of the superheater tubes by so altering the nature of the slag (or incombustible fuel residue) contacting the superheater tubes that the slag will not accumulate excessively upon those tubes.

As the fuel firing rate is reduced at decreasing vapor generating demands, the invention involves a plurality of temperature control factors and heat absorption control factors to so co-ordinate the proportioning of total heat absorption between vapor generation and vapor superheating (and reheating) that the inherent rising curve tendency of the convection superheater is overcome and predetermined superheat and reheat temperatures attained. As load decreases, the manner of recirculated gas introduction is changed from the coring manner of introduction to a manner of introduction wherein furnace wall heat absorption is decreased by "blanketing," or, interposing relative to the main combustion zone and the furnace boundary heat absorption surfaces, strata or bodies of the lower temperature recirculated gas. This action simultaneously increases the heat radiating distance from the radiating source to the heat receptive surface and decreases the surface extent of the radiating source. Both effects are operative to decrease the furnace wall heat absorption. Furthermore, both effects are increased by a gravity effect when at least some of the recirculated gas is introduced into the furnace between the lowermost burner and the hopper bottom of the furnace. Then the hopper bottom tends to be filled up with the higher density recirculated gas.

Another control factor operative under decreasing load is the percentage flow of recirculated gas. By "percentage flow" I refer to the relationship of recirculated gas flow to the total gas flow at a position beyond the gas inlet of the recirculated gas system. In one embodiment of the invention the percentage of recirculated gas flow is increased from about 50% at top load to about 100% at low load.

The invention also involves a vapor generating and superheating unit in which controlled proportioning of the superheater absorbed heat and the vapor generating absorbed heat under varying load conditions is effected in quite a different manner. The latter involves the reduction of heat input to the economizer as load is decreased. This is accomplished by gas by-passing the economizer in an increasing degree up to a maximum of 100% at, say, 25% of full load or control point load. As the heat input to the economizer is thus decreased, the temperature of the gases recirculated to the furnace is increased, and maximum furnace temperature as well as furnace gas outlet temperature increased. Another pertinent factor increasing heat input to the vapor generating tubes and the superheater is the increase in furnace gas temperature due to increased gas temperature over the air heater surfaces when the economizer is wholly or partially by-passed. Concomitantly also there is a decrease in vapor generation absorbed heat by reason of the decreased economizer heat absorption, if the economizer absorbed heat is regarded as a part of the total heat absorbed for the purpose of vapor generation. This reduction of economizer absorbed heat results from a decrease in the velocity of the gases passing over the economizer. This decrease in economizer absorbed heat is somewhat offset, from a vapor generation standpoint, by the tendency of the increased furnace gas temperature to increase furnace wall heat absorption. A further offsetting effect possibly arises from the consequent increase in temperature of the gases to the airheater, and the consequent effect upon furnace combustion by the increase in the temperature of the combustion (or secondary) air supplied to the furnace.

However, the above mentioned effects are accompanied by an increase in superheater (and reheater) heat absorption by reason of the increased temperature of the furnace gases entering the superheater.

The superheat control (or steam temperature control) method of the invention is materially enhanced by a predetermined sequence of shutting off the fuel burners of different horizontal rows as the load decreases. When three horizontal rows of burners at different levels are involved together with a furnace gas exit opposite the burners, the optimum sequence for steam temperature control is obtained by shutting off the lower row burners first, and then the top row burners. When this method is practiced in conjunction with the above indicated control involving variation of recirculated gas flow and variation of the mode of introduction of recirculated gases into the furnace, the optimum superheat (and reheat) may be obtained over a load range greater than 100%–25%.

The invention is clearly set forth in the claims annexed hereto but for a more complete understanding of the invention, reference should be had to the accompanying drawings and description in which a preferred embodiment of the invention is disclosed.

In the drawings:

Fig. 1 is a sectional side elevation on the line 1—1 of Fig. 2, of a high pressure vapor generating and superheating unit adapted for the practice of the invention;

Fig. 2 is a plan section on the plane of the line 2—2 of Fig. 1; and

Fig. 3 is a control diagram.

The vapor generating and superheating unit of Figs. 1 and 2 includes a small hopper bottom furnace **1**, fired at its front wall **2** by three vertically spaced horizontal rows, R^1, R^2 and R^3, of circular burners. The burners shown are pulverized coal burners, Fig. 2 indicating six burners, **3–8**, in each row.

Each row of burners is disposed within its separate secondary duct, the three ducts being indicated at **9**, **10** and **11**. Each duct is in communication at its ends with upright air ducts **12** and **13** which, in turn, communicate with a corresponding horizontal air duct **14** disposed at the lower part of the unit and leading from an airheater (not shown).

Alternating with the horizontal air ducts **9—11** are recirculated gas ducts **15—18** having multiple dampered outlets **19—22** extending across the burner wall. Each outlet has six dampers, the dampers for one outlet being indicated at **23—28**, in Fig. 2. They are subject to separate control to concentrate the furnace introduction of recirculated gases in a stratifying manner in front of the furnace side walls, as at decreasing and low vapor generating loads, or the dampers may be so separately controlled as to concentrate the furnace introduction of recirculated gases centrally of the main combustion zone for tempering purposes as at top load or increasing load near top load. Such separate control of the dampers may be automatically effected from such variables as vapor generating load and final vapor temperature, but, in the present instance, the dampers are shown as subject to manual control, with each damper having an operating rod such as **29**, pivoted to the damper and actuable through an opening in the wall **30**. Each rod is preferably adjustably held in a selected position by appropriate holding means associated with the wall **30**.

Each of the horizontal ducts **15—18** (for recirculated gas, has end portions **31** and **32** (Fig. 2) extending beyond the furnace side walls **33** and **34** for dampered communication with the upright ducts **35** and **36**.

The top and bottom horizontal ducts **15** and **18** have sets of dampers A and A′, respectively, controlling gas flow from the upright ducts **35** and **36**, and the intermediate horizontal gas ducts **16** and **17** have sets of dampers B and B′ controlling gas flow thereto from the upright gas ducts **35** and **36**. The latter are in communication, at their lower ends with the lateral recirculated gas ducts **37** and **38** which receive gas from the transverse duct **39** disposed beneath the bottom **40** of the gas pass for the superheater **41** and the reheater **42**. The duct **39** receives recirculated gas from the outlet **43** of a fan **44** through the upright duct **45**. Dampers G in the latter control gas flow from the fan. The inlet of the fan is connected by a duct **46** with the breeching **47** through which heating gases flow from the economizer **48** past the sets of economizer by-pass dampers C and D and the sets of main dampers E and F to an air heater.

The reheater **42** and the superheater **41** are separated, as to gas flow, by a longitudinally and vertically extending division wall **49** which extends to the rear wall **50** and to positions close to the series of economizer by-pass dampers C and D and to the main dampers E and F. For descriptive purposes the sets of dampers C and E are considered as disposed on the reheater side of division wall **49** and the sets of dampers D and F are considered as disposed on the superheater side of the division wall.

The reheater and the superheater are of the convection type, having pendent platens of upright return bend tubes disposed transversely of substantially horizontal gas flow from the furnace **1**. The construction of the superheater is similar to the construction of the reheater, the latter being particularly indicated in Fig. 1. Vapor to be reheated enters the reheater inlet header **51** and thence passes in generally counter-current relation to gas flow, through the successive and serially connected return bend tubes to the intermediate header **52**. The latter has criss-cross tubular connections **53** leading to second intermediate reheater header **54**. Vapor flow continues through a high temperature parallel flow section consisting of pendent return bend tubes, leading to the reheater outlet header **55**.

The superheater inlet header, similar to the reheater inlet header **51** receives vapor from a vapor and liquid drum **56** into which vapor and liquid mixtures are discharged by a multiplicity of vapor generating tubes receiving heat radiantly transmitted from the main combustion zone of the furnace. Some of these tubes lead upwardly from the lower header **57** along the left hand hopper bottom wall **58**. They continue along the burner wall and then along the furnace roof **59** to the drum **56**. Others of the vapor generating tubes lead upwardly from the opposite header **60**, along the inner side of the right hand hopper wall **61**, then along the bottom **40** of the convection gas pass, thence upwardly across gas flow as indicated at **62** (Fig. 1), and then forwardly along the roof **63** of the gas pass, to the drum **56**.

The side walls of the furnace similarly have upright vapor generating tubes therein, appropriately connected by suitable circulators and upper and lower side wall headers to the vapor and liquid space of the drum **56**, in a manner well known in the art. Such side wall tubes are indicated at **66** and **67**, in Fig. 2.

Fig. 1 also indicates that some of the vapor generating tubes from the header **60** are bent upwardly at a position adjacent the header **64**. From this position they extend vertically to the drum **56**, forming part of a tubular superheater and reheater screen **65**. The remainder of this screen is formed by upright tubes directly connecting the header **64** to the drum **56**.

Accordingly to the control diagram of Fig. 3, the dampers G, and hence the percentage of recirculated gas flow, are regulated in response to changes in steam flow (or vapor generation rate), changes in gas mass flow over the superheater, and changes in the product of the temperature and the mass flow of gases over the superheater. Steam flow is measured by an instrumentality **70** which is effective through the pilot valve **71** to vary the pneumatic loading in a line **72** leading to a multiple pneumatic chamber ratio relay **73**. Gas mass flow is measured by the device **74** which is effective through the pilot valve **75** to vary the pneumatic loading in line **76** in accordance with changes in gas mass flow. The line **76** is connected to a second pneumatic chamber in relay **73** to influence the output of this relay.

This part of the control system regulates the percentage of recirculated gas flow in accordance with load changes to promote the maintainance of a predetermined final vapor temperature over a wide load range. It is effective, for example, to change the percentage of recirculated gas flow from 50% at a control point load (or full load) of 1,000,000 lbs. of steam per hour to 75% at half load, and, further, to 100% at 25% of full load. Under these conditions, and considering the changes in load it is estimated that 700,000 lbs. of gas is recirculated at a full load of 1,000,000 lbs. of steam per hour, 560,000 lbs. of gas will be recirculated at one half load, and 420,000 lbs. at 25% of full load.

Simultaneously with the above indicated changes in percentage of recirculated gas flow, the illustrative system changes the manner of furnace introduction of recirculated gas from the "coring" manner of introduction to the wall blanketing type of introduction. For example, the dampers A and A′ are 90% closed at full load and the dampers B and B′ are gradually closed, and the dampers A and A′ gradually opened until at the lowest load value the dampers B and B′ are 90% closed and the dampers A and A′ fully open. This action involves a maximum blanketing of the roof and lower parts of the furnace walls by the recirculated gases at lowest load. Thus, the radiant heat transmission to the furnace vapor generating surfaces is relatively reduced and the superheater absorbed heat is relatively increased to further promote the maintenance of a predetermined final vapor (or steam) temperature over a wide load range.

In the interpretation of the Fig. 3 diagram, the rectangle marked A may be taken as representing the different sets of dampers A and A′ together with suitable damper operating devices actuating the dampers in accordance with pressure loading changes in the pneumatic lines **77** and **78** leading from the averaging relay **79**. Similarly the reactangle marked B may be taken as representing the different sets of dampers B and B′ together with suitable damper operating devices actuating dampers B and B′ reversely to the operation of the dampers A and A′ and in accord with pressure loading changes in lines **77** and **78**.

There are three influences effecting the pressure loading changes in lines **77** and **78**. The first influence is change in load as measured by the instrumentality **70** and made effective on lines **77** and **78** through pilot valve **71**, lines **72** and **80**, ratio relay **81**, line **82**, averaging relay **79**, and lines **83** and **84**. The second operative influence upon dampers A and B is change in the product of gas mass flow and gas temperature (at the superheater) as measured by instrumentalities **74** and **85** and made effective by pilot valve **86** in changing the pressure loading in line **87**. Relay **81** combines the effects of the latter pressure loading changes with the loading changes in line **80** and passes the combined effect on to averaging relay **79**. The third influence affecting the operation of the A (and A′) and the B (and B′) series of dampers is change in final, or superheated, steam temperature as measured and recovered by the instrumentality **88** and made controllably effective upon averaging relay **79** through the pilot valve **89**, the line **90**, the relay **91** and the line **92**.

The relative effects of the above indicated three influences in producing the operative pressure loading changes in lines **77** and **78** may be regulated as desired by adjustment of the relays **78**, **91** and **79**. Thus changes in steam flow (or load) from the instrumentality **70** may be caused to exercise a major part of the end effect, modified by changes in mass flow, final steam temperature and changes in the product of gas temperature and gas mass flow.

The C, D, E and F series of dampers are operated to affect proportioning of gas flow between the reheater and superheater gas passes to maintain a predetermined reheat temperature. Their further selective operation affects maximum furnace temperature, gas temperatures entering the superheater and reheater gas passes (furnace outlet gas temperatures), and the division of total heat absorption between vapor generation and vapor heating, by regulating the amount of gas by-passing the economizer.

In a preferred method, the series of dampers C and D are fully closed at full load, and the series of dampers E are fully open at full load. The dampers F are 90% open at full load. The substantially reverse situation obtains at lowest load when dampers C are 100% open and dampers D 60% open. There is then a maximum (or 100%) gas by-passing of the economizer. With such maximum by-passing the temperature of the recirculating gases entering the furnace is increased, causing an increase in maximum furnace temperature and an increase in gas temperature at the furnace outlet. The attendant increase in temperature of the secondary air entering the furnace augments both of these increases. Thus, there is a relative increase in heat input to the furnace wall vapor generating tubes, with an offsetting influence involved in the reduction of heat input into the economizer.

The series of dampers C, D, E and F are controlled by four influences. Three of these are the same influences which combine to control the series of dampers A, A′, B and B′ (previously referred to). They are effective from the line **83**, through the line **93** and its branch **94** upon the calibrating relays **95** and **96** which place dampers C and D and E and F in sequence with C and D closed and dampers E and F open at full load. The output of calibrating relay **95** is effective upon selective relays **97** and **98** through lines **99**, **100** and **101** and the calibrating relay **96** is similarly effective upon selective or biasing relays **102** and **103** through lines **104**, **105** and **106**. The outputs of the selective relays **97** and **102** are also affected by pressure loading changes in lines **107**, **108**, **109** and **110** leading through the pilot valve **111** from the instrumentality **112** which measures the difference between superheater and reheater output temperatures and effects changes in the pneumatic pressure loading of lines **107**—**110** representative of changes in the difference of those temperatures. The operative changes in the series of dampers D and F are reversed, relative to the simultaneous operative changes in the series of dampers C and E, as a result of the interposition of the reversing relay **113** and its connected lines **114**—**116** between the input line **107** and the selective relays **98** and **103**. Thus, if superheat temperature decreases from optimum and reheat temperature increases from optimum there is immediate corrective action by an increase in the opening of the series of dampers D and F and a simultaneous increase in the closing of the series of dampers C and E. Selective relays **97**, **98**, **102** and **103** are used instead of averaging relays to avoid opening of the dampers C, D, E and F by the effect of re-heat-superheat control instrumentality **112** when any of these dampers are (or tend to be) closed by other influences or impulses effective upon the selective relays take the impulses calling for most closed positions of the dampers and therefore throttle as necessary to correctly proportion superheat and reheat results.

Manual-automatic selector valves may be placed in the lines **73′**, **77**, **78**, **118**, **119**, **120** and **121** leading directly to the operators for the series of dampers G, A, B, C, D, E and F to provide for hand operation of any particular set of dampers, when desired. Such a selector valve is shown by Fitch 2,202,485.

The calibrating relays **95** and **96**, and the reversing relays **113** may be of the type shown by the Gorrie Reissue Patent 21,804. The other relays may be of the type described in the patent to Dickey 2,098,913, covering a relay having two or more variables entering it to produce a result.

The instrumentalities **88** and **112** may be steam temperature controllers of the type disclosed by Wheaton 2,155,986 positioning the movable element of a pilot valve such as the valves **71**, **75**, **86**, **89** and **111**. The latter are of the type disclosed in Johnson 2,054,464.

Whereas the invention has been described with reference to a preferred vapor generating, reheating and superheating unit, and with reference to a particular method of operation thereof, and a particular of controlling superheat temperatures over a wide load range, the invention is not to be considered as limited to all of the details thereof. It is rather of a scope commensurate with the scope of the sub-joined claims.

What is claimed is:

1. In a vapor generating and superheating unit, a fuel burning furnace having a vapor generating section including vapor generating wall tubes receiving radiantly transmitted heat from the furnace combustion zone, a convection section including a convection vapor superheater receiving the generated vapor from said wall tubes and heated by gases from the furnace, a convection economizer beyond the superheater and heated by the gases

from the furnace, a system recirculating to the furnace combustion gases partially cooled by the superheater and the economizer from a point in the gas flow path beyond said economizer, an economizer gas by-pass arranged to conduct combustion gases around said economizer to said gas withdrawal point, means for controlling gas flow through the by-pass, and means controlling the recirculated gas flow.

2. In a vapor generating and superheating unit, a furnace having fuel burning means along one wall for creating a main combustion zone of high temperature centrally of the furnace, the remaining furnace walls about the combustion zone including vapor generating wall tubes receiving heat radiantly transmitted from the combustion zone, a convection section including a convection vapor superheater receiving the generated vapor from said wall tubes and heated by gases from the furnace, a convection economizer beyond the superheater and heated by the gases from the furnace, a system recirculating to the furnace combustion gases partially cooled by the superheater and the economizer, an economizer gas bypass, means for controlling gas flow through the by-pass to change the temperature of the recirculated gases, said system including recirculated gas furnace inlet means for varying the position of main recirculated gas introduction relative to its closeness to said wall tubes as the vapor generating rate decreases, said inlet means including separately dampered openings disposed along the furnace burner wall in succession away from positions close to the wall tubes of adjoining furnace walls.

3. In a vapor generating and superheating unit, a furnace having vertically spaced horizontal rows of pulverized fuel burners along one upright wall for creating a high temperature main combustion zone, the remaining furnace walls about the combustion zone including vapor generating wall tubes receiving heat radiantly transmitted from the combustion zone, a separate fuel pulverizer for each row of fuel burners, a convection section including a convection vapor superheater receiving the generated vapor from said wall tubes and heated by gases from the furnace, superheat control means effecting the correlation of vapor generating absorbed heat and superheater absorbed heat and thereby maintaining a predetermined and superheated vapor temperature over a wide load range, said last named means including a system recirculating to the furnace combustion gases partially cooled by the superheater, said gas recirculated system including ductwork and separately dampered furnace inlet openings through the burner wall communicating with the ductwork and disposed in horizontal rows alternating with the horizontal rows of fuel burners, there being a plurality of separately dampered openings disposed in each horizontal row in succession away from positions close to the wall tubes.

4. In a vapor generating and superheating unit, a furnace having vertically spaced horizontal rows of pulverized fuel burners along one wall for creating a high temperature main combustion zone, the remaining furnace walls about the combustion zone including vapor generating wall tubes receiving heat radiantly transmitted from the combustion zone, a separate fuel pulverizer for each row of fuel burners, a convection section including a convection vapor superheater receiving the generated vapor from said wall tubes and heated by gases from the furnace, a convection economizer beyond the superheater and heated by the gases from the furnace, a system recirculating to the furnace combustion gases partially cooled by the superheater and the economizer, means forming an economizer gas by-pass, means for controlling gas flow through the by-pass operable to controllably vary the temperature of the recirculated gas, said gas recirculated system including ductwork and separately dampered furnace inlet openings through the burner wall communicating with the ductwork and disposed in horizontal rows alternating with the horizontal rows of fuel burners, there being a plurality of separately dampered recirculated gas furnace inlet openings disposed in each horizontal row in succession away from positions close to the wall tubes of adjacent furnace walls of boundaries.

5. In a vapor generating superheating unit, a fuel burning furnace having walls and other boundary surfaces including upright vapor generating tubes subject to heat radiantly transmitted from the combustion zone of the furnace, fuel burning means disposed in an upright wall of the furnace and directing fuel and air streams substantially horizontally toward the furnace gas outlet, means forming a horizontal gas pass disposed in communication with the furnace gas outlet and arranged for uni-directional gas flow from the fuel burning means through the gas pass, an upright division wall dividing the gas pass into two parallel subpasses, a convection section including a vapor superheater having horizontally spaced upright tubes disposed in one of said sub-passes and a vapor reheater formed by similarly arranged tubes in the other sub-pass, a convection economizer having tubes disposed in the sub-passes beyond the superheater and reheater in a gas flow sense, gas flow control means for each of the sub-passes at a position downstream from the economizer for proportioning the flow of gases between the sub-passes, an economizer gas by-pass for each of the sub-passes, gas flow control means for the economizer by-passes, a gas recirculation system including a fan and associated ductwork having inlet means communicating with the gas flow from the sub-passes at a position downstream of the economizer by-passes and having recirculated gas furnace inlets with separately controllable dampers distributed over the burner wall of the furnace with the inlet disposed in succession away from radiantly heated furnace boundary surfaces, and means for controlling the recirculated gas flow through the said system in coordination with changes in the rate of vapor generation consequent to changing rate of fuel firing.

6. In a method of controlling superheat in a vapor generator having a furnace radiantly transmitting heat from a main combustion zone to vapor generating tubes along the furnace walls and having a convection heating zone including a convection superheater subject to gas flow from the furnace, the method comprising burning fuel in suspension in the main combustion zone to effect temperatures in the range of 2400° F.–3000° F. in the main combustion zone, causing the gases to pass through the convection zone, introducing combustion gases recirculated from the convection zone into the main combustion zone in a coring manner therethrough at high vapor generating rates and thereby mixing the recirculated gases with the fresh combustion gases to decrease as temperatures at the entrance of the convection zone, and gradually decreasing said coring manner of recirculated gas introduction as vapor generating load decreases and simultaneously gradually increasing the introduction of the recirculated gases in a furnace wall blanketing manner as the load decreases.

7. In a method of generating a high pressure vapor and superheating the generated vapor to a temperature in the 950 F. to 1200 F. range, burning fuel in suspension in a main combustion zone to effect temperatures in the 2200 F. to 3000 F. range therein, radiantly transmitting heat from the main combustion zone to a vaporizable liquid to generate high pressure vapor, passing the generated vapor through a convection zone, convectionally transmitting heat from the products of combustion to the generated vapor in the convection zone, recirculating combustion products which have been partially cooled in the convection zone to the main combustion zone, introducing the recirculated combustion products in a coring manner centrally of the main combustion zone at high rates of vapor generation to thereby mix the recirculated and unrecirculated combustion products and

decrease the gas temperature at the gas entrance to the convection zone, decreasing said coring manner of gas introduction as vapor generating rate decreases from a high value and simultaneously increasing a combustion zone bordering stratum of introduced recirculated gases until at a lowest rate of vapor generation the coring manner of introduction is substantially terminated and there is a maximum of stratum introduction of the recirculated gases to effect a maximum decrease in radiant transmission of heat for vapor generation.

8. In a method of generating and superheating a vapor at high pressures and temperatures effecting high temperatures in a combustion zone, burning fuel in suspension in the combustion zone to generate a vapor by absorbing heat radiantly transmitted from the combustion zone to a vaporizable liquid, directing the generated vapor in confined streams to a convection zone, absorbing heat convectionally transmitted to the vapor from the flow of gases from the combustion zone, recirculating to the combustion zone combustion gases partially cooled in the convection zone, tempering the combustion zone gases at high vapor generation rates and high combustion rates by introducing the recirculated combustion gases into the combustion zone in a coring manner concentrating the recirculated gases substantially centrally of the combustion zone, terminating the coring manner of recirculated gas introduction and introducing the recirculated combustion gases in a combustion zone enveloping manner at low combustion rates and low vapor generation rates, and effecting by stages transition from the coring manner of recirculated gas introduction toward the combustion zone enveloping manner of recirculated gas introduction as the vapor generation rate decreases.

9. In a vapor generating unit of the type having a vapor generating section including a fuel fired furnace with vapor generating tubes along its walls, a convection section including a convection superheater heated by gases developed in the furnace and a convection economizer heated by the furnace gases after loss of heat therefrom in the superheating; the combination therewith of superheat control means for regulating the temperature of the superheated vapor over a wide range of rate of vapor generation, said superheat control means including a gas recirculation system having a fan associated with fan inlet ductwork in communication with the flow of gases developed in the furnace after loss of heat from the gases by economizer heat absorption, the gas recirculation system also including fan outlet ductwork communicating with the furnace, means for increasing the flow of recirculated gases to the furnace as the rate of vapor generation decreases, and means for decreasing the economizer absorbed heat concomitantly with the increase in flow of recirculated gases to simultaneously increase superheater absorbed heat by an increase in the mass flow of gases over the superheater and by an increase in the temperature of the gases passing over the superheater.

10. In a vapor generating unit of the type having a vapor generating section including a fuel fired furnace with vapor generating tubes along its walls, a convection section including a convection superheater heated by gases developed in the furnace and a convection economizer heated by the furnace gases after loss of heat therefrom in the superheating; the combination therewith of superheat control means for regulating the temperature of the superheated vapor over a wide range of rate of vapor generation, said superheat control means including a gas recirculation system having a fan associated with fan inlet ductwork in communication with the flow of gases developed in the furnace after loss of heat from the gases by economizer heat absorption, the gas recirculation system also including fan outlet ductwork communicating with the furnace, means for increasing the flow of recirculated gases to the furnace as the rate of vapor generation decreases and means for decreasing the economizer absorbed heat concomitantly with the increase in flow of recirculated gases to simultaneously increase superheater absorbed heat by an increase in the mass flow of gases over the superheater and by an increase in the temperature of the gases passing over the superheater, said means for changing the economizer absorbed heat involving a dampered bypass for at least a part of the economizer surface.

11. A vapor generating and superheating unit comprising vertical front and side walls and a roof defining a furnace chamber, means in said vertical front wall for burning fuel in suspension in said furnace chamber, vapor generating tubes arranged along one of said vertical side walls to receive radiant heat from the burning fuel in said furnace chamber, a convection gas pass arranged to receive heating gases from said furnace chamber, a convection vapor superheater arranged to receive generated vapor from said wall tubes and to be heated by heating gases from said furnace chamber, a series of horizontally spaced gas inlet openings in a vertical wall normal to said side walls and at different horizontal distances from said furnace wall generating tubes and arranged to discharge heating gases in a direction parallel to said side walls, means for recirculating heating gases after being partially cooled by said vapor superheater to said series of gas inlet openings, and means for independently controlling the supply of recirculated gas to each of said gas inlet openings and operable to increase the percentage of recirculated gas flowing in a path of travel close to said furnace wall generating tubes, and thereby decrease the radiant heat absorption of said furnace wall generating tubes, as the vapor generating rate decreases.

12. A vapor generating and superheating unit comprising vertical front and side walls and a roof defining a furnace chamber, means in said vertical front wall for burning fuel in suspension in said furnace chamber, vapor generating tubes arranged along one of said vertical side walls to receive radiant heat from the burning fuel in said furnace chamber, a convection gas pass arranged to receive heating gases from said furnace chamber, a convection vapor superheater arranged to receive generated vapor from said wall tubes and to be heated by heating gases from said furnace chamber, and means for increasing the convection superheat temperature comprising a series of horizontally spaced gas inlet openings in said front wall at different horizontal distances from said furnace wall generating tubes and arranged to discharge heating gases in a direction parallel to said side walls, means for recirculating heating gases after being partially cooled by said vapor superheater to said series of gas inlet openings, and damper means for independently controlling the supply of recirculated gas to each of said gas inlet openings and operable to increase the percentage of recirculated gas flowing in a path of travel close to said furnace wall generating tubes, and thereby decrease the radiant heat absorption of said furnace wall generating tubes, as the vapor generating rate decreases.

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