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APPARATUS AND METHOD FOR COMPOUND CYCLONE COMBUSTION
OF COAL AND OTHER FUELS
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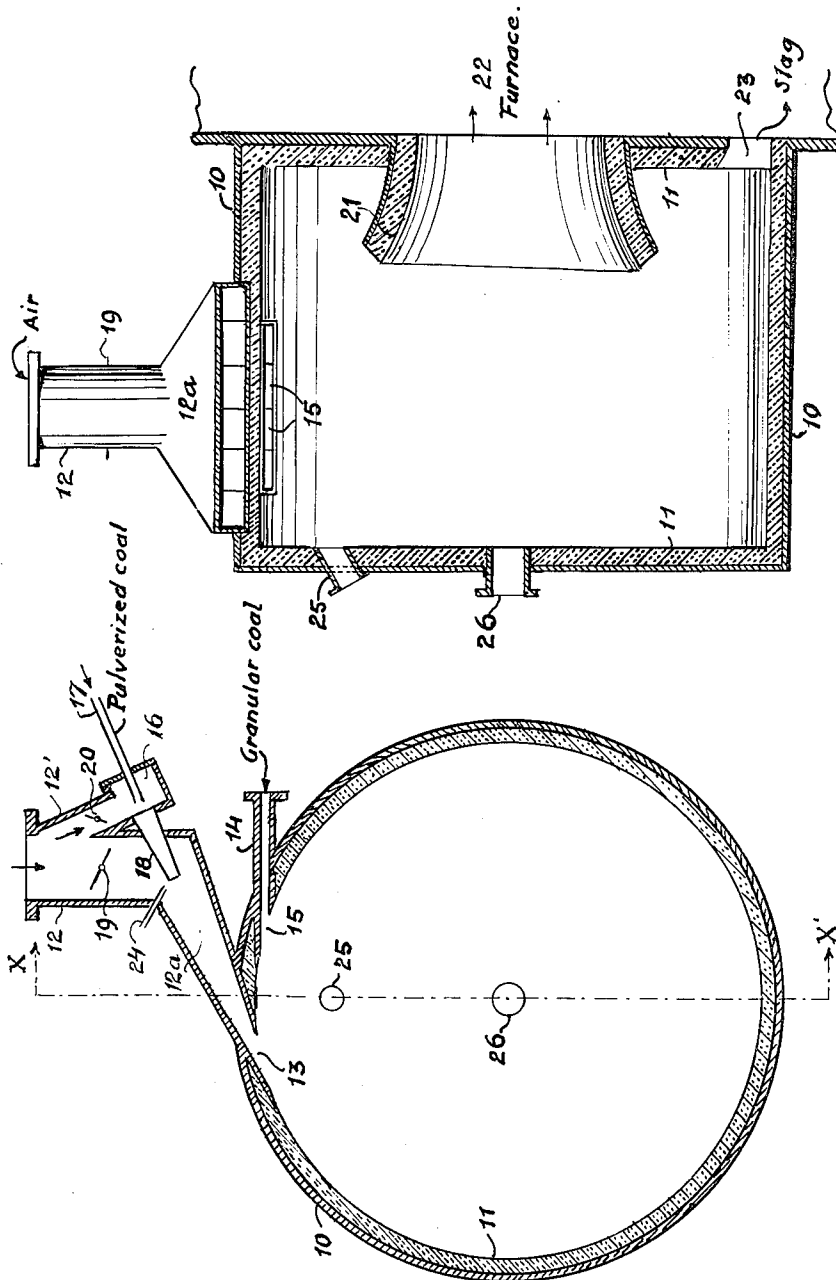


Fig. 2.

Fig. 1.

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3,199,476 APPARATUS AND METHOD FOR COMPOUND CYCLONE COMBUSTION OF COAL AND OTHER FUELS

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The best known methods and means to utilize fuel, in particular coal, are in finely pulverized form or in granulated form, respectively. Pulverized coal is burned in more or less conventional burners, while granulated coal is burned in what is known as cyclones.

Both methods have their peculiar advantages and disadvantages which most importantly concern the amount of flyash produced and either passed through the boilers, or carried off with the liquid slag.

Which of the two mentioned methods is preferred is determined in many cases by the properties of the coal (volatile contents, ash contents, slag characteristics, grindability index, for example).

The recognized disadvantages of pulverized coal are:

- (1) Large power consumption for pulverizers,
- (2) High maintenance costs for pulverizers,
- (3) High fly-ash discharge from the stack (in many cases up to 80% for dry-ash removal furnaces),
- (4) Erosion of boiler tubes by fly-ash,
- (5) Large furnace volumes required for good combustion.

Conversely, cyclones involve:

- (a) Special, water-cooled spaces outside the boiler proper.
- (b) Very high heat release in a very small space to keep the slag liquid.
- (c) Necessity of very high preheating of the combustion air.
- (d) Very high pressures of the combustion air (up to abt. 50" WC.).

(e) These pressures may cause very high air leakage losses in the air pre-heaters of the Ljungstrom type.

(f) Restricted ability of operation at partial loads.

(g) Restricted ability to use certain grades of coal.

As to the total power requirements of the two above mentioned systems, there is very little difference: For example certain bituminous coals require 1.62 k.w.h. per million B.t.u. input into the furnace, while cyclone firing needs 1.63. Generally, the power for coal preparation (pulverizing vs. grinding) favors cyclones. However, this difference is eaten up by the very large power requirement for the forced draft fan in the case of cyclones, as compared with the power required for the primary air and forced draft fans of coal pulverizing.

Important advantages of using coal in finely pulverized form are:

- (1) Ability to burn practically all grades of coal due to better ignition.
 - (2) Ease of combination with oil or gas firing, while the most serious disadvantage lies in the high fly-ash discharge from the stack, unless ash removers are employed.
- It is this last-mentioned defect which has most importantly led to the adoption of cyclone firing which may reduce the dust discharge to the atmosphere radically.

Cyclone firing has, however its own peculiar shortcomings: Before the cyclone can start functioning normally, it must be heated up while the secondary combustion air introduced into it is still cold. This heating from cold state is normally done by a gas- or oil-fired heating torch, and takes considerable time. Presence of liquid slag is essential to the proper function of a cyclone because it ensures the retention of most of the fly-ash in

the slag before the combustion gases enter into contact with the convention surfaces of the boiler.

Liquid slag formation within the cyclone requires very high combustion air temperatures which are available only at boiler loads from full to about one half. At lower loads there is danger of the slag to solidify, if the temperature of the combustion air entering the cyclone drops, as it will, when the boiler output drops substantially. It would obviously be uneconomical to keep a cyclone operating under such condition by putting the gas or oil fired starting torch in operation for extended periods of time.

Stable cyclone operation requires, as mentioned above, secondary combustion air of the highest possible temperature, generally about 600° F. The volatile content of the coal should exceed 15 percent.

It is the principal object of this invention to reduce or eliminate the defects of the pulverized coal firing, as well as of the conventional cyclone, by creating a new combination of both, which for the purposes of this specification may be called "compound cyclone firing."

This and other objects and advantages will become clear from the following specifications and drawings which show in diagrammatic form by way of non-limiting examples embodiments of my invention.

In the drawings,

FIG. 1 illustrates a cyclone according to my invention in cross section,

FIG. 2 is a longitudinal section of the same cyclone.

The principal object of my invention is attained by burning coal or other solid fuels in a cyclone-type combustion chamber in such manner, that a portion of the fuel is burned in finely pulverized fuel in a portion of the combustion air (primary air) while the remainder of the fuel is introduced in coarser (granular) form which granular fuel is then burned in a mixture of the remainder of combustion air (secondary air) and the hot gases resulting from the combustion of the finely pulverized fuel.

It is another object of this invention to regulate the temperature within the cyclone chamber by increasing or decreasing the ratio of coal quantity burned in finely pulverized state to the quantity of coal burned in granular state so as to keep the slag within the cyclone liquid and at the desired viscosity irrespective of the output of the cyclone and of the temperature of the combustion air.

It is a further object of this invention to facilitate starting of the cyclone from cold by first starting operation of pulverized fuel combustion to preheat the cyclone, and by subsequently introducing granular fuel.

It is still another object of this invention to operate a cyclone with combustion air of near-ambient temperature by adjusting the quantity of fuel burned in finely pulverized state, and consequently the quantity of hot combustion gases produced by this combustion in such manner that the temperature of the mixture of said hot gases with the secondary combustion air of near-ambient temperature is high enough to maintain the slag liquid in the cyclone and at the desired viscosity.

Presently, coals with high ash melting points and/or low volatile content, are not suitable for combustion in cyclones. Experiments have shown, however, that many such coals can be burned efficiently in cyclones if the air temperature at cyclone inlet can be raised substantially above the usual 600° F.

If a temperature increase of, for example, 200° F. appears necessary, and if the pulverized coal burner furnishes gases of abt. 2600° F. one pound of gas heats 9 lbs. of air from 600 to 800° F. Thus only a relatively small pulverized coal burner will extend the applicability of cyclone firing to most grades of coals.

Presently coal fines are burnt along with the granular coal, and while it probably helps ignition somewhat, the fines are unregulated, and no attempt is known to use the fines, or other pulverized coal for starting the cyclone and, in particular, to regulate its operating temperature in wide operation ranges.

In many cases it may not be necessary to install a coal pulverizer, because the coal fines unavoidably, produced in the coal granulating mill (10 to 20%) may be taken from a coal classifier. In some cases a small additional coal pulverizing mill may be installed which feeds a bin for pulverized coal and may be used for cyclone operation at low outputs for long periods and for starting of the cyclone or cyclones.

When the pulverized coal burner is working alone, unburnt particles and fly-ash may temporarily be carried into the boiler. However, when the stream of secondary air enters the operating cyclone at high speeds (abt. 300 ft./sec.) these particles are carried with it and are by the centrifugal force of the cyclone thrown against its liner which is covered by liquid slag. There the unburnt particles are burned and most of the fly-ash melts into the slag which leaves in liquid state as in conventional cyclones.

In practice there are cases where the boiler exhaust gases are not available for preheating the air for the cyclones. In these cases my invention provides for an increase in the quantity of coal handled by the pulverized coal burner to such degree, that the secondary combustion air of near-ambient temperature is heated by mixing with the burner gases from, say, 100° F. to 600° F. In such cases abt. one pound of hot gas for four pounds of secondary air may be required. While a separate coal pulverizer will be necessary in this case, the principal advantage of cyclone-firing, viz. reduction of fly-ash discharge, remains intact.

Conventional cyclones depend to a large degree on heat input via the hot combustion air and thus, from a thermal viewpoint, are not self-supporting. In compound cyclones according to my invention the combustion air is heated by burning a portion of the coal in the burner to suit changing operating conditions and thus are thermally self-supporting.

Reverting now in more detail to FIG. 1 of the drawing, in which 10 is the cylindrical cyclone wall with inner refractory lining 11. 12 is the conduit for the secondary combustion air which is connected to the cyclone interior so that the air enters in a tangential direction through the inlet port 13. 14 is another conduit for the granular fuel through which said fuel enters in a similar way via the port 15. Branched off the conduit 12 is conduit 12' which is connected to a pulverized coal burner 16. The latter receives pulverized coal through the pipe 17 from a source (not shown). The burner 16 discharges hot combustion gases through a throat 18 which ends in the mixing chamber 12a forming part of the conduit 12, near the port 13.

FIG. 2 shows the cyclone in section along the line X-X', indicating the mixing chamber 12a for the secondary air extending over a great part of the length of the cyclone and the entrance ports 15 for the granulated fuel similarly extended. 19 and 20 are throttle flaps arranged in the conduits 12 and 12', respectively. At the right hand end of the cyclone there is a throat 21 through which the combustion gases from combustion of both the pulverized and granulated coal are discharged into the boiler furnace 22. At the lower right hand end of the cyclone an opening 23 permits the liquid slag to leave the cyclone as in conventional cyclones. 24 is a lighting torch for igniting the fuel-air mixture from the burner 16 while starting the cyclone. Flame observation holes 25 and 26 may be provided as shown.

The cyclone may be water-cooled (not shown).

A compound cyclone is started and operated as follows:

At first throttle valve 19 is closed and valve 20 partly

opened. The pulverized fuel is fed through the pipe 17. The mixture of this coal with air formed in the burner 16 is ignited by the torch 24, whereupon the hot gases enter the cyclone through the throat 18 and discharge via 12a into the ports 13. Now granulated coal is fed to the cyclone through the conduit 14 while simultaneously secondary air is admitted by opening of the throttle flap 19. This secondary air mixes within the chamber 12a with the hot gases and the mixture of predetermined temperature hits the granular coal, which it ignites and burns at high temperature, thus causing a layer of slag to form at the inner lining of the cyclone as in conventional cyclones, which slag is continually discharged through the opening 23. By regulating the amount of pulverized coal burned in 16, the temperature of the gas air-mixture entering the cyclone through the ports 13 can be controlled over a wide range so as to ensure satisfactory combustion of the granular coal entering through 14, irrespective of both the temperature of the secondary air and the amount of coal fed through the conduit 14.

In other words, the compound cyclone becomes suitable for burning practically any grade of coal, irrespective of its contents of ash, moisture and volatile matter and to operate within a vastly enlarged range of output.

It is within the scope of this invention to use more than one burner for pulverized fuel in one cyclone, to use a fuel different from that introduced in granular form in the burner which heats the secondary air.

Having now described and illustrated an embodiment of my invention, I wish it to be understood that my invention is not limited to the specific form and arrangement described and shown herein, or specifically covered by my claims.

What I claim is:

1. In a fuel burning system burning solid comminuted fuel, the combination of a substantially cylindrical cyclonic furnace chamber having an opening for discharging fuel residue in molten state and another opening for discharging combustion gases generated in said furnace, a first source of coarse comminuted (granular) solid fuel, a second fuel source of finely comminuted (pulverized) solid fuel, first regulatable conduit means for admitting a stream of combustion air into said furnace chamber in a substantially tangential direction to the inner surface of said furnace for forming a violent vortex flow therein, first regulatable pipe means for admitting a stream of granular fuel from the said first fuel source into said furnace in substantially tangential direction to the inner surface of said furnace and in the direction of the vortex flow in such manner that the stream of granular fuel penetrates into said vortex stream of combustion air, regulatable pulverized fuel burner means, second pipe means for admitting a regulatable stream of pulverized fuel from the said second fuel source to said burner means, second conduit means for regulatably branching off combustion air from said first conduit means into said pulverized fuel burner wherein said branched off air serves as combustion air, third conduit means for leading the hot combustion gases generated in said burner means into said first conduit means for mixing with the air stream therein, thereby forming a hot air-gas mixture outside the furnace proper on its way into the furnace, said hot mixture serving as combustion supporting medium of regulatable temperature for the granular fuel issuing from the said first pipe means.

2. In the method of operating a system of burning comminuted solid fuel in a cyclonic furnace chamber comprising a first fuel source supplying fuel in coarse comminuted (granular) form, a second fuel source supplying fuel in finely comminuted (pulverized) form, first conduit means for supplying a stream of combustion air into said furnace, pulverized fuel burner means, second conduit means branched off from said first conduit means connected to said pulverized fuel burner means, third conduit means for the combustion gases generated in said

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burner means connected to the said first conduit means, the steps of regulatably leading a stream combustion air from the said first conduit means into the furnace chamber in a substantially tangential direction to the inner surface of said furnace forming therein a violent vortex flow, burning therein a regulatable stream of granular fuel from said first fuel source introduced into said furnace in a substantially tangential direction to the inner surface of said furnace in the direction of travel of said vortex, and disposed to penetrate said vortex, operating said pulverized fuel burner means regulatably on fuel from the said second source and on combustion air from the said second conduit means for producing hot combustion gases in said third conduit means, mixing said combustion gases with the air flowing through the said first conduit means on its way into said furnace, so as to produce an air-gas mixture of regulatable temperature before its entrance into the furnace proper, using said mixture as combustion supporting medium for the granular fuel in said furnace.

3. In the method of operating a system as set forth in claim 2, the preliminary steps of closing the said first conduit means toward the furnace chamber, disconnecting the said first source of fuel, operating the pulverized fuel burner on fuel from the said second source and on air

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branched off the said first conduit means, leading the combustion gases issuing from the said third conduit means into the furnace for preheating same and, after the walls of the furnace chamber have reached a predetermined temperature, opening the said first conduit means toward the furnace and connecting said first fuel source for supplying air and granular fuel into the furnace for combustion therein.

4. In the method as set forth in claim 3, which includes supplying different kinds of fuels in the said two sources of fuel.

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