



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
22.10.2008 Bulletin 2008/43

(51) Int Cl.:
F23C 6/04 (2006.01)

(21) Application number: **07112706.2**

(22) Date of filing: **18.07.2007**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK RS

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(30) Priority: **08.11.2006 US 557733**

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(54) **Staged coal injection for boiler reliability and emissions reduction**

(57) A staged-coal injection procedure for coal-fired boilers used in power generation. The procedure includes the steps of combusting a first type of coal in a

first zone (115) of a furnace (120); and combusting a second type of coal in a second zone (114) of the furnace (120). The second zone is at a position separate from the first zone.

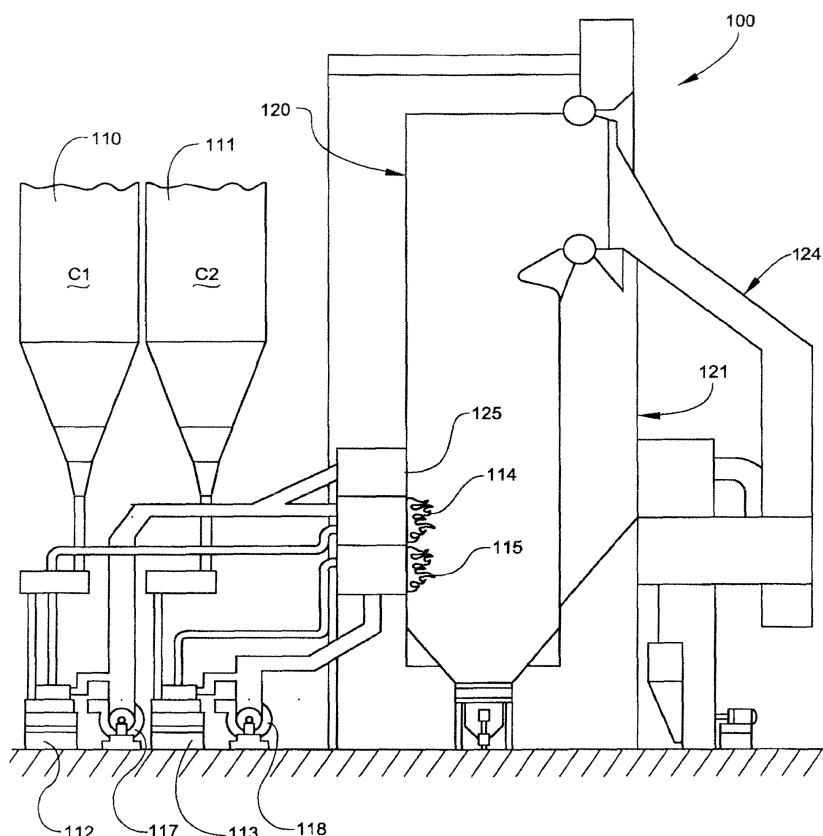


Fig. 2

Description

Technical Field and Background of the Invention

[0001] The present invention relates to the field of power generation. In particular, the invention relates to a staged-coal injection procedure for coal-fired boilers used for power generation.

[0002] As economical performance and compliance with stringent environmental regulations becomes increasingly important, energy companies must find cheaper ways to create power while reducing nitrogen oxides (NOx) and unburned carbon (UBC) emissions. One method currently being employed by energy companies is to use Powder River Basin (PRB) coal in boilers instead of eastern bituminous coal.

[0003] PRB coal is relatively low in cost, has a low sulfur content, and is in reliable supply. It also has a higher reactivity than eastern bituminous coal due to a lower fixed carbon-to-volatile ratio. This results in lower NOx and UBC emissions. The volatile portion of PRB coal carries a significant amount of nitrogen, and under staged combustion, the volatiles are released early in the combustion process and burned in the overfire air zone, resulting in a lower potential to form NOx.

[0004] Despite the lower cost and reduction in emissions associated with PRB coal, the use of PRB coal in boilers has created problems that can reduce the boiler's efficiency and reliability. PRB coal has a higher moisture content, a lower energy content, and a different ash composition than eastern bituminous coal. The higher moisture content and lower energy content results in the need to burn larger quantities of PRB coal than eastern bituminous coal to produce the same amount of energy. However, it is the ash composition of PRB coal that causes the greatest impact on boiler efficiency and reliability.

[0005] While all coal-fired boilers experience some ash deposits, the ash composition of PRB coal can create special problems. Ash deposits formed from the combustion of PRB coal are difficult to remove, and may cause severe slagging and fouling on heating surfaces. As a result, deposits from the PRB coal can have a significant effect on the amount of heat absorbed by the boiler. This reduction of heat absorption in the boiler results in higher exit gas temperatures and in less heat being absorbed by the water walls. Thus, the superheater and reheater sections in the convection passes must absorb more heat to maintain full load steam conditions.

[0006] Because the exit gas temperatures are higher, ash entering the convection passes is often above its fusion temperature, causing ash to deposit on the superheater and reheater surfaces and further reduce the ability of the boiler to make steam, thereby reducing the boiler's efficiency. Additionally, these higher temperatures may result in the production of NOx, thereby increasing emissions.

[0007] One of the methods currently being used to reduce the negative effects of PRB coal while maintaining

lower emissions of NOx and UBC is to blend PRB coal with eastern bituminous coal. Blending PRB coal and eastern bituminous coal provides the added energy content of the eastern bituminous coal, the lower NOx and UBC emissions of PRB coal, and a reduction in ash deposition. Although the benefits of blending are numerous, boiler tube fireside corrosion can be a significant problem due to the formation of alkali chloride compounds which attach to the boiler tube surface, especially in a reducing environment such as that caused by staged combustion. The deposition of these compounds also subtracts from the formation of oxidized mercury (HgCl_2), which is important to facilitate the downstream removal of mercury. By minimizing the formation of alkali chlorides, more chloride may be available to form mercuric chloride in the flue gas.

[0008] The formation of unburned carbon (UBC) during coal combustion also helps to reduce vapor mercury emissions due to the absorption of mercury on the carbon. Studies have shown that UBC formed from PRB coal is more reactive than those formed from bituminous coals. With staged combustion, the combustion of PRB coal can be better controlled to optimize the UBC formation for additional mercury capture.

[0009] Accordingly, there is a need for a staged-coal injection procedure that provides the benefits of using PRB coal and eastern bituminous coal while reducing the formation of alkali chlorides.

Summary of the Invention

[0010] Therefore it is an object of the invention to provide a staged-coal injection procedure that reduces fireside corrosion.

[0011] It is another object of the invention to provide a staged-coal injection procedure that minimizes mercury emissions by (1) enhancing the ability to form mercuric chloride, and (2) maximizing the formation of PRB based carbon in ash.

[0012] It is another object of the invention to provide a staged-coal injection procedure that reduces the production of NOx.

[0013] These and other objects of the present invention are achieved in the preferred embodiments disclosed below by providing a coal combustion method including the steps of combusting a first type of coal in a first zone of a furnace, and combusting a second type of coal in a second zone of the furnace, the second zone being at a position above the first zone.

[0014] According to another preferred embodiment of the invention, the first type of coal has a high alkali content.

[0015] According to another preferred embodiment of the invention, the second type of coal has a high chlorine content.

[0016] According to another preferred embodiment of the invention, the method includes the steps of feeding the first type of coal to fed to a first burner for combustion

in the first zone of the furnace, and feeding the second type of coal to a second burner for combustion in the second zone of the furnace.

[0017] According to another preferred embodiment of the invention, the first burner is optimized to combust the first type of coal and the second burner is optimized to combust the second type of coal.

[0018] According to another preferred embodiment of the invention, a coal combustion method includes the steps of providing a first type of coal including a selected first compound; providing a second type of coal including a selected second compound; combusting the first type of coal in a first zone of a furnace; and combusting the second type of coal in a second zone of the furnace. The first and second zones are positioned so as to substantially prevent the first compound from combining with the second compound during combustion of the first and second types of coals.

[0019] According to another preferred embodiment of the invention, the first compound is an alkali compound and the second compound is a chloride compound.

[0020] According to another preferred embodiment of the invention, the method includes the steps of feeding the first type of coal to a first burner for combustion in the first zone and feeding the second type of coal to a second burner for combustion in the second zone.

[0021] According to another preferred embodiment of the invention, the method includes the step of providing combustion air to the first burner and second burner. According to another preferred embodiment of the invention, the amount of combustion air provided to the first burner is less than the amount of air provided to the second burner.

[0022] According to another preferred embodiment of the invention, the method includes the step of providing overfire air in a third zone of the furnace to aid in complete combustion of the first type of coal and second type of coal.

[0023] According to another preferred embodiment of the invention, a coal combustion method is provided and includes the steps of providing a boiler having a furnace section, a first burner positioned in a first zone of the furnace section, and a second burner positioned in a second zone of the furnace section. The method further includes the steps of feeding a first type of coal including a selected first compound to the first burner, combusting the first type of coal in a first zone of the furnace section, feeding a second type of coal to the second burner, and combusting the second type of coal in a second zone of the furnace section. The first compound is consumed in the first zone so as to be substantially unavailable for reaction in the second zone.

[0024] According to another preferred embodiment of the invention, the first type of coal is a Powder River Basin coal.

[0025] According to another preferred embodiment of the invention, the first compound is an alkali compound.

[0026] According to another preferred embodiment of

the invention, the second type of coal is an eastern bituminous coal.

[0027] According to another preferred embodiment of the invention, the second compound is a chloride compound.

[0028] According to another preferred embodiment of the invention, the method includes the step of feeding the first type of coal from a first storage hopper to a first pulverizer where the first type of coal is pulverized.

[0029] According to another preferred embodiment of the invention, the method includes the step of feeding the second type of coal from a second storage hopper to a second pulverizer where the second type of coal is pulverized.

[0030] According to another preferred embodiment of the invention, the method includes the step of providing a combustion air to the first burner, second burner, and an overfire port.

[0031] According to another preferred embodiment of the invention, the amount of combustion air provided to the first burner is less than the amount of air provided to the second burner.

[0032] According to another preferred embodiment of the invention, the overfire port introduces combustion air into a third zone of the furnace to aid in complete combustion of the first and second types of coal.

Brief Description of the Drawings

[0033] The invention may be best understood by reference to the following description in conjunction with the accompanying drawing figures in which:

[0034] Figure 1 shows a prior art staged-coal boiler;

[0035] Figure 2 shows a staged-coal boiler adapted to use a staging procedure according to an embodiment of the invention; and

[0036] Figure 3 is schematic of the staging procedure for the staged-coal boiler of Figure 1.

Description of the Preferred Embodiment and Best Mode

[0037] Referring now specifically to the drawings, a prior art staged-coal boiler is illustrated in Figure 1 and shown generally at reference numeral 10. The boiler 10 includes a hopper 11 for storing and feeding coal to a pulverizer 12, a blower 13 for delivering the pulverized coal and transport air (primary air) mix and secondary combustion air to a burner 16, a furnace section 17 for combusting the coal therein, a boiler tube section 18 for absorbing heat created by the combustion of the coal to create steam, and an economizer and bag section 20 for cooling the flue gas exiting the furnace section 17 and collecting ash particles.

[0038] As illustrated, the boiler 10 uses an air staging procedure by introducing overfire air through an overfire air port 14 into the furnace section 17 in a region above the burner 16. When using an air staging procedure, combustion air provided by blower 13 is separated into pri-

mary (for coal transport), secondary (main burner), and tertiary (overfire) air flows. This encourages complete burnout and the formation of N₂ instead of NO_x.

[0039] For example, the combustion air may be separated into 70%-90% primary and secondary air and 10%-30% overfire or tertiary air. The primary and secondary air is mixed with the coal at the burner to produce a relatively low temperature, oxygen deficient, fuel rich zone that creates moderate amounts of NO_x. The overfire or tertiary air is injected above the combustion zone where combustion is completed at an increased flame volume that limits the production of NO_x.

[0040] Referring to Figure 2, a staged-coal boiler adapted to use a staging procedure according to an embodiment of the invention is illustrated and shown generally at reference numeral 100. While the staging procedure is being discussed with a pulverized coal-type boiler, it should be appreciated that the staging procedure may be used with other suitable boilers, and that the pulverized coal-type boiler is being used as an example boiler for discussion purposes only.

[0041] The boiler 100 includes a pair of coal hoppers 110 and 111 for storing and feeding coal to pulverizers 112 and 113, respectively. The pulverizers 112 and 113 pulverize the coal for delivery to burners 114 and 115. The coal is delivered to the burners 114 and 115 by a portion of the forced air from blowers 117 and 118 where the coal is mixed with the air from the blowers 117 and 118 in the burners 114 and 115 to combust the coal within a furnace section 120 of the boiler 100. The blowers also provide overfire air through an overfire air port 125 for complete burnout. Heat created by the burners 114 and 115 in the furnace section 120 is absorbed by a boiler tube section 121 to create steam. Flue gas, including ash particles, exits the furnace section 120 and into an economizer and bag section 124 where the flue gas is cooled and the ash particles are collected.

[0042] The boiler 100 uses a combination of air staging, like that discussed with reference to Figure 1, and fuel staging to minimize No_x formation, fireside corrosion and mercury (by maximizing mercury oxidation and PRB based carbon). This is done by injecting different types of coal at different levels/stages of the furnace section 120 as well as controlling the coal feed rates and size distribution. For example, coal hopper 110 contains a higher chloride coal "C1" (such as eastern bituminous coal) and coal hopper 111 contains a more reactive coal "C2" with higher alkali and lower chloride content (such as PRB coal). The higher chlorine coal C1 is delivered to pulverizer 112 where it is pulverized and delivered via a portion of the blower air to burner 114 for combustion. The more reactive coal C2 is delivered to pulverizer 113 where it is pulverized and delivered by a portion of the blower air to burner 115 for combustion.

[0043] As illustrated in Figure 3, the more reactive coal C2 with higher alkali but low chlorine content is injected at a lower, deeper staged level of the furnace section 120 while the higher chloride coal C1 is injected into an upper

staged level of the furnace section 120. This allows the chlorides in the higher chlorine coal C1 to be separated from and less accessible to the alkali compounds in the more reactive coal C2, thereby increasing the interaction of the chlorides with mercury and decreasing the formation of alkali chloride compounds. The separation of the chlorides and alkali compounds can be seen in the flow of ash particles "AP1" and "AP2" of coals C1 and C2, respectively. As can be seen, the ash particles AP2 deposit on a lower section of a waterwall 123 of the furnace section 120 and the ash particles AP1 deposit on a higher section of the waterwall 123. Flue gas flows "F1", "F2", and "F3" are also shown exiting the furnace section 120.

[0044] The amount of combustion air being used in the burners 114 and 115 is also different at the lower and upper staged levels of the furnace section 120. For example, the amount of air "A2" used in burner 115 to combust the more reactive coal C2 is lower than the amount of air "A1" used in burner 114 to combust the higher chlorine coal. In addition, overfire air "A3" is injected into the furnace section 120 in a region above the burners 114 and 115 to encourage complete burnout and the formation of N₂ instead of NO_x.

[0045] In addition to increased reaction with mercury, many other benefits may be obtained by using the staging procedure outlined above. For example, improved NO_x reductions may be obtained due to the fact that the more reactive coal may be deeper staged without operability issues. The performance of the mill can also be optimized. By using different coals in separate burners, the burners can be optimized for that specific type of coal. Also, by using both higher chlorine coal and more reactive coal in a boiler, the benefits of both types of coals may be optimized while the problems associated with those coals may be minimized. For example, the problems of slagging/fouling associated with more reactive coals may be minimized by replacing a portion of the more reactive coal with higher chlorine coal. The problem of NO_x production associated with higher chloride coals may be minimized by replacing a portion of the higher chloride coal with more reactive coal. In addition, the amount of energy per unit weight of coal may be increased by replacing a portion of the more reactive coal with the higher chloride coal.

[0046] A staged-coal injection procedure is described above. Various details of the invention may be changed without departing from its scope. Furthermore, the foregoing description of the preferred embodiments of the invention and best mode for practicing the invention are provided for the purpose of illustration only and not for the purpose of limitation.

Attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

All of the features disclosed in this specification (including

any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings) may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

Claims

1. A coal combustion method, comprising the steps of:
 - (a) combusting a first type of coal in a first zone of a furnace; and
 - (b) combusting a second type of coal in a second zone of the furnace, the second zone being at a position separate from the first zone.
2. The coal combustion method according to claim 1, wherein the first type of coal has a substantially higher alkali content than the second type of coal.
3. The coal combustion method according to claim 1, wherein the second type of coal has a substantially higher chlorine content than the first type of coal.
4. The coal combustion method according to claim 1, and further including the steps of feeding the first type of coal to a first burner for combustion in the first zone of the furnace and feeding the second type of coal to a second burner for combustion in the second zone of the furnace.
5. The coal combustion method according to claim 4, wherein the first burner is adapted to combust the first type of coal and the second burner is adapted to combust the second type of coal.
6. A coal combustion method, comprising the steps of:
 - (a) providing a first type of coal including a selected first compound;
 - (b) providing a second type of coal including a selected second compound;
 - (c) combusting the first type of coal in a first zone
- of a furnace;
- (d) combusting the second type of coal in a second zone of the furnace; and
- (e) positioning the first and second zones in relation to each other so as to substantially prevent the first compound from combining with the second compound during combustion of the first and second types of coal.
7. The coal combustion method according to claim 6, wherein the first compound is an alkali compound and the second compound is a chloride compound.
8. The coal combustion method according to claim 6, and further including the steps of feeding the first type of coal to a first burner for combustion in the first zone and feeding the second type of coal to a second burner for combustion in the second zone.
9. The coal combustion method according to claim 8, and further including the step of providing combustion air to the first burner and second burner.
10. The coal combustion method according to claim 9, wherein the amount of combustion air provided to the first burner is less than the amount of air provided to the second burner.
11. The coal combustion method according to claim 6, and further including the step of providing overfire air in a third zone of the furnace to aid in complete combustion of the first type of coal and second type of coal.
12. A coal combustion method, comprising the steps of:
 - (a) providing a boiler having:
 - (i) a furnace section;
 - (ii) a first burner positioned in a first zone of the furnace section; and
 - (iii) a second burner positioned in a second zone of the furnace section;
 - (a) feeding a first type of coal including a selected first compound to the first burner;
 - (b) combusting the first type of coal in a first zone of the furnace section;
 - (c) feeding a second type of coal to the second burner;
 - (d) combusting the second type of coal in a second zone of the furnace section; and
 - (e) wherein the first compound is consumed in the first zone so as to be substantially unavailable for reaction in the second zone.
13. The coal combustion method according to claim 12, wherein the first type of coal is a Powder River Basin

coal.

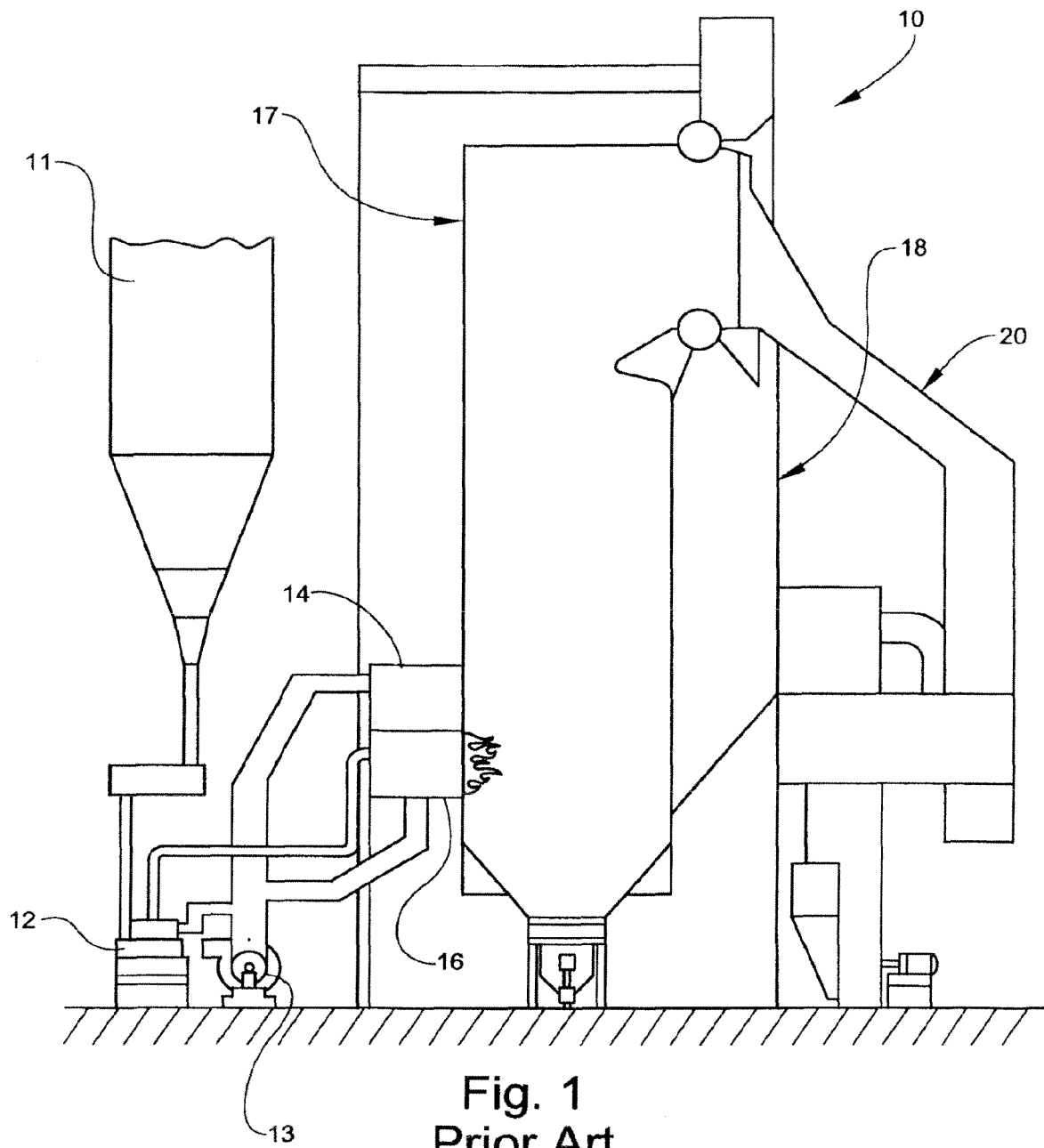
14. The coal combustion method according to claim 12,
wherein the first compound is an alkali compound. 5
15. The coal combustion method according to claim 12,
wherein the second type of coal is an eastern bitu-
minous coal.
16. The coal combustion method according to claim 12, 10
wherein the second compound is a chloride com-
pound.
17. The coal combustion method according to claim 12,
and further including the step of feeding the first type 15
of coal from a first storage hopper to a first pulverizer
where the first type of coal is pulverized.
18. The coal combustion method according to claim 12,
and further including the step of feeding the second 20
type of coal from a second storage hopper to a sec-
ond pulverizer where the second type of coal is pul-
verized.
19. The coal combustion method according to claim 12, 25
and further including the step of providing a combus-
tion air to the first burner, second burner, and an
overfire port.
20. The coal combustion method according to claim 19, 30
wherein the amount of combustion air provided to
the first burner is less than the amount of air provided
to the second burner.
21. The coal combustion method according to claim 19, 35
wherein the overfire port is adapted to introduce
combustion air into a third zone of the furnace to aid
in complete combustion of the first and second types
of coal.

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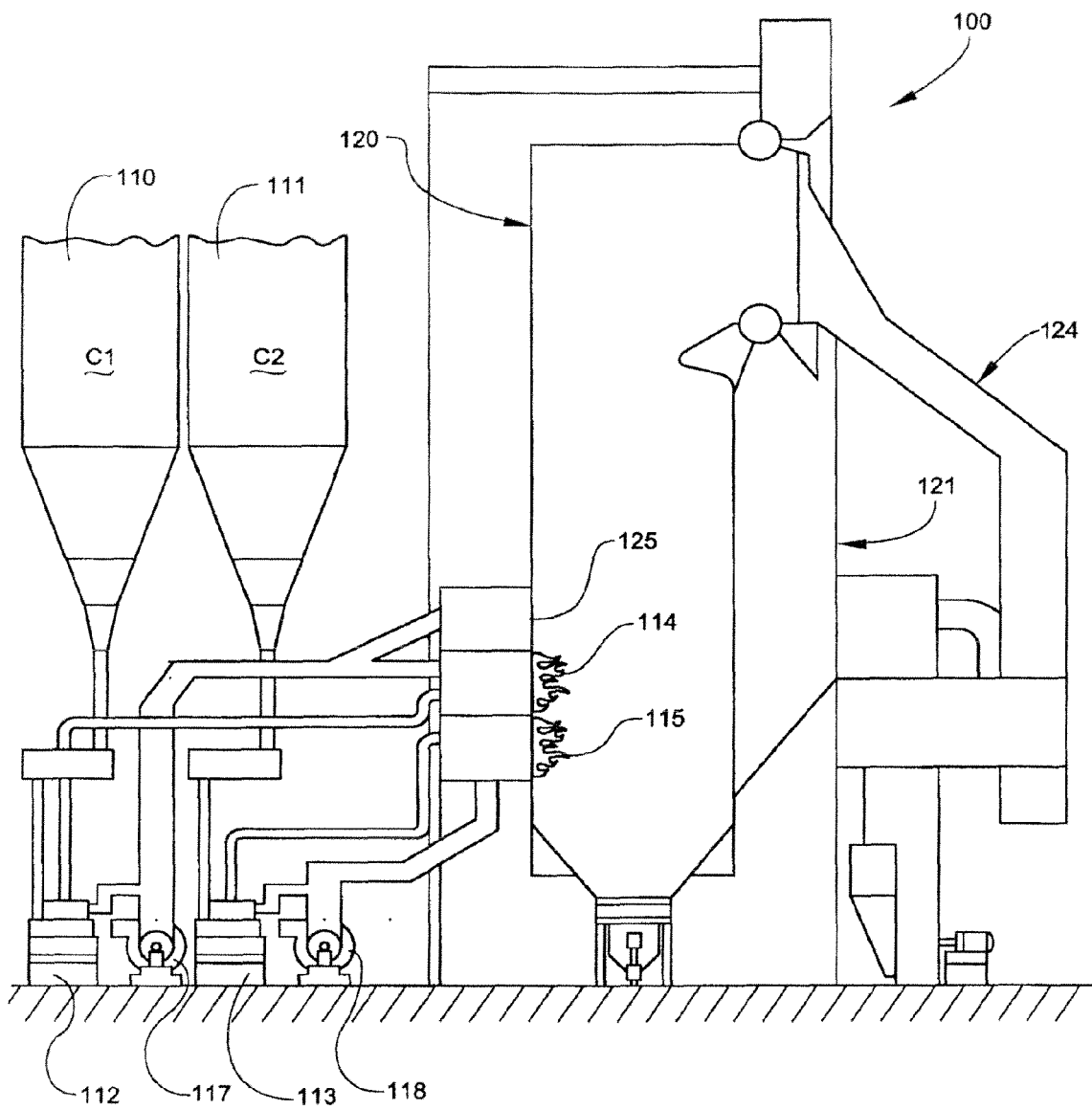


Fig. 2

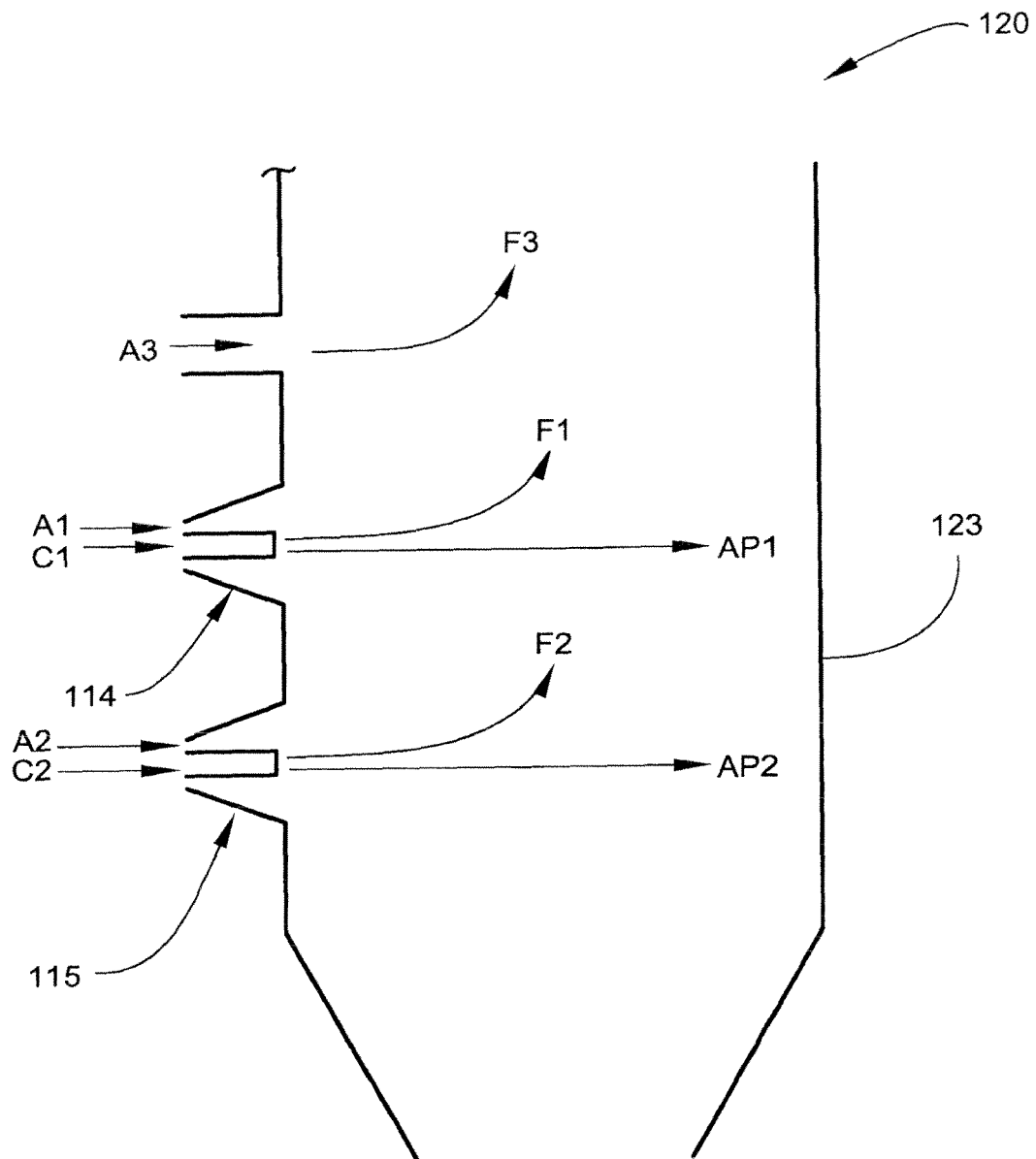


Fig. 3