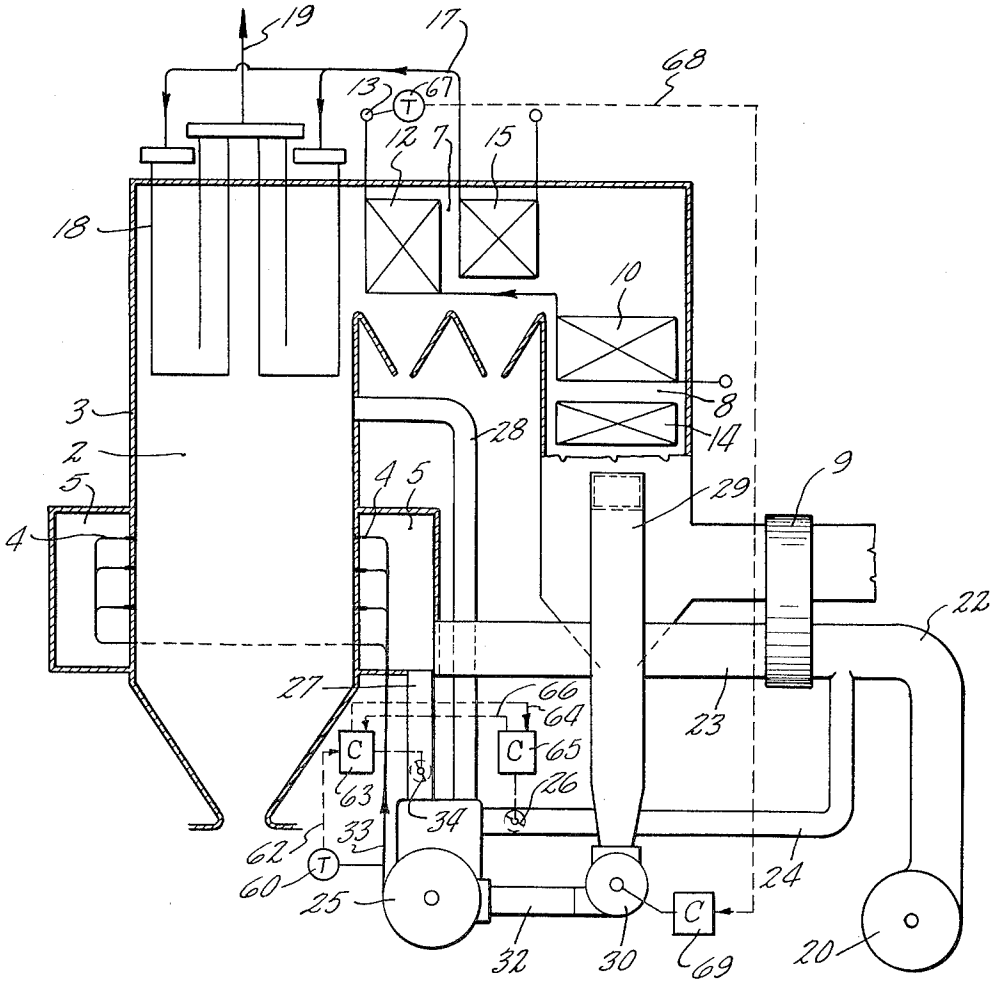
April 19, 1966 E. M. POWELL ETAL 3,246,635

VAPOR GENERATOR WITH GAS RECIRCULATION

Filed April 7, 1965 3 Sheets-Sheet 1

FIG. 1



VAPOR GENERATOR WITH GAS RECIRCULATION

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FIG. 2

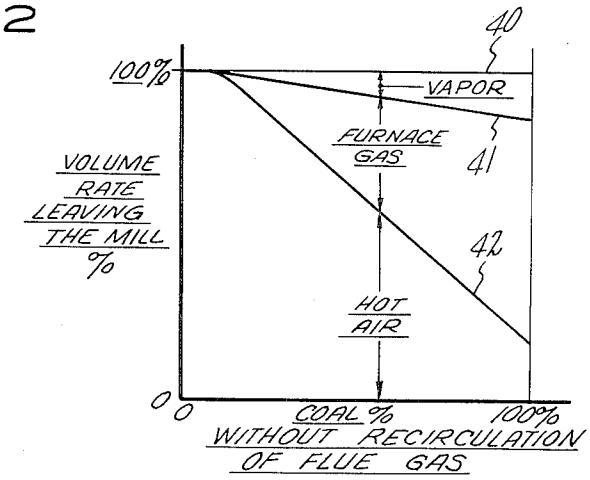

FIG. 3

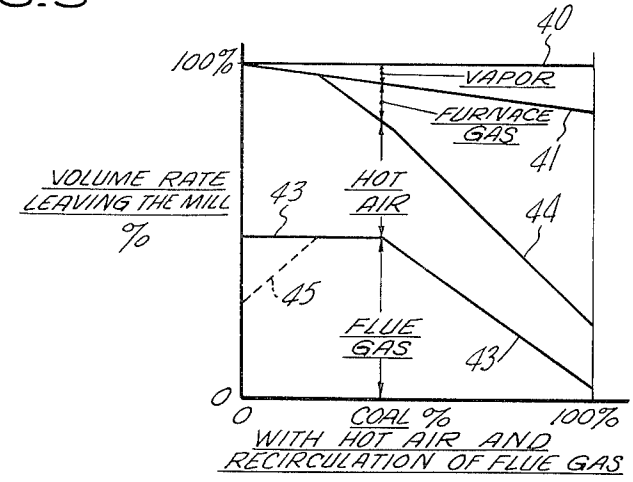

FIG. 4

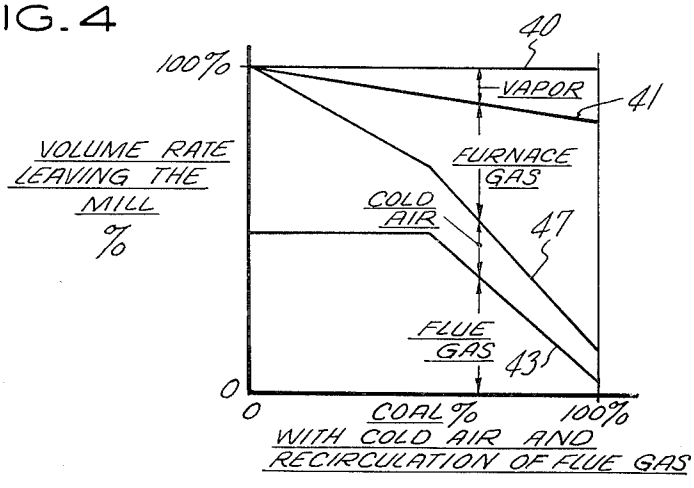

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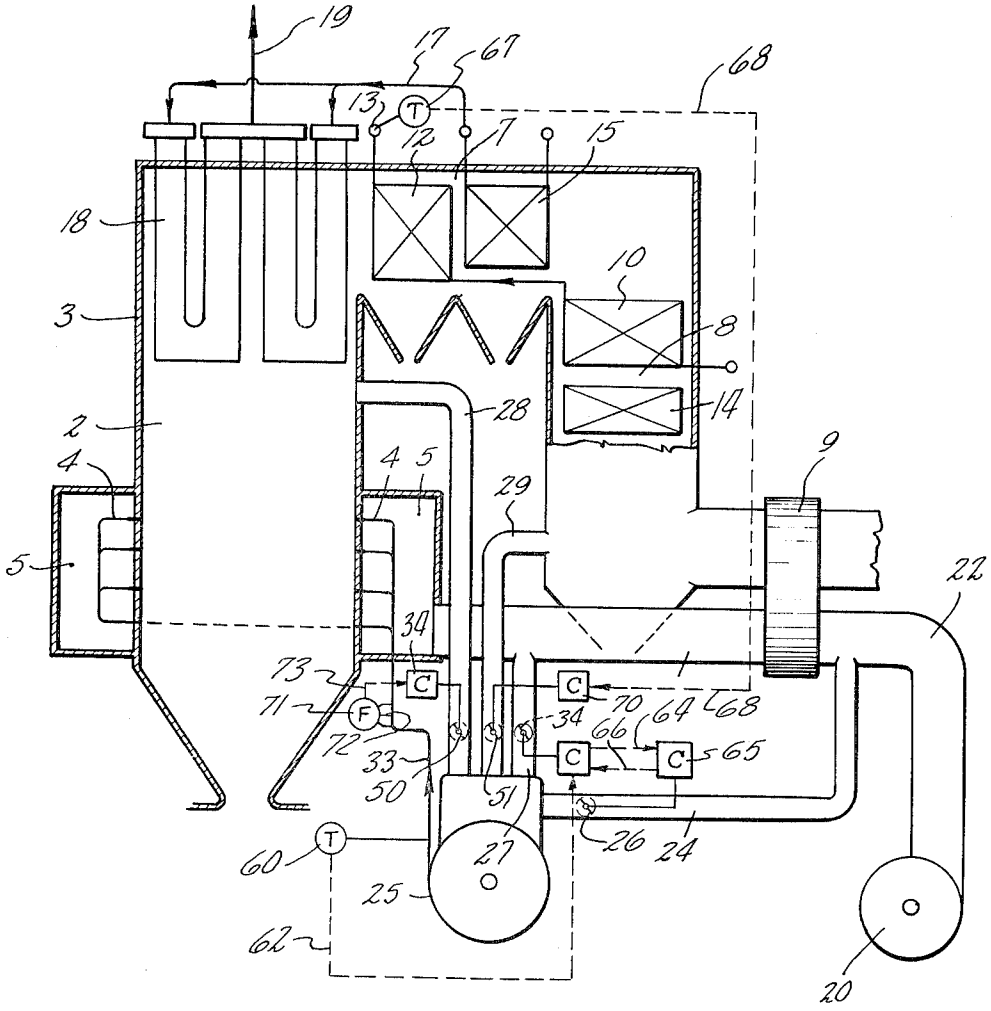
FIG. 5



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VAPOR GENERATOR WITH GAS RECIRCULATION

Elno M. Powell and Robert H. Wolin, Avon, Conn., assignors to Combustion Engineering, Inc., Windsor, Conn., a corporation of Delaware

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11 Claims. (Cl. 122—479)

This application is a continuation-in-part of our prior co-pending application Serial No. 331,751 filed on December 19, 1963, now abandoned.

This invention relates to steam generators which burn high moisture content coal and in particular to a method and apparatus for using gas recirculation for steam temperature control therein.

High moisture content coals such as brown coal require substantial drying before they can be introduced into a furnace. This is accomplished in the mill which simultaneously pulverizes and dries the coal, an integral part of this mill being a paddle wheel fan or blower of some sort. In order to obtain sufficient heat for adequate drying, gas from the furnace is admitted to the mill suction in quantities required for satisfactory drying. The remainder of the gas which the mill draws is supplied by preheated air taken from the air stream after the air heater. A characteristic of such mills is that the volume air flow leaving the mill is essentially constant regardless of the quantity of fuel being pulverized.

Brown coal not only has a high moisture content but usually a high ash content as well. This in combination with the large quantity of inert gas which is being supplied through the mill creates a situation where it is very difficult to maintain proper ignition of the fires. Introduction of recirculated gas into the furnace for steam temperature control would further increase the quantity of inert gas and aggravate this already difficult situation of flame stability. Superheat and reheat temperature control on such jobs has therefore been limited to alternative means such as gas bypass and fluid-to-fluid heat exchangers.

In the instant invention gas recirculation is made possible by selectively supplying gas to the mill from various sources thereby concurrently obtaining the benefits of high gas temperature for drying and steam temperature control via gas recirculation.

It is an object of the invention to provide an improved vapor generator.

Another object of the invention is to provide a practical means of steam temperature control using gas recirculation in steam generators burning high moisture coal.

A further object is to maintain satisfactory drying and therefore proper mill air temperatures while firing high moisture coal.

Other and further objects of the invention will become apparent to those skilled in the art as the description proceeds.

With the aforementioned objects in view, the invention comprises an arrangement, construction and combination of the elements of the inventive organization in such a manner as to attain the results desired, as hereinafter more particularly set forth in the following detailed description of illustrative embodiments, these embodiments being shown by the accompanying drawings wherein:

FIGURE 1 shows a preferred embodiment of the invention where a gas recirculation fan is used to move the flue gas from the rear pass of the boiler to the mill;

FIGURE 2 illustrates the source of the gas flow which is leaving the mill when there is no recirculation through the duct from the convection pass;

FIGURE 3 shows the source of gas which is leaving the mill when flue gas is recirculated from the convection pass for steam temperature control and hot air is introduced into the mill;

FIGURE 4 shows the source of gas which is leaving the mill when flue gas is recirculated from the convection pass for steam temperature control and cold air is introduced into the mill; and

FIGURE 5 illustrates another embodiment of the invention which differs from FIGURE 1 in that all motive power for recirculation is supplied by the mill, thereby omitting the gas recirculation fan, and dampers are installed in the furnace gas recirculating duct.

FIGURE 1 illustrates a steam generator having a furnace **2** surrounded by radiant heating surface **3**. Fuel enters through burners **4** and air through windbox **5** so that combustion takes place in the furnace **2**. Hot combustion gases then pass through horizontal flue **7** thence through vertical flue or rear gas pass **8** passing out of the unit through air heater **9** as cooler gas.

Disposed within the steam generator is low temperature reheater **10** and high temperature reheater **12** with steam passing therethrough to be reheated, returning to a steam turbine (not shown) from header **13**. The rear gas pass **8** also includes economizer surface **14**. Superheating is accomplished in low temperature superheater **15** with steam being conveyed through pipe **17** to high temperature superheater **18** from which it is conveyed to the steam turbine (not shown) through steam pipe **19**.

Combustion supporting air is supplied from forced draft fan **20** through duct **22** and through air heater **9**. This air may then be supplied through duct **23** to windbox **5** from which it is delivered to the furnace **2** as combustion supporting air. Cold air ahead of the air heater may be withdrawn through duct **24** for supply to the mill **25**, while hot air may be withdrawn from duct **23** through duct **27** to mill **25**. The pressure of the air at each of these locations is higher than the furnace and mill suction pressures.

Furnace gases may be recirculated from the furnace **2** through the furnace gas recirculating duct **28** to mill **25**, while cooler gas from the rear gas pass **8** may be recirculated through duct **29** and gas recirculating fan **30** reaching the mill through duct **32**. Fuel being supplied to the mill from a feeder (not shown) together with the drying gases is conducted from the mill through coal pipes **33** to burners **4**. The temperature of this mixture, known as mill air temperature, is maintained by controlling the relative quantity of these gases entering the mill.

Operation of the unit without the use of gas recirculating duct **29**, or air duct **24**, is as follows. Mill **25** supplies through pipe **33** the amount of fuel which is being fed to the mill plus an essentially constant volume of gas. At high loads where considerable drying is required the mill temperature tends to be low, whereby air damper **34** is closed down decreasing the relatively cool air supply to the mill. The mill taking essentially constant flow draws more hot furnace gas through duct **28**, thereby raising the mill temperature. Thus the preheated air supplied through duct **27** is regulated such that the desired temperature is obtained in the gases leaving the mill. As load is decreased the required drying decreases, and the mill temperature tends to increase. The air damper

34 is then opened admitting more relatively cool air and the flow of recirculated furnace gas is decreased.

This is illustrated in FIGURE 2 where the abscissa is coal supplied to the mill as percent of rating and the ordinant is the volume of gases leaving the mill. The coal quantity is, in general, in proportion to steam generator output. Line **40** illustrates the total volume leaving the mill which is essentially constant for any capacity. The space between line **40** and line **41** shows the amount of vapor in the gases leaving the mill as a result of the coal drying, where the space between lines **41** and lines **42** shows the portion of the gas leaving the mill which is supplied through the furnace recirculation duct **28**. The remainder between line **42** and the base line shows the quantity of air which is supplied through duct **27**.

The foregoing discussion concerned mills where the fan characteristics were such that essentially constant volume flow occurs when the mill is floating on an open recirculating system. If, however, other fan characteristics are encountered, dampers may be installed in the furnace gas recirculating duct **28** to control this gas such that the flow leaving the mill is constant.

It is well known that increased gas flow through convection sections such as horizontal flue **7** and particularly in vertical flue **8** by means of gas recirculation is effective to increase heat transfer in those areas thereby increasing the steam temperature leaving sections such as reheaters **10** and **12** and superheater **15**. In the illustrated embodiments gas recirculation is employed to control the steam temperature leaving reheater **12** through header **13**, although it could equally be used to control superheater temperature.

In this invention the flue gas which is recirculated for steam temperature control through duct **29** is introduced into the mill **25**. The temperature of this flue gas is lower than the furnace gas which is being supplied to the mill and higher than the preheated air which is being supplied to the mill. During this operation the mill still delivers the same volume of gas that it had previously, but since the flue gas is being introduced, the furnace gas and hot air must decrease. The hot air dampers **34** are controlled in the same manner as they were previously to hold the desired mill air temperature, while the recirculated furnace gas through duct **28** readjusts itself, or alternately may be controlled by dampers to maintain the proper flow.

The operation of the preceding paragraph may be obtained with the control equipment illustrated in FIGURE 1 wherein temperature transmitter **60** detects the mill air temperature in line **33**. This transmitter sends a control signal through control line **62** to controller **63**. This controller operates the damper **34** to maintain the preselected temperature in line **33**. When this damper reaches its wide open position, a control signal is emitted through control line **64** to controller **65** which operates to open control damper **26** so that the temperature in line **33** may be maintained. When damper **26** reaches a wide open position, a control signal is emitted from controller **65** through control line **66** back to controller **63** and opreates to close damper **34** whereby an increased percentage of the air is passed through the cold air duct **24**. The steam temperature leaving reheater **12** is sensed by temperature transmitter **67** which emits a control signal through line **68** to controller **69**. This operates to vary the speed of the gas recirculation fan **30** carrying the gas recirculation through duct **29** and accordingly regulating the temperature of the steam leaving the reheater **12**. The previously described mill air temperature control system operates to maintain the mill air temperature at a preselected value.

This is illustrated in FIGURE 3 where the desired flue gas quantity to obtain proper reheat temperatures is shown by line **43**. The total volume leaving the mill is again shown by line **40** and the vapor in the gases leaving the mill is shown by the difference between lines **40** and **41**. The hot air is reduced to that now indicated by the difference between lines **43** and **44**, while the furnace gas is reduced to that indicated by the difference between lines **41** and **44**. At low loadings on the mill the recirculated flue gas may have to be reduced to avoid overheating of the mill, as indicated by line **45**.

The amount of recirculated gas required for steam temperature control depends on the particular design of the steam generator. It is possible that in some designs more flue gas would have to be recirculated than in the instant embodiment and therefore this problem of overheating the mill may occur at higher loadings. A similar situation occurs where fewer mills are used for low load operation, thereby increasing the gas recirculation per mill. This overheating can be limited by introducing to the mill, in place of preheated air, the air ahead of the preheater through duct **24**. This is illustrated in FIGURE 4 where line **43** again shows the required flue gas for steam temperature control. The difference between line **43** and line **47** shows the cold air requirements for the mill while the difference between line **41** and line **47** shows the furnace gas requirements. It can be seen that in this type operation less air is required and more furnace gas is required than is the case when hot air is being recirculated. It follows that more recirculated flue gas can be tolerated before the furnace gas is decreased to zero.

Operation of this system in the preferred embodiment would involve recirculating gas to obtain proper steam temperature. The hot air to the mill and the recirculated furnace gas would be controlled so that a constant gas flow is held leaving the mill at the proper temperature. If the mill temperature rises above the desired level and at the same time there is no furnace gas being recirculated, cold air from ahead of the air heater would be introduced in place of the hot air to hold the mill temperature down to acceptable limits. It is desirable whenever possible to use the preheated air for the mill since the additional air flow passing through the air heater has a beneficial effect on steam generator efficiency.

Since all of these variables are intimately related, control of any of the controlled items could be initiated by any one of the controlling variables; for instance, when it is desired to decrease the reheat temperature, the hot air dampers **34** could be opened thereby increasing the flow through duct **27** and concurrently decreasing the flow through duct **28**, thereby decreasing the mill temperature, while the volume leaving the mill remains constant. Recirculated gas flow would then be decreased which would permit an increase in the recirculated furnace gas flowing through duct **28**, which will return the mill temperature to the desired level. In this way steam temperature is controlled by movement of the hot air dampers **34** while mill temperature is maintained through control of the recirculating flue gas flow.

FIGURE 5 illustrates another embodiment of our invention where the sole motive power for the gas recirculation is the mill itself. The general structure of the steam generator is similar to that of FIGURE 1, the only difference being the arrangement of the gas and air ducts to the mill. Control dampers **50** are included in duct **28** for control of the recirculated furnace gases. The flue gas is recirculated through duct **29** being controlled by dampers **51**. The hot air again passes through duct **27** through dampers **34** to the mill while the cold air again passes through duct **24** and dampers **26** to the mill.

When excess mill temperatures are obtained with recirculated furnace gas at zero, the cold air through duct **24** is again used. Considering, as illustrative the operation of only ducts **28** and **29** and **27**, the dampers on these three ducts are controlled to maintain total mill flow, mill temperature, and proper recirculation for reheat steam temperature. Dampers **51** may be opened to increase flue gas recirculation thereby increasing reheat steam temperature while damper **34** controlling the hot

air is decreased to restore the mill flow to its proper amount, and furnace recirculating gas damper **50** may be closed to maintain the proper mill air temperature.

The apparatus shown in FIGURE 5 may be controlled in a manner similar to that of FIGURE 1 wherein the temperature transmitter **60** detects the temperature of the mill air in pipe **33** and operates dampers **34** and **26** to maintain the temperature at a preselected value. The reheated steam temperature is detected by temperature transmitter **67** which emits a control signal through control line **68** to controller **70** which operates damper **51** to control gas recirculation in response to reheated steam temperature. In this manner the reheated steam temperature may be maintained at a preselected value. Flow meter **71** is connected across orifice **72** in line **33** to determine the total flow of mill air. A signal is emitted from this transmitter through control line **73** to controller **74** which operates damper **50** to maintain the flow in line **33** at a preselected value.

The volume of gases leaving the mill may be varied with load as desired in line with another mode of mill operation.

While we have illustrated and described a preferred embodiment of our invention it is to be understood that such is merely illustrative and not restrictive and that variations and modifications may be made therein without departing from the spirit and scope of the invention. We therefore do not wish to be limited to the precise details set forth but desire to avail ourselves of such changes as fall within the purview of our invention.

What we claim is:

1. A vapor generator comprising in combination a furnace having heat exchange tubes on its wall, a gas pass extending from the furnace, means for heating vapor having at least a portion thereof disposed in said gas pass, means for firing said vapor generator with a particulate fuel of high moisture content and for regulating the temperature of the vapor heated in said vapor heating means comprising; a pulverizing means, the effluent from which is conveyed to the furnace, means supplying said fuel to the pulverizing means; means passing a hot gaseous medium through the pulverizing means for fuel entrainment and drying including means conveying thereto hot gases from the furnace, separate means conveying thereto combustion gases which have traversed said vapor heating means, means conveying thereto air; and means regulating the supply of gaseous medium to the pulverizing means in response to the temperature of the vapor leaving said vapor heating means and to meet the temperature and flow requirements of the mill.

2. A vapor generator including a fluid cooled furnace, vapor heating means disposed so that gases produced in said furnace pass thereover, means for firing the furnace with a high moisture content fuel including a gas swept pulverizing means the effluent of which is conveyed to and introduced into the furnace; means for supplying said pulverizing means with a high moisture content fuel and with carrying and drying gases, with these latter including air, hot gases from the furnace at a location upstream of said vapor heating means, and gases which have traversed at least a portion of said vapor heating means; means for regulating the supply of gases which have traversed said vapor heating means in response to the temperature of the heated vapor independent of the firing rate; and means for regulating the supply of other gases to the pulverizing means in response to the temperature of the pulverizing means effluent.

3. An apparatus as in claim **2** where the means for supplying said pulverizer means with carrying and drying gases including gases which have traversed at least a portion of said vapor heating means includes a gas recirculation fan receiving gases which have traversed at least a portion of said vapor heating means and delivering these gases to said pulverizing means.

4. An apparatus as in claim **2** where the heating means comprises steam reheating surface.

5. In combination a steam generator for burning high moisture content fuel and a mill for pulverizing and drying the fuel, comprising: a furnace for the combustion of the fuel, hot gases thereby being formed; an air heater; a flue conveying the hot gases to the air heater; steam heating surface disposed within the flue, for heating steam, and cooling the gases; means for supplying air at elevated pressure to the air heater; means for conveying the heated air to the furnace; means for conveying hot gases from the furnace to the mill; means for conveying cooled gases to the mill from the flue at a location downstream of at least a portion of the steam heating surface, but upstream of the air heater, and means for regulating the flow of these cooled gases in response to the temperature of steam leaving said steam heating surface; means for conveying a portion of the heated air to the mill; means for conveying air at elevated pressure to the mill from a location ahead of the air heater; means for supplying fuel to the mill; means for conveying the mill products to the furnace; and means for regulating the flow of air to the mill in response to the temperature of said mill products.

6. In a steam generator for burning high moisture content solid fuel, having a mill for pulverizing this fuel, and steam heating surface disposed within the steam generator, the method of operation comprising: burning fuel in a combustion zone, thereby forming hot gases; cooling these gases by transferring heat to steam; determining a measure of the quantity of heat transferred to the steam; conveying a portion of the hot gases from the combustion zone to the mill; conveying a portion of the cooled gases to the mill; regulating the flow of these cooled gases in response to said measure of heat transferred to control the quantity of heat transferred to steam; introducing air into the mill; introducing fuel into the mill; and conveying the products from the mill to the combustion zone, for the burning of fuel therein.

7. The method of operation as in claim **6** including also the step of regulating the air introduced to the mill to control mill air temperature.

8. The method of operation as in claim **7** including also the step of regulating the remaining gaseous mediums entering the mill to maintain the volume flow of products leaving the mill essentially constant.

9. The method of operation as in claim **7** where the volume flow leaving the mill is maintained essentially constant by allowing the portion of hot gases being conveyed from the furnace to the mill, to assume a quantity which meets the mill's natural volume demand.

10. In a steam generator having steam heating surfaces disposed therein, and a mill for the pulverizing and drying of high moisture content fuel, the method of operation comprising: burning fuel in a combustion zone forming hot gases; passing these gases over steam heating surface to transfer heat to the steam and cool the gases; measuring the temperature of the steam so heated; conveying a portion of the hot gases from the combustion zone to the mill; conveying a portion of the cooled gases to the mill; supplying air to the mill; feeding fuel into the mill; conveying the mill products to the combustion zone; controlling one of the gaseous mediums entering the mill in response to the steam temperature to control steam temperature; controlling a second gaseous medium entering the mill to control mill temperature; and controlling the remaining gaseous medium entering the mill to control the volume flow leaving the mill.

11. A vapor generator including a fluid cooled furnace, vapor heating means disposed so that the gases produced in said furnace pass thereover, means for firing a furnace with a high moisture content fuel including a gas swept pulverizing means the effluent of which is conveyed to and introduced into the furnace; means for supplying said pulverizing means with a high moisture content fuel and with carrying and drying gases, with these latter including

air, hot gases from the furnace at a location upstream of said vapor heating means, and gases which have traversed at least a portion of said vapor heating means; means for regulating the supply of gases which have traversed said vapor heating means in response to the temperature of the heated vapor independently of the firing rate; means for regulating the supply of one of the remaining gases to control the flow rate of gases through said pulverizing means; and means for controlling the other of said remaining gases to control the temperature of the gases leaving said pulverizing means.

References Cited by the Examiner

UNITED STATES PATENTS

2,812,747	11/1957	Armacost	122—479

FOREIGN PATENTS

1,202,239	7/1959	France.
312,707	6/1929	Great Britain.
756,803	9/1956	Great Britain.

JAMES W. WESTHAVER, *Primary Examiner.*
CHARLES J. MYHRE, *Examiner.*