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METHOD OF AND APPARATUS FOR VAPOR GENERATION BY AXIAL INTRODUCTION OF RECIRCULATED GASES INTO A CYCLONE FURNACE

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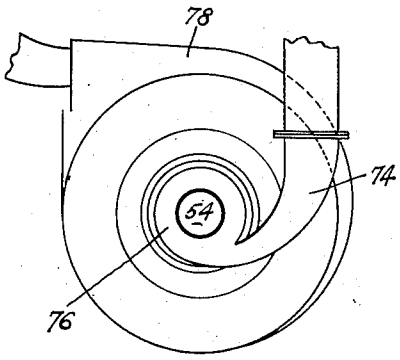


FIG. 2

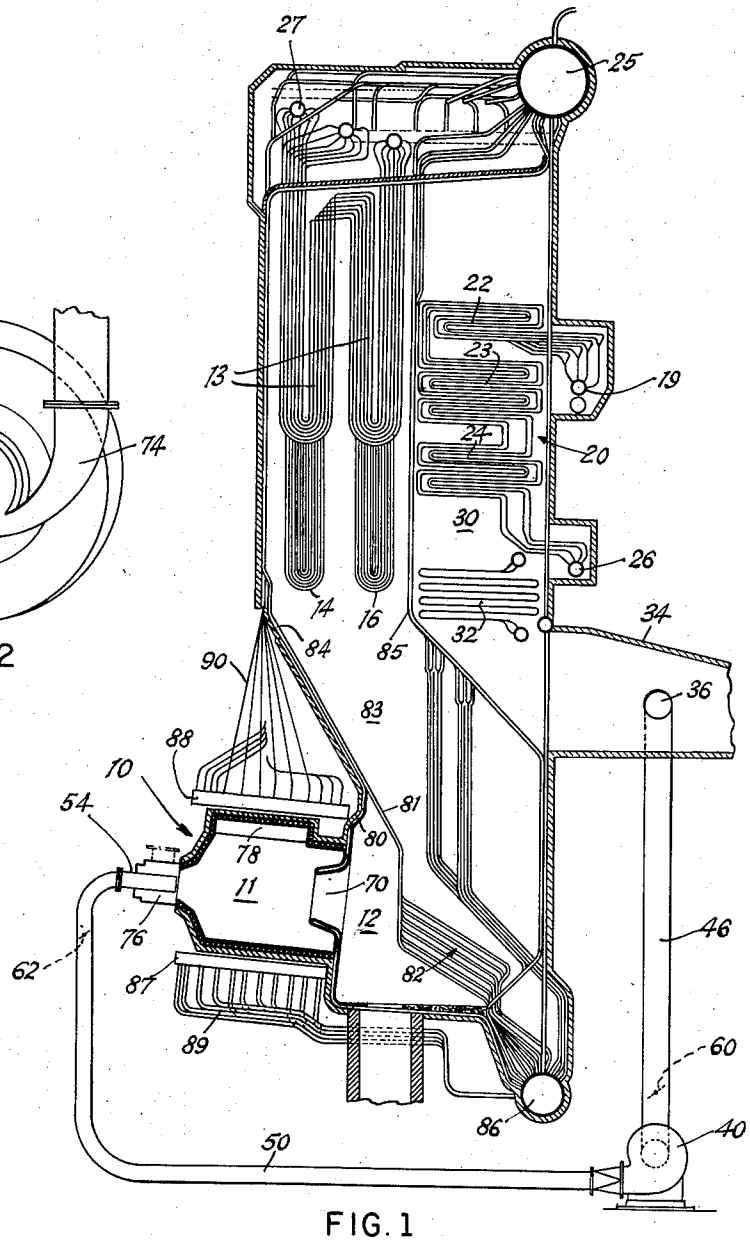


FIG. 1

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METHOD OF AND APPARATUS FOR VAPOR GENERATION BY AXIAL INTRODUCTION OF RECIRCULATED GASES INTO A CYCLONE FURNACE

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4 Claims. (Cl. 122—478)

This invention relates to a vapor generating and superheating unit in which the heat for vapor generation and for superheating of the generated vapor results from combustion in a cyclone furnace. The vapor generation takes place in tubes which are subject to the heat of the furnace, and a superheater for heating the generated vapor includes tubes which are subject to the heat of the combustion gases originating in the furnace. The invention is particularly characterized by the specific manner in which a recirculated gas system is associated with the cyclone furnace of the vapor generating and superheating unit. The recirculated gas system withdraws combustion gases which have been partially cooled by the heat absorption effected by the superheater. The withdrawn gases, at a temperature lower than the gases within the cyclone furnace, are, in a preferred embodiment of the invention, injected into the cyclone furnace combustion chamber in a direction axially related to the vortex or the cyclonic action of the gases in the combustion chamber, and the air and fuel mixtures within the cyclone. The cyclone furnace preferably has an axially and centrally arranged gas outlet, and the pertinent manner of introduction into the cyclone of the recirculated gases has the advantage that substantial mixing of the recirculated and lower temperature gases, with the higher temperature combustion gases is effected at the axial outlet of the cyclone, thus eliminating the necessity of a large volume and expensive gas mixing chamber ahead of the superheater.

The above advantage as to mixing of the recirculated gases and the unrecirculated gases is attained while maintaining the high temperature and cyclonic action characteristics of the cyclone. These characteristics result from the action of the fuel and air streams and the burning fuel within the cyclone. They are particularly evident when mixtures of solid fuel particles and high temperature combustion supporting air are introduced into the cyclone in such a manner as to set up a cyclonic action within the combustion zone of the cyclone. The high temperature of the combustion results in the fusion of the incombustible of the fuel and such fused particles are thrown against the circumferential wall of the cyclone until they gather and form a continuous sticky layer of slag substantially coating the interior surface of the cyclone. Continued cyclonic or vortex action resulting from the substantially tangential introduction of the fuel and air streams further promotes substantially complete combustion by the impact of fuel particles upon the sticky slag lining of the cyclone. This action results in substantially complete combustion before the gas outlet of the cyclone is reached, and the action is such that there is an almost complete elimination of fly-ash carried in suspension by the gases moving from the furnace and over the superheater and other components of the illustrative unit.

The above indicated centrifugal effects of the cyclone or vortex action within the combustion chamber take place predominantly in the radially outward part of the combustion zone which may be regarded as disposed externally of a central core of the cyclone extending axially through the combustion chamber directly towards an axially and centrally located gas outlet of the chamber. This invention takes advantage of these attributes of cyclonic or vortex fuel combustion by directing a stream of lower temperature and recirculated gases centrally and axially of the cyclonic action, and provides for a high degree of mixing of the lower temperature recirculated gases and the higher temperature combustion gases exiting from the cyclone, at the gas outlet of the combustion chamber. Thus the temperature of the gases exiting from the combustion chamber is reduced to values consonant with effective and high availability operation of the superheater and the vapor generating and superheating unit. In the interest of optimum combustion, temperatures are maintained at high values, of the range of 2400° F. to 3000° F. in the immediate fuel burning zone, and yet the temperatures of the gases exiting from the combustion zone may be reduced to effective values of the order of 1900° F. This method and arangement of elements permits the effective operation of the superheater to attain, for example, continuously, superheat values of the order of 1100° F. without involving exiting gas temperatures so high as to involve the maintenance of any remaining suspended particles of incombustible in the exiting gases in such a condition that they will stick to the superheater tubes and thereby interfere with effective superheater operation.

The above indicated method and apparatus are intended for controlled or variable operation in which the operation of the superheater is so affected that there will be compensation for its inherent tendency (in the event that the superheater is a convection superheater) to result in superheat temperatures substantially below an optimum or predetermined temperature as the vapor generating load and the rate of firing of the furnace decrease toward minimum rates.

The invention also involves a method of burning fuel in which fuel and air mixtures are interoduced in a cyclone effecting manner into a confined combustion zone, the igniting of the fuel and air mixtures, the introducing into the combustion zone of a stream of lower temperature gases directed centrally and axially of the cyclone action within the combustion zone, and the mixing of the lower temperature gases and the higher temperature combustion gases at the gas outlet of the combustion zone.

The invention is also considered to involve a method of operation of a cyclone furnace, the method involving the steps or acts which have been above related.

The invention will be concisely and clearly set forth in the appended claims, but for a more complete understanding of the invention, its uses, and advantages, reference should be had to the following description which relates to apparatus indicated in the accompanying drawings.

Of the drawings:

Fig. 1 is a somewhat diagrammatic view in the nature of a sectional elevation, indicating vapor generating and superheating unit in connection with which the invention is described; and

Fig. 2 is an end elevation of the cyclone furnace of the Fig. 1 unit.

Fig. 1 shows a cyclone furnace generally indicated at **10**. This furnace includes a generally cylindrical cyclone combustion chamber **11** receiving crushed coal and combustion supporting air in a substantially tangential direction so as to effect a cyclone action in the burning of the fuel within the combustion chamber.

The cyclone furnace which is generally of the class indicated of the U. S. Patent 2,357,301 to Bailey et al., the combustion gases exiting from the cyclone combustion chamber **11** may enter a primary furnace chamber **12**

from which the combustion gases pass to the zone of a high temperature convection superheater **13** involving rows of pertinent platens **14** and **16** which constitute banks of tubes over which combustion gases flow. The superheater receives superheated steam from the outlet header **19** of the primary superheater **20** which may include the banks of tubes **22–24** preferably arranged transversely of gas flow in a down flow pass **30** which receives gases at its upper end from the space in which the high temperature superheater **13** is disposed. Saturated steam flows through appropriate tubes from the drum **25** to the inlet header **26** of the primary superheater **20**, and other tubes lead from the header **19** to the inlet header **27** of the superheater **13**.

Within the downflow pass **30** and below the primary superheater **20** is an economizer **32** subject to the flow of combustion gases.

Below the economizer there is ductwork **34** which under normal conditions directs the gas flow to an air heater and thence to a stack.

Below the economizer the ductwork **34** has a lateral opening **36** through which some of the combustion gases are withdrawn, recirculated, and introduced in a unidirectional stream the direction of which is parallel and coincident with the longitudinal axis of the cyclone combustion chamber **11**.

The recirculated gas system includes a fan **40** the inlet of which communicates by a duct **46**, with the opening **36** in the ductwork below the economizer. The outlet of the fan **40** is connected by the ductwork **50** to the tubular inlet **54** arranged centrally and directed axially of the cyclone combustion chamber. The flow of gases through the recirculated gas system may be controlled by appropriate dampers such as indicated at **60** and **62**. It is within the purview of the invention that the recirculated gas flow will be controlled with respect to the rate of firing of the cyclone furnace to permit optimum gas temperatures beyond the outlet **70** of the cyclone combustion chamber and to promote the maintenance of a predetermined superheat temperature.

The gas outlet **70** of the combustion chamber **11** is preferably centrally and axially arranged, and this structure, in combination with the central and axial direction of the introduced recirculated gas promotes a high degree of mixing of the recirculated gas and the high temperature combustion gases, in the region of the outlet of the combustion chamber.

The cyclonic action of the combustion chamber is promoted by the introduction of the secondary air in a substantially tangential direction through circumferential openings such as the opening **78**. This cyclonic action within the combustion chamber **11** is also promoted by the substantially tangential introduction of the primary air and fuel stream with the respect to the recirculated gas inlet duct **54**. A stream of fuel (crushed coal) and air is introduced through the volute inlet **74** (Fig. 2) and enters the annular passage **76** surrounding the recirculated gas inlet duct **54**. Secondary air enters the combustion chamber **11** substantially tangentially through the inlet **78**.

The manner of introduction into the cyclone combustion chamber of the fuel and air stream, and the accompanying ignition of the accompanying fuel in the combustion chamber develops temperatures well above the fusion temperatures of the incombustible components of the fuel. Such fused particles are thrown against the circumferential wall of the combustion chamber where they fuse and agglomerate to form a substantially complete combustion chamber lining of molten slag. Subsequent centrifugal effects of the cyclonic action within the combustion chamber project fuel particles into the slag lining and thereby promote rapid and complete combustion. This action is such that the percentage of fly-ash exiting from a cyclone furnace is substantially negligible.

The high temperature and the above indicated centrifugal action in the combustion chamber is effective mainly within an annular zone surrounding what may be termed the core of the pertinent cyclonic action so that the unidirectional axial injection of the stream of recirculated gases affects the desired results while maintaining the high temperatures and the cyclonic fuel combustion within the combustion chamber.

The high temperature gases resulting from the combustion must exit through the centrally arranged gas outlet **70**, and this fact, together with the arrangement of the component elements, results in a high degree of mixing of the high temperature combustion gases and the lower temperature recirculated gases in the zone of the gas outlet. This reduction of gas temperature may be such that the high temperature superheater **13** may be disposed at a position much nearer the combustion chamber outlet than is indicated in Fig. 1. In fact, it may be such that the gases from the gas outlet **70** may immediately contact the tubular elements of the superheater.

It is to be understood that the use of the vapor generating and superheating unit of Fig. 1 is to promote a clear description of the invention and that the invention is such that many parts of the unit may be differently constructed and arranged, one example of such other arrangement being indicated above.

The walls of the substantially cylindrical combustion chamber **11** preferably include vapor generating tubes connected into the circulatory system which includes wall tubes **80** and **81**, forming walls of the primary furnace chamber which receives the gas discharged from the combustion chamber **11**. These tubes are appropriately connected to a lower drum and their upper ends are connected to a vapor and liquid drum by appropriate headers and tubes.

Some of the above indicated tubes have their lower ends arranged in screen formation across the gas outlet **82** through which the gases pass from the primary furnace chamber **11** into the secondary furance chamber **83** which directs the gases over the high temperature superheater **13**.

The walls of the secondary furance chamber **83** are preferably defined by rows of vapor generating wall tubes such as **84** and **85** having their lower ends appropriately connected to the lower drum **86** and their upper ends connecting with the vapor and liquid drum **25**.

The combustion chamber wall tubes may be of semicircular formation, connecting the lower cyclone header **87** with the upper cyclone header **88** with these headers being appropriately connected into the circulatory system by the circulators **89** (leading from the drum **86**) and by the risers **90**, leading upwardly from the header **88** to the drum **25**.

Although the invention as been described with reference to the details of preferred embodiments, it is to be understood that the invention is not to be considered as limited to all of the details thereof. It is rather to be taken as of a scope commensurate with the scope of the subjoined claims.

What is claimed is:

1. A vapor generating and superheating unit comprising walls defining an elongated heating gas chamber, a natural circulation vapor generating system including vapor generating tubes lining walls of said gas chamber, a convection heated vapor superheater arranged to be heated by heating gas in said gas chamber, means for supplying heating gas to said gas chamber comprising a cyclone furnace chamber of circular transverse cross-section having a restricted gas outlet to said gas chamber at one end thereof, vapor generating tubes lining the walls of said furnace chamber and proportioned to maintain a furnace chamber temperature above the fuel ash fusion temperature in the normal operating load range, means for supplying a combustible mixture of slag-form-

ing particulate fuel and air to the opposite end of said furnace chamber in a direction producing a whirling stream of fuel and air and burning the fuel in a helical flow path along the circumferential wall of said furnace chamber towards said restricted gas outlet while depositing a layer of molten slag on said circumferential wall, and means for increasing the convection vapor superheating effect comprising means for withdrawing heating gas from said gas chamber downstream of said vapor superheater and introducing the withdrawn gas into the fuel inlet end of said furnace chamber axially thereof and in a direction towards said restricted gas outlet so as to mix with the fresh combustion gases leaving through said restricted gas outlet.

2. A vapor generating and superheating unit comprising walls defining an elongated heating gas chamber, a natural circulation vapor generating system including vapor generating tubes lining walls of said gas chamber, a convection heated vapor superheater arranged to be heated by heating gas in said gas chamber, means for supplying heating gas to said gas chamber comprising a cyclone furnace chamber of circular transverse cross-section arranged with its axis substantially horizontal and having a restricted gas outlet to said gas chamber at one end thereof, vapor generating tubes lining the walls of said furnace chamber and proportioned to maintain a furnace chamber temperature above the fuel ash fusion temperature in the normal operating load range, a circular fuel inlet chamber at the opposite end of said furnace chamber, means for supplying a combustible mixture of slag-forming particulate fuel and air to said fuel inlet chamber in a direction producing a whirling stream of fuel and air therein and burning the fuel in a helical flow path along the circumferential wall of said furnace chamber towards said restricted gas outlet while depositing a layer of molten slag on said circumferential wall, and means for increasing the convection vapor superheating effect comprising means for withdrawing heating gas from said gas chamber downstream of said vapor superheater and a gas discharge pipe arranged axially of said fuel inlet chamber for introducing the withdrawn gas into the fuel inlet end of said furnace chamber axially thereof and in a direction towards said restricted gas outlet so as to mix with the fresh combustion gases leaving through said restricted gas outlet.

3. In combination, a cyclone furnace chamber of circular transverse cross-section having a restricted gas outlet at one end thereof, vapor generating tubes lining the

walls of said furnace chamber and proportioned to maintain a furnace chamber temperature above the fuel ash fusion temperature in the normal operating load range, means for supplying a combustible mixture of slag-forming particulate fuel and air to the opposite end of said furnace chamber in a direction producing a whirling stream of fuel and air and burning the fuel in a helical flow path along the circumferential wall of said furnace chamber towards said restricted gas outlet while depositing a layer of molten slag on said circumferential wall, and means for introducing relatively cool inert gas into the fuel inlet end of said furnace chamber axially thereof and in a direction towards said restricted gas outlet so as to mix with the fresh combustion gases leaving through said restricted gas outlet.

4. In combination, a cyclone furnace chamber of circular transverse cross-section arranged with its axis substantially horizontal and having a restricted gas outlet to said heating gas chamber at one end thereof, vapor generating tubes lining the walls of said furnace chamber and proportioned to maintain a furnace chamber temperature above the fuel ash fusion temperature in the normal operating load range, a circular fuel inlet chamber at the opposite end of said furnace chamber, means for supplying a combustible mixture of slag-forming particulate fuel and air to said fuel inlet chamber in a direction producing a whirling stream of fuel and air therein and burning the fuel in a helical flow path along the circumferential wall of said furnace chamber towards said restricted gas outlet while depositing a layer of molten slag on said circumferential wall, a gas discharge pipe arranged axially of said fuel inlet chamber, and means for introducing relatively cool inert gas into the fuel inlet end of said furnace chamber axially thereof and in a direction towards said restricted gas outlet so as to mix with the fresh combustion gases leaving through said restricted gas outlet.

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