Sept. 29, 1964 R. K. GRIFFITH 3,150,644

STEAM GENERATING UNIT

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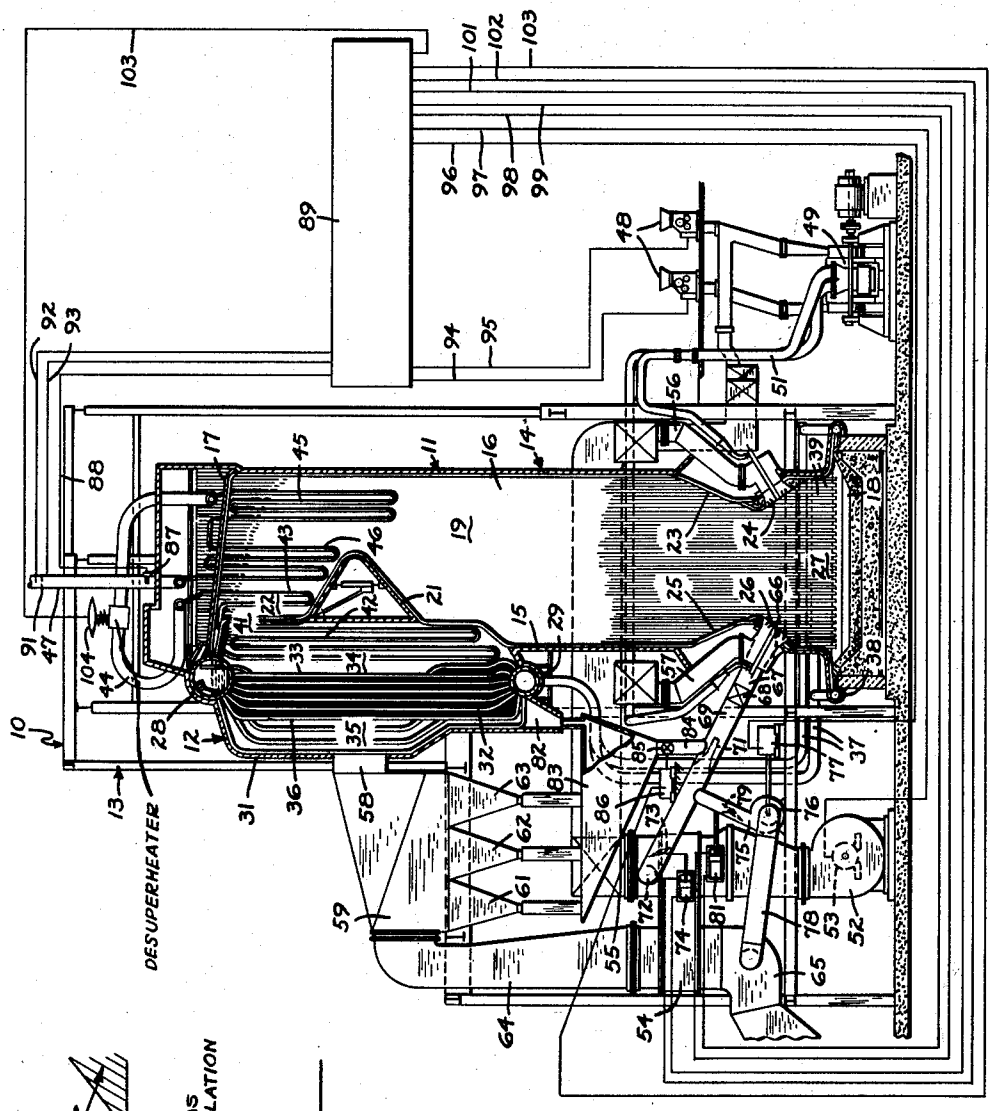


Fig. 1

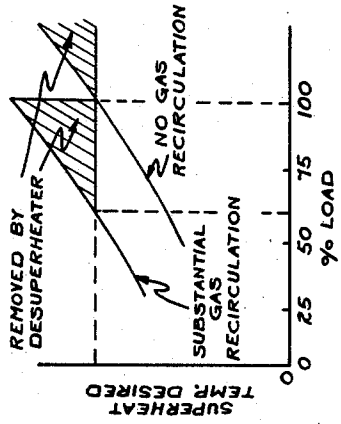


Fig. 2

INVENTOR.
Robert K. Griffith
BY
Norman S. Blodgett
Attorney

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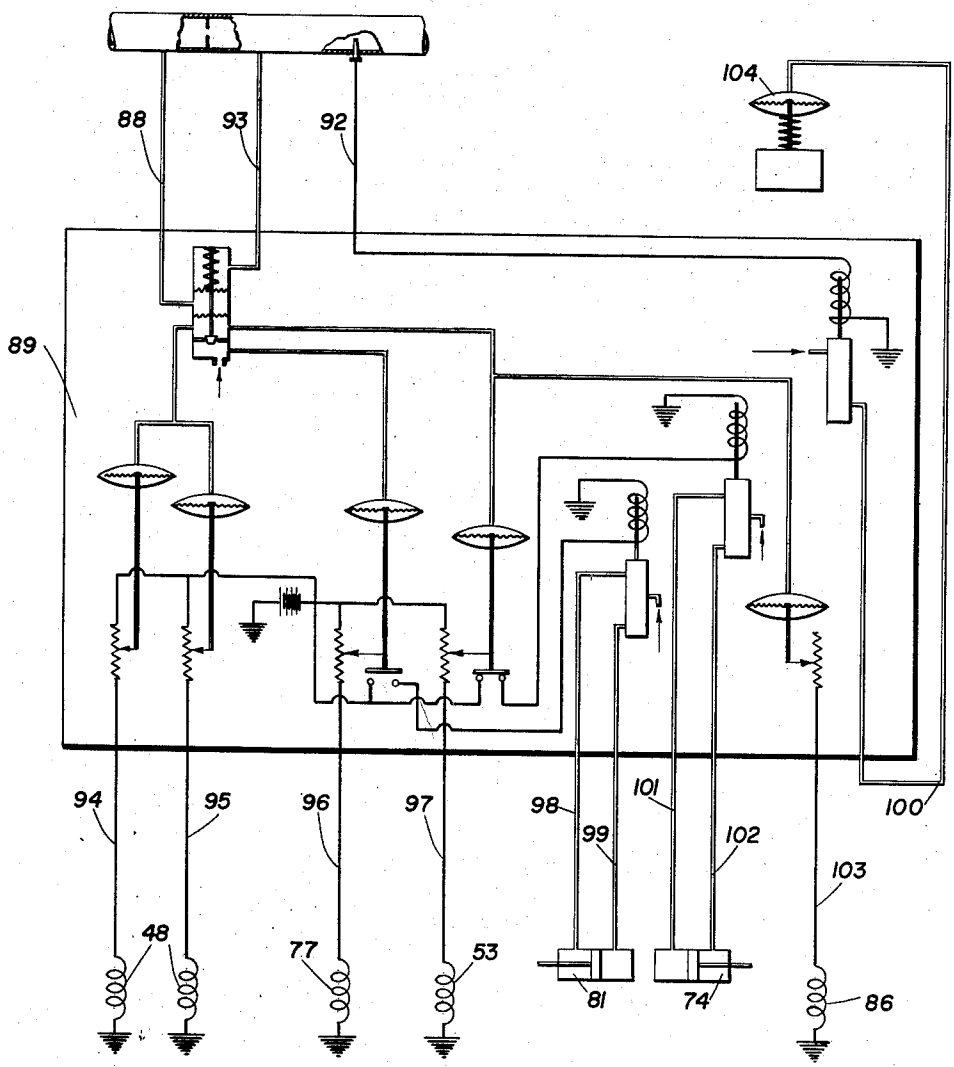


FIG. 3

ROBERT K. GRIFFITH
INVENTOR.

BY Norman S. Blodgett

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STEAM GENERATING UNIT

Robert K. Griffith, Holden, Mass., assignor to Riley Stoker Corporation, Worcester, Mass., a corporation of Massachusetts

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This invention relates to a steam generating unit and, more particularly, to apparatus arranged to produce steam by the burning of fuel for use in a turbine.

It is common practice in the steam generating art to dispose of flyash and cinders by introducing them into a very hot portion of the unit where they are converted to slag and then removing the slag in liquid form. This slag is chilled to produce a glass-like material which has many uses, including use as a filler for concrete. Re-injection of flyash, however, requires a considerable amount of equipment and it is not possible to make use of this equipment at all loads because it is difficult to slag the flyash at low heat-release operation of the unit. It is also common practice to regulate the combustion and regulate the temperature of the superheated steam in the unit by re-circulating part of the products of combustion after they have been cooled; the introduction of this re-circulated gas into the usual products of combustion in the boiler results in increasing the mass flow. Even though the average temperature of the gas is reduced by doing this, nevertheless, the increase in mass flow affects the temperature of superheat to a greater degree than the cooling of the gas lowers it, so the net result is an increase in superheated steam temperature. Using gas circulation in this manner to regulate superheat involves supplying some expensive auxiliary equipment to the unit which it is not possible to use at all times. Generally speaking, gas recirculation is used only at low loads to increase a steam temperature which would otherwise fall at that load. Thus, both the re-injection system and the gas re-circulation system involve expensive equipment which is not possible to use at all times with the unit, so that the capital cost is sometimes not warranted and so that units must often be constructed without these beneficial features. These and other difficulties experienced with the prior art devices have been obviated in a novel manner by the present invention.

It is, therefore, an outstanding object of the invention to provide a steam generating unit having the advantages of flyash re-injection and gas re-circulation at a relatively low cost.

Another object of this invention is the provision of a steam generating unit in which apparatus for gas re-circulation and flyash re-injection have been combined and in which a substantial portion of the equipment is in use at all times.

A further object of the present invention is the provision of a steam generating unit having means for re-injecting flyash and for re-circulating gas, the equipment including control means for changing from one type of operation to the other at a pre-determined load.

It is another object of the instant invention to provide a steam generating unit having automatic control means for providing for flyash re-injection at high loads and for gas re-circulation at low loads.

It is a further object of the invention to provide a steam generating unit having a novel means of introducing combustion air and maintaining gas re-circulation openings in the furnace at a safe temperature.

With these and other objects in view, as will be apparent to those skilled in the art, the invention resides in the combination of parts set forth in the specification and covered by the claims appended hereto.

The character of the invention, however, may be best understood by reference to one of its structural forms as illustrated by the accompanying drawings in which:

FIG. 1 is a vertical sectional view of a steam generating unit embodying the principles of the present invention;

FIG. 2 is a graphical representation of certain temperature-load relationships in the unit; and

FIG. 3 is a schematic view of a control apparatus.

Referring to FIG. 1, the steam generating unit, indicated generally by the reference numeral **10**, is shown as consisting of a furnace **11** and a boiler **12** mounted in a supporting structure **13**. The furnace **11** consists of a front wall **14**, a rear wall **15**, side walls **16**, a roof **17**, and a bottom **18** defining a vertically-elongated combustion chamber **19**. The rear wall **15** is provided with a nose **21** which extends from side wall **16** to side wall **16** and toward the front wall **14**; the nose is spaced from the roof **17** to define therewith an upper horizontal convection pass **22**. The front wall **14** is provided in its lower portion with an abutment **23** having a downwardly-directed surface on which is mounted an inter-tube directional flame burner **24** of the type shown and described in the patent of Craig No. 2,759,460. A similar abutment **25** extends forwardly from the lower portion of the rear wall **15** and is provided on a downwardly-directed surface with an inter-tube directional flame burner **26**. The abutments **23** and **25** define with the bottom **18** a high-temperature cell **27** in the lower part of the furnace.

The boiler **12** is provided with a steam-and-water drum **28** aligned with the roof **17** and a lower drum **29** located behind the rear wall **15** intermediate of the distance between the bottom **18** and the roof **17**. The space between the steam-and-water drum **28** and the lower drum **29** is encased in a housing **31** providing a back pass **32**. A row of closely-spaced tubes extending between the steam-and-water drum **28** and the lower drum form a baffle **33** which divides the back pass into a forward portion **34** and a rear portion **35**, alternate tubes being bent out of the plane of the baffle to provide an opening just above the lower drum. A set of downcomer tubes **36** extend from the steam-and-water drum **28** to the lower drum **29** in the rear portion **35** of the back pass. Large downcomer tubes **37** connect the lower drum **29** with a ring-like header **38** extending around the periphery of the bottom **18**, which bottom is of a refractory nature and has a slag tap opening, not shown. Water-wall tubes **39** leave the header **38** and extend upwardly along the surface of the front wall **14**, the rear wall **15**, and the side walls **16**, all of these tubes discharging into the steam-and-water drum **28**. The tubes covering the front wall **14** also extend over the underside of the roof **17**. Some of the tubes which extend up the rear wall **15** also pass over the outer surface of the nose **21**. The tubes on the rear wall come together again between the uppermost part of the nose **21** and the steam-and-water drum **28**; in that area they are spread longitudinally to provide a gas offtake **41** permitting passage of the gases from the upper end of the combustion chamber **19** into the back pass **32**. In the forward portion **34** of the back pass is located a convection superheater **42** whose input end is connected to the upper part of the steam-and-water drum **28**. The output end of this superheater is connected to a convection superheater **43** located in the convection pass **22** and which discharges into a pipe **44** leading to the input side of a platen-type radiant superheater **45**. The radiant superheater **45** discharges into another convection superheater **46** which, in turn, is connected to a pipe **47** leading to the turbine (not shown).

Fuel feeders **48** lead to an attrition-type pulverizer **49** which is capable of reducing solid fuel, such as coal, into a powdered condition for burning. Pipes **51** lead from

the pulverizer output to the burners 24 and 26 in the usual manner. A forced draft fan 52 driven by a motor 53 is connected by suitable ducting to a rotary regenerative air heater 54 which, in turn, is connected by a main hot air duct 55 to branch ducts 56 and 57 leading to the burners 24 and 26, respectively. It will be understood that, depending upon the distance from side wall 16 to side wall 16, a plurality of burners 24 are provided in association with the abutment 23 and a similar number of burners 26 are associated with the abutment 25.

At the back side of the rear portion 35 of the back pass the housing 31 is provided with an opening 58 leading to a dust collector 59 having flyash hoppers 61, 62, and 63. The gas output of the dust collector is connected by a duct 64 through the air heater 54 to a breaching 65 leading to an induced draft fan and a stack (not shown).

The burners 26, being of the inter-tube type, fire fuel and air through openings in the water-wall tubes provided by bending the tubes rearwardly of one another in a well-known manner. Between these burners the lower surface of the abutment 25 is provided with return openings 66 in the same manner shown and described in the patent of Parmakian No. 3,095,863 and the patent of Miller No. 3,095,864. Each opening 66 is connected by a duct 67 to a main transverse manifold 68 to which is connected a rearwardly-directed, upwardly-and-rearwardly inclined duct 69. The duct 69 is provided with an ejector nozzle 71. The rearward end of the duct 69 is connected to the duct 55 at an opening 72 just above the air heater 54 to provide air for the nozzle 71, the amount of air being controlled by a damper 73 connected by a suitable linkage to a linear actuator such as a hydraulic cylinder 74. Connected to the duct 69 between the portion in which the nozzle 71 is positioned and the portion in which the damper 73 is positioned is a duct 75 connected to the output of a fan 76 capable of handling relatively high temperature gas and driven by an electric motor 77. The input of the fan 76 is connected by a duct 78 to the breaching 65. Lying in the duct 75 is a damper 79 which is connected by a suitable linkage to a hydraulic cylinder 81.

The housing 31 is formed with a flyash hopper 82 located beside the lower drum 29 and underlying the back portion 35 of the back pass. This hopper is connected to one side of a storage hopper 83 to which are also connected the hoppers 61, 62, and 63 associated with the dust collector 59. The storage hopper 83 is provided with inclined bottom surfaces which terminate in a vertical pipe 84 connected at its lower end to the duct 69 at a location beside the ejector nozzle 71. In the pipe 84 is located a rotary feeding valve 85 driven by an electric motor 86.

Located in the steam output pipe 47 is a temperature-measuring device 87 which is connected by a line 88 to the input side of a main control 89. This main control is of the type commonly used in this art for converting input signals in the form of electrical and pneumatic pulses to output signals which also may be electrical, pneumatic or hydraulic for controlling elements of the unit in response to certain measured quantities. The general arrangement of the main control is shown in FIG. 3. The pipe 47 is also provided with an orifice plate 91 to the opposite sides of which are connected lines 92 and 93, which, in turn, are connected to the input side of the main control 89 to give a signal therein indicative of flow of steam and, therefore, indicative of load.

The output side of the main control is connected by lines 94 and 95 to the feeders 48 to control the rate of fuel feed into the pulverizer 49. The output side of the main control 89 is connected by a line 96 to the motor 77 to control the rate of operation of the gas re-circulation fan 76. The output side of the main control is also connected by a line 97 to the motor 53 to regulate the rate of operation of the forced draft fan 52. Lines 98 and 99 extend from the output side of the main control 89 to the hydraulic cylinder 81 which determines the aspect of the damper 79. Lines 101 and 102 extend from the output side of the main control 89 to the hydraulic cylinder 74 controlling the aspect of the damper 73. A line 103 extends from the output side of the main control 89 to the electric motor 86 to regulate the rate of rotation (and, therefore, of feeding) of the valve 85. A line 103 extends from the output side of the main control 89 to the operating portion of a steam desuperheater 104 located in the pipe 44 leading from the superheater 43 to the superheater 45.

The operation of the invention will now be readily understood in view of the above description. Fuel arrives at the burners 24 and 26 through the pipes 51. The amount of pulverized solid fuels so provided is determined by the signals sent from the main control 89 through the lines 94 and 95 to the feeders 48. The fuel from the feeders mixes with primary air arriving in the usual manner through ducting from the air heater 54 and enter the pulverizer 49 for comminution to a fine, readily-burnable fuel. Air is provided to the system by the forced draft fan 52 and the rate at which this air arrives is regulated by the main control 89 through the line 97 regulating the motor 53. The air from the fan passes through the air heater 54 into the main duct 55 from which it is distributed through branch ducts 56 and 57 to the burners 24 and 26, respectively. The air arriving at the burners through the branch ducts 56 and 57 is secondary air and is mixed in the burners with the fuel and primary air (which arrive from the pulverizer) to provide a combustible mixture which is projected into the high temperature cell 27 of the furnace. The products of combustion generated in the low temperature cell pass upwardly through the combustion chamber 19 and radiate thermal energy to the water tubes on the walls of the furnace. These gases supply heat to the superheater 45 partly by convection but predominantly by radiation. The gas flows around the nose 21 and through the convection pass 22 transmitting heat to the superheaters 43 and 46 by convection. The gas then flows through the gas off-take 41 and downwardly through the forward portion 34 of the back pass 32. The gas passes downwardly and around the bottom end of the baffle 33 adjacent the lower drum 29 and then flows upwardly through the rear portion 35 of the back pass. Flyash is thrown by centrifugal force into the hopper 82 as the gas flow reverses itself around the bottom of the baffle 33. The gas leaves the back pass through the opening 58 and flows through the dust collector 59, a considerable portion of the remaining flyash being deposited by the dust collector in the hoppers 61, 62, and 63. The gas then passes through the duct 64, through the regenerative air heater 54, into the breaching 65 and from there to the stack.

Water is introduced into the steam-and-water drum 28 by feed water pumps (not shown) and passes downwardly through the downcomer tubes 36 into the lower drum 29. The water then passes through downcomers 37 into the header 38 from which it passes through the water-wall tubes 39 along the walls of the furnace during which passage the water is converted into steam. The steam is discharged into the steam-and-water drum 28 and, after suitable cleaning and separation in the usual manner, passes into the low-temperature convection superheater 42. After being heated there it passes into the convection superheater 43. The output of the convection superheater 43 passes through the pipe 44 where it is subjected on occasion to reduction of temperature by the desuperheater 104 before flowing into the radiant superheater 45. The steam is finally heated again in the convection superheater 46 and passes to the turbine through the pipe 47.

An indication of the output steam temperature is furnished to the main control 89 by the temperature-measuring device 87 which sends its signal through the line 88. The main control also receives a signal indicative of load

because of the pressure drop across the orifice plate **99**; this signal is transmitted to the main control through the lines **92** and **93**. The main control receives the signals (of the steam temperature and of the load on the unit) and uses these signals to regulate the operation of the apparatus to maintain the temperature of the steam at a constant predetermined value. At the same time, it is necessary to collect the unburned components of the fuel and to maintain the efficiency of the unit as a whole at a high value by not permitting any fuel components to leave the unit until all of the heat value has been removed. In a typical unit firing pulverized coal, the loss of heat value in the flyash may represent 4% of the heat release in the unit with a resulting low efficiency.

When the signal which arrives at the main control **89** through the lines **92** and **93** indicates that the steam generating unit **10** is operating at low load, the main control acts through its output lines to anticipate the fact that, in the absence of control, the temperature of superheat at low load would be less than the predetermined desirable value. The main control accomplishes this function by controlling the amount of gas which is recirculated to the furnace. It will be understood that, according to conventional control practice, the amount of gas re-circulation will be determined, first of all, by the load, but also there will be an over-riding control directly from steam temperature which will also regulate the amount of gas re-circulated. The gas re-circulation operates as a broad control of steam temperature and fine adjustments are made by means of the desuperheater **104**. This is evident in FIG. 2 where it can be seen that at high loads no gas re-circulation is used and, as indicated by the arrow, the curve of Superheat Temperature versus Load shows that the temperature of steam above the 100% load mark is above the pre-determined desired value and this extra temperature is removed by the desuperheater **108** under command from the main control **89**. As also shown in FIG. 2, when the load is below a certain value, a large amount of gas is re-circulated giving the curve which is labeled "substantial gas re-circulation." At that time, at all values between, say, 60% load and 100% load, the desuperheater removes the extra temperature. This is the so-called "step" control method, but it will be understood that the main control **89** may operate to select a different curve at each different load, so that there is little need for removal of steam temperature by the desuperheater, according to the so-called "continuous" control method. Basically, however, large amounts of gas re-circulation are used at low loads and at high loads no gas re-circulation is used. The main control regulates this amount of gas re-circulation by means of the line **96** controlling the motor **77** of the gas re-circulation fan **76** and the setting of the damper **79** by the hydraulic cylinder **81**, this latter cylinder being controlled through the lines **98** and **99**. When the damper **79** is open and the motor **77** is driving the gas re-circulation fan **76**, gas leaves the breaching **65** through the duct **78**, passes through the fan **76**, around the damper **79**, and through the duct **75** to the duct **69**. It flows through the ejector nozzle **71** and flows into the manifold **68** which distributes it through the duct **67** to the openings **66** on the bottom surface of the abutment **25**. This re-circulated gas mixes with the regular products of combustion and increases the rate of mass flow over the convection surfaces. The net result of the added amounts of gas, even though the gas which is thus re-circulated is of a lower temperature, is to raise the temperature of superheated steam and, under the operation of the main control **89**, to assist in maintaining the temperature of superheated steam at a constant pre-determined value. Now, the amount of flyash which accumulates in the hoppers **61**, **62**, and **63** and **82** is substantial, but, at low loads, it is undesirable to introduce this flyash into the furnace because it not only interferes with combustion but the temperature of the cell **27** (because of the lower heat release at low load) is not at sufficient temperature to maintain all unburnable components of the fuel in a molten state. At low load, therefore, the flyash is not introduced into the furnace and it accumulates in the storage hopper **83**. When high load is reached, it is then desirable to re-introduce the flyash to recover the burnable components. At that time, the main control **89** sends a signal through the line **103** to the motor **86** which rotates the valve **85** and permits flyash from the storage hopper **83** to fall at a controllable rate through the duct **84** into the duct **69**. At the same time, the main control sends a signal through the lines **101** and **102** to operate the hydraulic cylinder **74** and open the damper **73** so that heated air in large amounts leaves the main duct **55** through the opening **72** and passes through the duct **69**. The air thus introduced passes through the ejector nozzle **71** and the ejector action causes a fluidization of the flyash from the storage hopper **83** by the air thus introduced. This fluidization permits the flow of air and flyash into the manifold **66** into the duct **67** and through the opening **66** into the furnace. At high load, when the flyash is thus being introduced along with air, the gas re-circulation apparatus is completely shut down, the damper **79** being closed and the motor **77** being inoperative. Because the ducts which are required to re-circulate substantial amounts of gas at low load are required to be quite large in cross-sectional area and, whereas in the past the pipes which were used for flyash re-injection were quite small, a problem is presented which is solved by using ducts which are large enough for the proper amount of gas re-circulation and by introducing into the flyash re-circulation system much greater amounts of air than have been used in the past. It should be noted, however, that the flyash re-injection takes place only at high load at which time substantially greater amounts of pre-heated air must be supplied to the combustion chamber than would be supplied at low loads. The main control **89** causes the feeders **48** to supply fuel to the furnace at a very high rate at high load. The control also operates to provide the furnace with the substantially additional air which is necessary. While it is true that considerable amounts of the added primary air arrive at the pulverizer **49** and other amounts of the secondary air arrive by means of the branch ducts **56** and **57**, there is no reason why additional amounts of air may not arrive through the duct **69** and the return openings **66**; this is exactly what is done according to the practice of the present invention.

It should be noted that, among other advantages of this system, is that at high loads (when gas re-circulation is not used) those openings through which the gas re-circulation in the past has been provided are protected from damage by radiation of thermal energy to their surfaces because at high load, at which time in the past these openings were idle, the openings according to the present invention are used for flyash re-injection with very large amounts of pre-heated air. At no time, therefore, are the openings **66** idle or subject to deterioration due to the heat in the high temperature cell **27**. It should also be noted that, according to the preferred embodiment, the storage hopper **83** underlies all of the major flyash removal elements of the steam generating unit so that this collected flyash may be passed into the storage hopper by gravity. Furthermore, according to the preferred embodiment, the ducting **69** is inclined toward the furnace to assist in the flyash re-introduction, although, normally, the flyash would be carried in suspension in the air coming from the ejector nozzle **71**. The damper **79** which serves to shut off the gas re-circulation ducts at high load also prevents the air which now exists in the ducts **69** under considerable pressure from entering the gas re-circulation ducts. At low load, of course, the damper **73** prevents any re-circulated gas from going through the opening **72** and polluting the air going to the burners, although, of course, this is not a critical matter, since the gas is passing ultimately to be mixed with the fuel and air. It is considered more desirable to introduce the re-circulated

gas at openings between the burners 26 rather than premix the gas with the fuel-air mixture in the burners, because ignition can be maintained more readily this way.

It is obvious that minor changes may be made in the form and construction of the invention without departing from the material spirit thereof. It is not, however, desired to confine the invention to the exact form herein shown and described, but it is desired to include all such as properly come within the scope claimed.

The invention having been thus described, what is claimed as new and desired to secure by Letters Patent, is:

1. A steam generating unit, comprising
(*a*) a combustion chamber having an upper and a lower end,
(*b*) fuel-burning means associated with the lower end of the chamber for producing hot gaseous products of combustion,
(*c*) a boiler associated with the chamber including a superheater mounted adjacent the upper end of the chamber, the boiler having convection heat exchange elements over which pass the products of combustion after they have passed through the chamber,
(*d*) a return duct connected at one end to openings into the combustion chamber,
(*e*) gas re-circulation means connected to the other end of the duct to introduce thereto products of combustion that have passed over the said heat exchange elements of the boiler,
(*f*) flyash return means connected to the other end of the duct to introduce thereto flyash that has accumulated in the boiler, and
(*g*) control means associated with the gas recirculation means and the flyash return means introducing relatively large amounts of products of combustion into the duct at low load and relatively large amounts of flyash into the duct at high load.

2. A steam generating unit as recited in claim 1, wherein the chamber is provided at its lower end with abutments defining a lower high-temperature cell and having downwardly-directed surfaces on which the fuel-burning means is mounted and in which the said openings are formed.

3. A steam generating unit as recited in claim 1, wherein a source of air is connected to the duct and the said control means acts to introduce the air into the duct at the same time as the flyash, the amount of air so introduced being substantially greater than is necessary to carry the flyash into the combustion chamber.

4. A steam generating unit as recited in claim 1, wherein the control means acts to introduce an amount of products of combustion sufficient to maintain the temperature of steam leaving the said superheater above a pre-determined temperature.

5. A steam generating unit as recited in claim 1, wherein the lowest load at which flyash is introduced into the chamber is that load at which slagging does not take place and the highest load at which products of combustion are re-circulated to the chamber is that load at which the superheat temperature would otherwise drop below a pre-selected value.

6. A steam generating unit as recited in claim 1, wherein the gas re-circulation means is used to maintain the temperature of superheat at a constant pre-determined value over a wide range of loads by making large incremental changes, disuperheater means connected to the superheater to produce the same effect by producing small incremental changes which are added algebraically to the changes produced by the gas re-circulation means.

7. A steam generating unit, comprising
(*a*) a vertically-elongated combustion chamber,
(*b*) fuel-burning means associated with the lower end of the chamber for producing hot gaseous products of combustion,
(*c*) a boiler associated with the chamber including a superheater mounted adjacent the upper end of the chamber, the boiler having convection heat exchange elements over which pass the products of combustion after they have passed through the chamber,
(*d*) a return duct connected at one end to openings into the combustion chamber associated with the fuel-burning means,
(*e*) gas re-circulation means connected to the other end of the duct to introduce thereto products of combustion that have passed over the said heat exchange elements of the boiler,
(*f*) flyash return means connected to the other end of the duct to introduce thereto flash that has accumulated in the boiler, and
(*g*) control means associated with the gas re-circulation means and the flyash return means alternately introducing products of combustion only into the duct at low load and flyash only into the duct at high load.

8. A steam generating unit, comprising
(*a*) a vertically-elongated combustion chamber provided at its lower end with abutments defining a lower high-temperature cell and having downwardly-directed surfaces,
(*b*) fuel-burning means mounted on the said surfaces for producing hot gaseous products of combustion,
(*c*) a boiler associated with the chamber including a superheater mounted adjacent the upper end of the chamber, the boiler having convection heat exchange elements over which pass the products of combustion after they have passed through the chamber, flyash collector means associated with portions of the boiler, said collector means discharging into an accumulator,
(*d*) a return duct connected at one end to openings into the high-temperature cell, the return duct underlying the said accumulator,
(*e*) gas re-circulation means connected to the other end of the duct to introduce thereto products of combustion that have passed over the said heat exchange elements of the boiler,
(*f*) flyash return means including a source of air connected to the other end of the duct introducing thereto flyash that has accumulated in the boiler, the amount of air introduced being substantially greater than is necessary to carry the flyash, and
(*g*) control means associated with the gas re-circulation means and the flyash return means to alternately introduce products of combustion only into the duct at low load to maintain the temperature of steam leaving the said superheater above a pre-determined temperature and flyash only into the duct at high load so that slagging may take place.

9. A steam generating unit, comprising
(*a*) a vertically-elongated combustion chamber provided at its lower end with abutments defining a high-temperature cell and having downwardly-directed surfaces,
(*b*) fuel-burning means including directional-flame intertube burners mounted on the said surfaces for producing hot gaseous products of combustion,
(*c*) a boiler associated with the chamber including a superheater mounted adjacent the upper end of the chamber, the boiler having convection heat exchange elements over which pass the products of combustion after they have passed through the chamber,
(*d*) flyash collector means associated with portions of the boiler, said collector means discharging into an accumulator,
(*e*) a return duct connected at one end to openings into the high-temperature cell, the return duct underlying the said accumulator,
(*f*) gas re-circulation means including a fan and a damper connected to the other end of the duct to introduce thereto relatively cool products of com-

bustion that have passed over the said heat exchange elements of the boiler,

(*g*) flyash return means including a valved connection from the accumulator and a source of pre-heated air connected to the other end of the duct to introduce thereto flyash that has been retained in the accumulator, the amount of air introduced being substantially greater than is necessary to carry the flyash, and

(*h*) control means associated with the gas re-circulation means and the flyash return means, alternately introducing products of combustion only into the duct at low load to maintain the temperature of steam leaving the superheater above a pre-determined value and flyash only into the duct at high load so that the slagging may take place.

10. A steam generating unit as recited in claim 9, wherein the amount of air introduced with the flyash is substantially equal to the difference between the total amount of air necessary in the chamber to complete combustion at high load and the total amount necessary to complete combustion at low load.

11. A steam generating unit, comprising

(*a*) a combustion chamber having an upper and a lower end,

(*b*) fuel-burning means associated with the lower end of the chamber for producing hot gaseous products of combustion, the chamber being provided at its lower end with abutments defining a lower high-temperature cell and have downwardly-directed surfaces on which the fuel-burning means is mounted and in which openings are formed,

(*c*) a boiler associated with the chamber including a superheater mounted adjacent the upper end of the chamber, the boiler having convection heat exchange elements over which pass the products of combustion after they have passed through the chamber,

(*d*) a return duct connected at one end to the openings into the combustion chamber,

(*e*) gas re-circulation means connected to the other end of the duct to introduce thereto products of combustion that have passed over the said heat exchange elements of the boiler,

(*f*) flyash return means connected to the other end of the duct to introduce thereto flyash that has accumulated in the boiler, a source of air connected to the duct and to a control means to introduce air into the duct at the same time as the flyash, the amount of air so introduced being substantially greater than is necessary to carry the flyash into the combustion chamber, and

(*g*) control means associated with the gas re-circulation means and the flyash return means introducing relatively large amounts of products of combustion into the duct at low load and relatively large amounts of flyash into the duct at high load, the control means acting to introduce an amount of products of combustion sufficient to maintain the temperature of steam leaving the said superheater above a pre-determined temperature, the lowest load at which flyash is introduced into the chamber being that load at which slagging does not take place and the highest load at which products of combustion are re-circulated to the chamber being that load at which the superheat temperature would otherwise drop below a pre-selected value, the gas re-circulation means being used to maintain the temperature superheat at a constant pre-determined value over a wide range of loads by making large incremental changes, desuperheater means connected to the superheater to produce the same effect by producing small incremental changes which are added algebraically to the changes produced by the gas re-circulation means.

References Cited in the file of this patent

UNITED STATES PATENTS

2,686,499	Sparks	Aug. 17, 1954
2,811,953	Feeley	Nov. 5, 1957
2,884,909	Koch	May 5, 1959
2,989,039	Frendberg et al.	June 20, 1961