March 10, 1964 W. L. SAGE ET AL 3,124,086

SLURRY FIRED CYCLONE FURNACE

Filed Dec. 8, 1960 2 Sheets-Sheet 1

FIG. 1

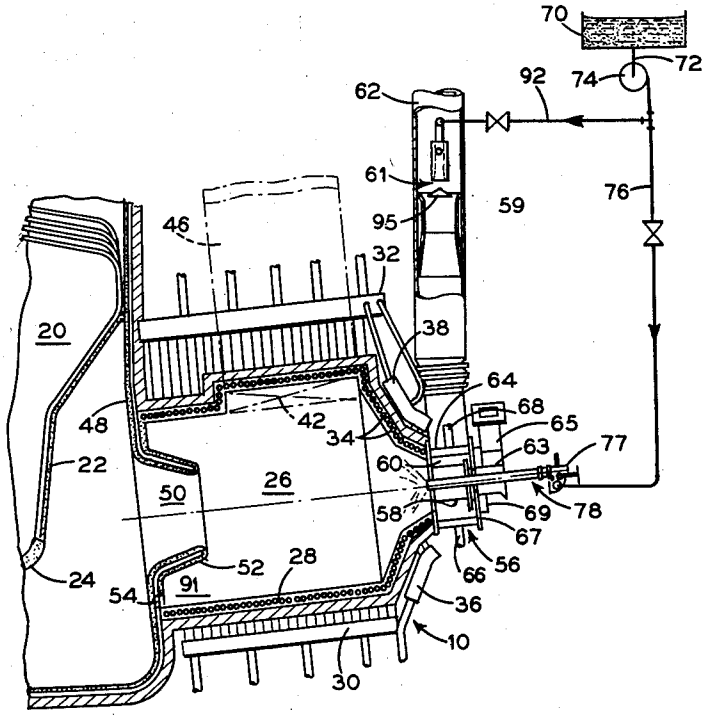
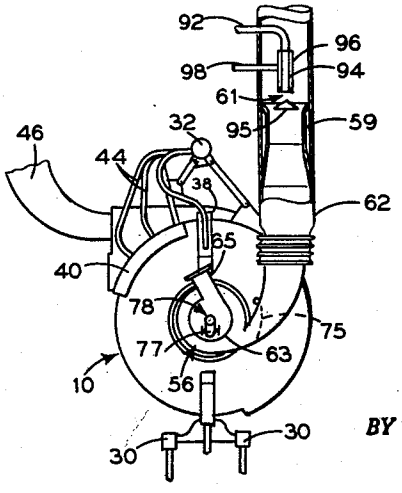


FIG. 2



BY

INVENTORS
Warnie L. Sage
Fritz L. Hemker
Ralph M. Hardgrove

ATTORNEY

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FIG. 3

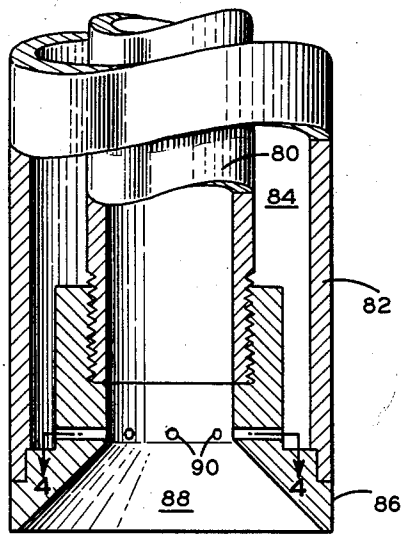
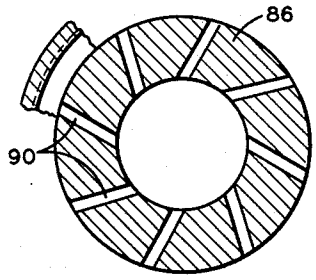


FIG. 4



INVENTORS
Warnie L. Sage
Fritz L. Hemker
Ralph M. Hardgrove

BY J. P. Moran
ATTORNEY

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SLURRY FIRED CYCLONE FURNACE

Warnie L. Sage, Louisville, Fritz L. Hemker, Wadsworth, and Ralph M. Hardgrove, North Canton, Ohio, assignors to The Babcock & Wilcox Company, New York, N.Y., a corporation of New Jersey

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13 Claims. (Cl. 110—7)

This invention relates in general to apparatus for and a method of burning particle-form coal and more particularly to the construction and operation of a cyclone type furnace adapted for the firing of crushed coal dispersed in and carried into the furnace by a stream of water.

The cyclone furnace was developed primarily to burn coarsely pulverized or granulated slag-forming solid fuels. In the normal operation of a cyclone furnace crushed coal, carried in a stream of preheated primary air is introduced tangentially to a cylindrical primary burner at one end of the furnace, and, to complete the combustion, high velocity secondary air is admitted in the same direction tangentially along part of the length of the furnace and imparts a further whirling or centrifugal action to the burning coal particles. The gas temperatures developed are sufficiently high to melt the ash content of the fuel into liquid slag, which forms on the walls of the furnace. The entering fuel and primary air stream is rapidly ignited and the centrifugal effect of the whirling stream causes the ash particles released from the burning fuel particles to deposit in a molten condition on the furnace wall and form a film or layer of molten slag thereon on which the larger fuel particles are caught and burned in place by the scrubbing action of the high velocity secondary air. The incombustible ash residue is continuously discharged in a molten stream through a slag outlet located in the lower part of the cyclone furnace, while the gaseous products of combustion are discharged from the furnace chamber through a central reentrant throat designed to retain solid particles which have not been fully reduced to molten slag. Cyclone furnaces of this type are disclosed in U.S. Patent No. 2,594,312.

Over the years continued advances have been made in the methods of preparing, handling and burning coal. The motivating factors were mainly economics and growth of industry. Economics determined the efficient use of the cheapest coals available. One such advance involves the transmission of coal by pipeline from the mine to the consuming plant. In this system the coal is washed, crushed to a fine size, then mixed with water to form a slurry containing anywhere from about 33 to 42% water by weight. The slurry is then fed into a pipeline and moved by pumps to the consuming plant. The prime purpose, of course, is to eliminate freight rates in moving the coal. Much interest is now evidenced in the burning of this slurry, but up to now the great difficulty has been to find a suitable method of and equipment for effectively and economically burning the fuel content of the slurry. One of the major deterrents to the use of pipeline slurry by industrial and utility plants is the high capital and operating costs for handling the slurry at the plant and for preparing the slurry for burning. While various schemes have been proposed and, in some instances, tried for handling and firing the slurry, each involves the use of dewatering, drying and, in some cases, pulverizing equipment to the end that the fuel is in a conventional dry form prior to its introduction into a combustion chamber. The capital and operating cost of the equipment required to so condition the fuel prior to firing offset to a considerable extent the freight savings realized in pipeline transmission of the fuel from the mine to the plant. Other attempts have been made to

introduce slurry directly into a combustion chamber without dewatering or drying, but the results have been uniformly unsatisfactory primarily because of unstable ignition and combustion, relatively low rates of retention of fly ash as slag and high loss of carbon carried from the furnace by the products of combustion.

The present invention provides a system for burning pipeline slurry characterized by: the supply of slurry directly to a cyclone type furnace without prior dewatering or drying so that coal firing of utility and industrial plants will approach the simplicity of oil handling from the standpoint of prefiring equipment; rapid and stable ignition and combustion of the slurry; high fuel burning efficiency; and separation and removal of substantially all of the recoverable ash content of the fuel in a molten condition before the gases leave the furnace chamber.

The various features of novelty which characterize our invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which we have illustrated and described a preferred embodiment of the invention.

Of the drawings:

FIG. 1 is a partly diagrammatic sectional elevation of a cyclone furnace constructed and operable in accordance with the invention;

FIG. 2 is a front view of the cyclone furnace;

FIG. 3 is an enlarged longitudinal section of the discharge end of the fuel atomizer assembly; and

FIG. 4 is a sectional view taken along the line 4—4 of FIG. 3.

The steam generating unit illustrated in part in FIG. 1 comprises as its main parts a cyclone type furnace 10 which is adapted to be fired by a water-borne crushed coal in a manner hereinafter more fully described. The products of combustion from the cyclone furnace flow into a secondary furnace 20 containing a reflecting arch 22 and slag screen 24 with which the products of combustion successively contact. The gaseous products of combustion flow upwardly into the secondary furnace to a convection heating section of the unit, not shown.

While various kinds of crushed coals in an aqueous suspension can be burned in the cyclone furnace illustrated, the construction illustrated and processes hereinafter described are especially designed and particularly adapted for burning water-borne crushed bituminous and semi-bituminous coals sized so that 100% will pass through an 8 mesh screen and 20 to 30% through a 200 mesh screen. The water content of the slurry may vary considerably, ranging from about 33% to 42% by weight.

The cyclone furnace 10 comprises a horizontally elongated combustion chamber 26 of substantially circular cross-section, the circular boundary wall being formed by closely spaced studded tubes 28 covered by a layer of refractory material, each tube having a semi-circular bent portion and adjacent tubes having their bent portions oppositely arranged to form the circumferential wall. The lower ends of the wall tubes are connected to interconnected supply headers 30 and their upper ends to a discharge header 32. The cyclone furnace is preferably set with its longitudinal axis at a slight angle to the horizontal to facilitate draining of molten slag into the secondary furnace. The outer end portion of the cyclone furnace is tapered outwardly in cross-section and formed by closely spaced circular studded tubes 34 of progressively smaller bend diameter connected to a supply header 36 and a riser header 38, the latter being connected to the discharge header 32. The circular tubes 34 thus form a double frusto-conical section sym-

metrically arranged relative to the combustion chamber axis.

Combustion chamber wall tubes 28 along one side are bent radially outwardly along an involute curve for a major portion of the combustion chamber length starting at the inner end of the tapering portion of the chamber, while the corresponding tubes along the opposite side are bent outwardly and connected to an intermediate outlet header 40, thus cooperating to define an axially elongated secondary air inlet port 42 opening tangentially to the combustion chamber. The header 40 is connected to the discharge header 32 by riser tubes 44. Air under a relatively high pressure is supplied to the cyclone furnace by way of a forced draft fan and an air-heater, both not shown, and a main air duct 46. The combustion air supplied to the furnace is preheated a substantial amount to speed up the ignition of the fuel content of the slurry adjacent the point of air entry. Main air duct 46 terminates in a transversely tapering curved section opening to the secondary air port 42. The lower portion of the duct 46 is subdivided by vertical partitions into a series of side-by-side sections extending longitudinally of the furnace chamber. Each duct section is provided with a damper for controlling the velocity of the corresponding secondary air stream while maintaining the entering secondary air stream at all times along the combustion chamber wall.

The rear end of the combustion chamber 26 is partly closed by a fluid cooled wall 48 having a gas outlet 50 in the form of a re-entrant throat 52 arranged therein concentric with the combustion chamber axis. A slag outlet 54 is formed in the wall 48 at a position below the throat 52 for the continuous discharge of molten slag. The wall 48 forms part of the fluid cooled boundary walls of the secondary furnace chamber 20. It is to be understood that the portions of the fluid circulation system described are suitably connected into the circulation system of the steam generating unit.

A fuel inlet chamber or primary burner 56 of substantially circular cross-section and of smaller diameter than the combustion chamber 26 is arranged at the front end of and opens concentrically to the combustion chamber. A filler member or deflector 58 of circular cross-section is arranged radially inwardly from the circumferential wall of the burner 56 and forms therewith a circumferentially continuous annular space 60 opening at one end directly to the combustion chamber 26. Preheated primary air is directed tangentially into the annular space 60 at a high angular velocity for whirling movement therethrough to the combustion chamber by a conduit 62 having an involute curved discharge portion which opens tangentially into the lower side portion of the burner. The effective flow area of the conduit 62 is controlled by a manually operated damper 75. A vertical portion of the conduit 62 is provided with a venturi dryer 59 and an auxiliary slurry supply and distribution assembly 61 adapted for use mainly when slurries of high water concentrations are fired and in accordance with the alternative method of operation hereinafter described. Primary air is supplied to the conduit 62 by way of a branch duct, not shown, connected to the main duct 46. Burner 56 is provided at its outer periphery with a cooling jacket 64 having a water inlet 66 at the bottom and a water outlet 68 at the top.

A circular tertiary air chamber 63 is arranged on the outer end of and concentric with the burner 56 and opens to the interior of the filler member 58. Preheated air is supplied to the chamber 63 by a duct 65 connected to the main duct 46 and controlled by a damper, not shown. The duct 65 has an involute curved connection to the chamber 63, producing a whirling stream of tertiary air which is directed axially of the burner 56 by an orifice plate 67 on the outer end of the burner 56. The whirling tertiary air entering the combustion chamber passes through the interior of the filler member 58 axially and inwardly of the whirling stream of primary air entering the combustion chamber. A water jacket 69 is formed about the front portion of the chamber 63 and adjacent the outer face of the orifice plate 67.

In accordance with the invention, the cyclone furnace is particularly adapted for the burning of pipeline slurry. The slurry supply system comprises a tank 70 adapted to receive the mine pipeline slurry and to discharge the slurry through a conduit 72, pump 74 and valve-controlled conduit 76 to a slurry atomizer assembly 78 associated with the cyclone furnace. Slurry atomizer assembly 78 extends through an aperture in the outer end of the tertiary air supply chamber 63 and along the central axis of the chamber 63 and burner 56, is axially adjustable so that it can be withdrawn during shutdowns, and has its discharge end positioned at the outlet of the burner 56 during operation. With reference to FIGS. 3 and 4, atomizer assembly 78 includes an elongated inner barrel or tube 80 which serves as a slurry passage and an outer surrounding barrel or pipe 82, with the annular space 84 therebetween serving as a compressed air passage. A hollow slurry sprayer head 86 is threaded onto the discharge end and forms a continuation of the inner tube 80 and engages in sealing contact the discharge end of the outer tube 82, with the inlet end of the head 86 being formed in the shape of a cylinder and the outlet end formed in the shape of a truncated cone having an included angle of the order of 90° to 120° and flaring outwardly in the direction of the furnace to provide a slurry whirl chamber 88. At the junction of the cylinder and truncated cone portions of the sprayer head 86 there is provided a plurality of cylindrical slots 90 extending in a direction normal to the axis of the tube 80 from the compressed air passage to the slurry passage and arranged with their centerlines tangent to a circle of less diameter than the inner diameter of the cylindrical portion of the head 86. On the outer end of the atomizer assembly 76 is a detachable coupling 77 of well known construction adapted to pass slurry from the supply conduit 76 to the tube 80 and to pass compressed air from a supply conduit, not shown, into the space 84.

In the operation of the cyclone furnace and slurry atomizer construction described, the furnace chamber 26 is initially heated to a predetermined temperature by an auxiliary oil or gas burner, not shown, before firing the slurry. Once stable slurry ignition and combustion is established, the auxiliary burner is removed from operation. Preheated air is supplied to the main duct 46 at a high positive pressure and split into three streams, 15–20% being used as primariy air, 75–80% as secondary air, and 3–4% as tertiary air, with 1–2% being supplied as atomizing air for the slurry. The total air supplied preferably ranges between 110 and 120% of the theoretical combustion air requirements. The primary air enters the combustion chamber in a high velocity stream whirling in a clockwise direction with the inner core of whirling tertiary air entering in the same direction; while the jets of high pressure compressed air discharging from the slots 90 impart a spinning motion to the slurry discharging from the inner tube 80, with the whirling effect being enhanced by the whirl chamber 88 so that on emerging from the whirl chamber the slurry is in an atomized condition. The atomized slurry stream enters the combustion chamber with a whirling movement in the same direction as the inwardly and axially of the whirling streams of primary and tertiary air, while moving in a rapidly diverging cone at a high velocity towards the circumferential wall of the combustion chamber so as to mix and whirl with the primary air. The streams of high velocity secondary air discharging from the secondary air ports 42 tangentially enter the combustion chamber in the same direction of rotation as and at the outer side of the whirling stream of primary air. With the air streams and slurry entering

the combustion chamber as described, vaporization of the water content of the slurry and combustion of the fuel content thereof will progress at a rapid rate, which increases in the zone of secondary air admission, with a gradual mixing of the secondary air streams with the enclosed streams of primary air and slurry. Combustion proceeds at a rate sufficient to maintain a normal mean temperature in the combustion chamber over a wide load range substantially above the fuel ash fusion temperature. Under such combustion conditions the water content of the slurry is quickly vaporized and the ash content of the fuel is rapidly reduced to a molten condition. Due to the centrifugal effect on the ash, the combustion chamber walls will be rapidly coated with a film of molten slag which adheres to the refractory inner face of the walls and provides a sticky surface against which fuel particles are thrown and to which they adhere. The high velocity of the burning slurry and air mixture causes the gas stream to follow a helical path toward the rear of the combustion chamber where the gas is caused to reverse direction before entering the gas outlet 50. The gas flow reversing action is effected by an annular pocket 91 and facilitates the separation of suspended slag particles from the outgoing gases. The tertiary air entering the combustion chamber about and immediately adjacent the discharge end of the atomizer assembly 78 serves in most part to promote the burning of extremely fine fuel particles that are not thrown to the periphery of the combustion chamber and which otherwise might be carried in suspension by gases discharging from the chamber. Molten slag resulting from combustion continuously discharges through the outlet 54 into the secondary furnace 20 for flow therefrom to a slag tank, not shown. The gases discharged through the outlet 50 contain little combustible, combustion of the fuel content of the slurry being substantially completed in the combustion chamber. A relatively small amount of fly ash is present in suspension in the outgoing gases.

By way of example, and not of limitation, in a firing run in a five foot diameter cyclone furnace of the character described a slurry consisting of 35% water and 65% crushed coal by weight was supplied directly from the tank 70 to the atomizer assembly 78 at a rate of 13600 lbs./hr. The coal had a heat content of 13500 B.t.u./lb. on a dry basis. The temperature of the combustion air supplied to the furnace was about 740° F., with the total supply of combustion air amounting to about 115% of the theoretical air requirements for combustion. Under these conditions ignition and combustion were stable, the combustion chamber was bright, and slag tapped well from the chamber. Other firing runs under similar conditions and in accordance with the invention method indicated that slurries having water concentrations from 33% to 41% by weight could be successfully burned but that stability of ignition and combustion efficiency diminished somewhat with slurry water concentrations beyond 38%.

In the event that the water concentrations of the slurry as received from the mine pipeline are relatively high, for example, over 38%, resort may be had, in accordance with the invention, to an alternate system of firing wherein a greatly predominant proportion of the slurry required to meet load demands is supplied directly to the atomizer supply assembly 78, while the remaining slurry is dried before entering the combustion chamber to enhance ignition and combustion of the slurry discharging from the atomizer 78. In this system the required slurry supply is split into two streams, 80 to 85% being directed to the atomizer supply assembly 78 by way of the conduit 76 and 15 to 20% being directed to the auxiliary supply assembly 61 by way of a valve-controlled branch conduit 92 leading from conduit 76. Slurry supply assembly 61 comprises a vertical inner pipe 94 disposed along the centerline of the duct 62 and supplied with slurry from the conduit 92 and a vertical outer pipe 96 surrounding pipe 94 and cooperating therewith to provide an annular passage supplied with compressed air by a conduit 98 for atomization of the slurry, with the discharge ends or atomizer head of the pipes 94 and 96 being constructed and arranged to produce a conical spray of atomized slurry which is uniformly distributed to the sides of a conical slurry distributor 95 situated intermediate of and close to the atomizer head and the inlet throat of the venturi dryer 59. Distributor 95 is suitably carried by support elements mounted on the throat and is positioned and formed so that the slurry flowing down its sides is uniformly distributed to the periphery of the rounded inlet throat of the dryer 59. The venturi dryer 59 operates on the principle of using the energy of the primary air, accelerated in a venturi throat, to vaporize the water content of the slurry. The high relative velocity and temperature of the primary air with respect to the slurry assures efficient scrubbing and heat transfer due to the intimate contact of the air and slurry as they pass through the dryer 59 which causes the water of the slurry to vaporize and the fuel content to enter the combustion chamber in substantially dry form in suspension in the whirling primary air stream. Ignition and combustion of the primary air-dry fuel mixture will progress at a rapid rate and thereby enhance ignition and combustion of the high water concentration slurry sprayed into the combustion chamber by the atomizer assembly 78. Other than introducing dried crushed fuel into the combustion chamber along with the primary air stream, operation of the cyclone furnace is substantially the same as that previously described.

By way of example, and not of limitation, in a firing run in a five foot cyclone furnace operated in accordance with the above-described alternative system, a slurry containing 38% water and 62% crushed coal by weight was split into two streams after leaving the tank 70, with one stream being directed through the conduit 92 and slurry assembly 61 to the dryer 59 at a rate of 2300 lbs./hr., representing 16% of the total slurry supply, and the other stream being directed to the atomizer assembly 78 at a rate of 11,750 lbs./hr. The coal had a heat content of 13,500 B.t.u./lb. on a dry basis. The division of combustion air supply to the primary, secondary and tertiary air ducts was about the same as previously indicated for direct introduction of all of the slurry into the combustion chamber by way of the atomizer assembly 78, with the total supply of combustion air amounting to about 120% of the theoretical air requirements for combustion. The primary air temperature was 785° F. at the inlet to the venturi dryer 59 and 485° F. at the inlet to the primary burner 56; while the secondary and tertiary air temperatures entering the combustion chamber were about 715° F. Primary air flow amounted to about 10,500 lbs./hr., with an average venturi throat velocity of 9,500 ft./min. and a pressure drop of 9.4 inches of water across the venturi. Under these conditions stability of ignition and combustion was good, fuel burning efficiency was high, the combustion chamber was bright and slag tapped without difficulty. Other firing runs under similar conditions indicated that slurries having water concentrations up to 42% by weight could be successfully and efficiently burned without diminishment of stability of ignition and combustion. While the described alternative system of operation is suited for firing slurries having water concentrations ranging from about 33 to 42%, direct introduction of all of the slurry into the combustion chamber by way of the atomizer assembly 78 is preferred where a continuous supply of slurry having a water concentration of from 33 to 38% is available for in such case the venturi dryer and the auxiliary slurry supply system could be eliminated.

While in accordance with the provisions of the statutes we have illustrated and described herein the best form and mode of operation of the invention now known to us, those skilled in the art will understand that changes may

be made in the form of the apparatus disclosed without departing from the spirit of the invention covered by our claims, and that certain features of our invention may sometimes be used to advantage without a corresponding use of other features.

What is claimed is:

1. Apparatus for burning pipeline slurry containing particle-form coal dispersed in and carried by water comprising a combustion chamber of substantially circular cross-section defined by walls having an inner exposed refractory surface, fluid cooling means for said walls proportioned for the maintenance of said refractory under a normal mean temperature in said combustion chamber above the fuel ash fusion temperature, means for introducing into said combustion chamber and effecting a helical path of travel therein along the circumferential wall of said chamber a combustible mixture including a major portion of the slurry required to maintain a predetermined rate of heat release in the combustion chamber, means for evaporating the water content of the remaining slurry required to maintain said predetermined rate of heat release and for introducing into said combustion chamber and effecting a helical path of travel therein along the circumferential wall of said chamber the resulting substantially dry particle-form coal, means forming a restricted gas outlet at one end of said chamber, and a slag outlet in the lower part of said combustion chamber.

2. Apparatus for burning pipeline slurry containing particle-form coal dispersed in and carried by water comprising a combustion chamber of substantially circular cross-section defined by walls having an inner exposed refractory surface, fluid cooling means for said walls proportioned for the maintenance of said refractory under a normal mean temperature in said combustion chamber above the fuel ash fusion temperature, means for introducing a major portion of the slurry required to maintain a predetermined rate of heat release in the combustion chamber into one end of the combustion chamber and effecting a helical path of travel thereof along the circumferential wall of said chamber, means for evaporating the water content of the remaining slurry required to maintain said predetermined rate of heat release and for directing the resulting substantially dry particle-form coal into said one end of said chamber and effecting a helical path of travel therein along the circumferential wall of said chamber, means forming a restricted gas outlet at the opposite end of said chamber, means for introducing a high velocity stream of air tangentially to the circumferential wall of said combustion chamber at a location between the point of fuel entry and the gas outlet, and a slag outlet in the lower part of said chamber.

3. The process of burning particle-form coal which comprises introducing whirling streams of air into a combustion chamber of circular cross-section so as to move at a high velocity along the circumferential wall thereof, introducing a stream of slurry comprising particle-form coal in an aqueous suspension into said combustion chamber so as to move towards the circumferential wall of the chamber and to mix and whirl with said air streams, while maintaining a normal mean temperature in the chamber above the coal ash fusion temperature, passing the slurry and air so introduced axially of the combustion chamber through a helical path along the circumferential wall of the combustion chamber of sufficient length to cause evaporation of the moisture content of the slurry, combustion of the fuel, and the release of fuel ash in a condition to form a sticky surface on the circumferential wall to which fuel particles adhere and are scrubbed by the contacting gases, discharging the combustion chamber gases from said combustion chamber, and collecting and withdrawing the ash separated in the combustion chamber in a molten condition.

4. The process of burning pipeline slurry containing particle-form coal dispersed in and carried by water in a combustion chamber of substantially circular cross-section having a gas outlet at one end and a slag outlet in its lower part which comprises introducing whirling streams of air into said combustion chamber so as to move at a high velocity along the circumferential wall thereof, introducing a stream of said slurry into said combustion chamber so as to move towards the circumferential wall of the chamber and to mix and whirl with said air streams, while maintaining a normal mean temperature in the chamber above the coal ash fusion temperature, passing the slurry and air so introduced axially of the combustion chamber towards the gas outlet end thereof through a helical path along the circumferential wall of the combustion chamber of sufficient length to cause evaporation of the moisture content of the slurry, combustion of the fuel, and the release of fuel ash in a condition to form a sticky surface on the circumferential wall to which fuel particles adhere and are scrubbed by the contacting gases, discharging the combustion chamber gases from the combustion chamber through said gas outlet, and withdrawing the ash separated in the combustion chamber in a molten condition through the slag outlet.

5. The process of burning particle-form coal in a combustion chamber of substantially circular cross-section having a gas outlet at one end and a slag outlet in its lower part which comprises introducing whirling streams of air into said combustion chamber so as to move at a high velocity along the circumferential wall thereof, introducing a stream of slurry comprising particle-form coal dispersed in and carried by water into said combustion chamber so as to move in a rapidly diverging cone at a high velocity towards the circumferential wall of the chamber and to intimately mix and whirl with said air streams, while maintaining a normal mean temperature in the chamber above the coal ash fusion temperature, passing the slurry and air so introduced axially of the combustion chamber towards the gas outlet end thereof through a helical path along the circumferential wall of the combustion chamber of sufficient length to cause evaporation of the moisture content of the slurry, combustion of the fuel, and the release of fuel ash in a condition to form a sticky surface on the circumferential wall to which fuel particles adhere and are scrubbed by the contacting gases, discharging the combustion chamber gases from the combustion chamber through said gas outlet, and withdrawing the ash separated in the combustion chamber in a molten condition through the slag outlet.

6. The process of burning pipeline slurry containing particle-form coal dispersed in and carried by water in a combustion chamber of substantially circular cross-section having a gas outlet at one end and a slag outlet in its lower part which comprises introducing a whirling stream of air into said combustion chamber so as to move at a high velocity along the circumferential wall thereof, introducing a stream of said slurry in a finely divided condition into said combustion chamber so as to move towards the circumferential wall of the chamber and to mix and whirl with said air stream, while maintaining a normal mean temperature in the chamber above the coal ash fusion temperature, introducing a high velocity stream of additional combustion air tangentially to the circumferential wall of the combustion chamber and between the point of fuel introduction and the gas outlet from the chamber, passing the slurry and air so introduced axially of the combustion chamber through a helical path along the circumferential wall of the combustion chamber of sufficient length to cause evaporation of the moisture content of the slurry, combustion of the fuel, and the release of fuel ash in a condition to form a sticky surface on the circumferential wall to which fuel particles adhere and are scrubbed by the contacting gases, discharging the combustion chamber gases from the combustion chamber through said gas outlet, and withdrawing the ash separated

in the combustion chamber in a molten condition through the slag outlet.

7. The process of burning particle-form coal in a combustion chamber of substantially circular cross-section having a fuel inlet at one end, a gas outlet at its opposite end and a slag outlet in its lower part which comprises introducing a whirling stream of high temperature combustion air into said one end of the combustion chamber so as to move at a high velocity along the circumferential wall thereof, introducing a slurry comprising particle-form coal in an aqueous suspension into said one end of the combustion chamber inwardly of the whirling air stream so as to move in rapidly diverging paths at a high velocity towards the circumferential wall of the chamber and to intimately mix and whirl with said air stream, while maintaining a normal mean temperature in the chamber above the coal ash fusion temperature, introducing a high velocity high temperature stream of additional combustion air tangentially to the circumferential wall of the combustion chamber and between the point of fuel introduction and the gas outlet from the chamber, passing the slurry and air so introduced axially of the combustion chamber towards the gas outlet end thereof through a helical path along the circumferential wall of the combustion chamber of sufficient length to cause evaporation of the moisture content of the slurry, combustion of the fuel, and the release of fuel ash in a condition to form a sticky surface on the circumferential wall to which fuel particles adhere and are scrubbed by the contacting gases, discharging the combustion chamber gases from the combustion chamber through said gas outlet, and withdrawing the ash separated in the combustion chamber in a molten condition through the slag outlet.

8. The process of burning particle-form coal in a combustion chamber of substantially circular cross-section having a fuel inlet at one end, a gas outlet at its opposite end and a slag outlet in its lower part which comprises introducing a whirling stream of high temperature combustion air into said one end of the combustion chamber so as to move at a high velocity along the circumferential wall thereof, introducing atomized slurry comprising particle-form coal in a whirling aqueous suspension into said one end of the combustion chamber inwardly of the whirling air stream so as to move in a rapidly diverging cone at a high velocity towards and along the circumferential wall thereof, while maintaining a normal mean temperature in the chamber above the coal ash fusion temperature, introducing a high velocity high temperature stream of additional combustion air tangentially to the circumferential wall of the combustion chamber and between the point of fuel introduction and the gas outlet from the chamber, merging the slurry and air so introduced while passing the slurry and air axially of the combustion chamber towards the gas outlet end thereof through a helical path along the circumferential wall of the combustion chamber of sufficient length to cause evaporation of the moisture content of the slurry, combustion of the fuel, and the release of fuel ash in a condition to form a sticky surface on the circumferential wall to which fuel particles adhere and are scrubbed by the contacting gases, discharging the combustion chamber gases from the combustion chamber through said gas outlet, and withdrawing the ash separated in the combustion chamber in a molten condition through the slag outlet.

9. The process of burning particle-form coal which comprises introducing into a combustion chamber of substantially circular cross-section of combustible mixture including a slurry containing particle-form coal dispersed in and carried by water, while maintaining a normal mean temperature in the chamber above the coal ash fusion temperature, passing the combustible mixture so introduced axially through the combustion chamber in a helical path along the circumferential wall of the chamber of sufficient length to cause evaporation of the moisture content of the slurry, combustion of the fuel, and the release of fuel ash in a condition to form a sticky surface on the circumferential wall to which fuel particles adhere and are scrubbed by the contacting gases, discharging the combustion chamber gases from said combustion chamber, and collecting and withdrawing the ash separated in the combustion chamber in a molten condition.

10. The process of burning particle-form coal in a combustion chamber of substantially circular cross-section having a gas outlet at one end and a slag outlet in its lower part which comprises introducing into said combustion chamber a combustible mixture including a stream of substantially dry particle-form coal and a slurry containing particle-form coal dispersed in and carried by water, while maintaining a normal mean temperature in the chamber above the coal ash fusion temperature, passing the combustible mixture so introduced axially through the combustion chamber in a helical path along the circumferential wall of the chamber of sufficient length to cause evaporation of the moisture content of the slurry, combustion of the fuel, and the release of fuel ash in a condition to form a sticky surface on the circumferential wall to which fuel particles adhere and are scrubbed by the contacting gases, discharging the combustion chamber gases from the combustion chamber through said gas outlet, and withdrawing the ash separated in the combustion chamber in a molten condition through the slag outlet.

11. The process of burning particle-form coal in a combustion chamber of substantially circular cross-section having a gas outlet at one end and a slag outlet in its lower part which comprises introducing whirling streams of air into a combustion chamber so as to move at a high velocity along the circumferential wall thereof, introducing a stream of slurry comprising particle-form coal in an aqueous suspension into said combustion chamber so as to move towards the circumferential wall of the chamber and to mix and whirl with said air streams, while maintaining a normal mean temperature in the chamber above the coal ash fusion temperature, introducing a whirling stream of substantially dry particle-form coal into said combustion chamber so as to move at a high velocity along the circumferential wall thereof, passing the slurry, dry coal and air so introduced axially of the combustion chamber through a helical path along the circumferential wall of the combustion chamber of sufficient length to cause evaporation of the moisture content of the slurry, combustion of the fuel, and the release of fuel ash in a condition to form a sticky surface on the circumferential wall to which fuel particles adhere and are scrubbed by the contacting gases, discharging the combustion chamber gases from the combustion chamber through said gas outlet, and withdrawing the ash separated in the combustion chamber in a molten condition through the slag outlet.

12. The process of burning particle-form coal in a combustion chamber of substantially circular cross-section having a gas outlet at one end, a fuel inlet at its opposite end and a slag outlet in its lower part which comprises introducing a whirling stream of air and particle-form substantially dry coal in suspension through said fuel inlet into said combustion chamber so as to move at a high velocity along the circumferential wall of the chamber, introducing a slurry comprising particle-form coal in an aqueous suspension through said fuel inlet into said combustion chamber inwardly of said whirling fuel-air stream so as to move in diverging paths at a high velocity towards the circumferential wall of the chamber and to intimately mix and whirl with said dry fuel-air stream, while maintaining a normal mean temperature in the chamber above the coal ash fusion temperature, introducing a high velocity high temperature stream of additional combustion air tangentially to the circumferential wall of the combustion chamber and between the point of fuel introduction and the gas outlet from the chamber, passing the slurry, dry coal and air so intro-

duced axially of the combustion chamber towards the gas outlet end thereof through a helical path along the circumferential wall of the combustion chamber of sufficient length to cause evaporation of the moisture content of the slurry, combustion of the fuel, and the release of fuel ash in a condition to form a sticky surface on the circumferential wall to which fuel particles adhere and are scrubbed by the contacting gases, discharging the combustion chamber gases from the combustion chamber through said gas outlet, and withdrawing the ash separated in the combustion chamber in a molten condition through the slag outlet.

13. The process of burning pipeline slurry containing particle-form coal dispersed in and carried by water in a combustion chamber of substantially circular cross-section having a gas outlet at one end, a fuel inlet at its opposite end and a slag outlet in its lower part which comprises introducing a major portion of the slurry required to maintain a predetermined rate of heat release in the combustion chamber through said fuel inlet into said combustion chamber so as to move in rapidly diverging paths at a high velocity towards the circumferential wall of the chamber, while maintaining a normal mean temperature in the chamber above the coal ash fusion temperature, evaporating the water content of the remaining slurry required to maintain said predetermined rate of heat release and then passing the resulting substantially dry particle-form coal into said combustion chamber in suspension in a whirling stream of air so as to move at a high velocity along the circumferential wall of the chamber, introducing a high velocity high temperature stream of combustion air tangentially to the circumferential wall of the combustion chamber and between the point of fuel introduction and the gas outlet from the chamber, passing the slurry, dry coal and air so introduced axially of the combustion chamber towards the gas outlet end thereof through a helical path along the circumferential wall of the combustion chamber of sufficient length to cause evaporation of the moisture content of the slurry directly introduced into the combustion chamber, combustion of the fuel, and the release of fuel ash in a condition to form a sticky surface on the circumferential wall to which fuel particles adhere and are scrubbed by the contacting gases, discharging the combustion chamber gases from the combustion chamber through said gas outlet, and withdrawing the ash separated in the combustion chamber in a molten condition through the slag outlet.

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