ABSTRACT

A system and method for drying, cleaning and upgrading coal and biomass solid fuel while integrating the steps with the normal on site steps in coal preparation for a utility boiler, such that boiler efficiency is improved and emissions are reduced. The present invention carefully sequences steps to employ latent heat from one step to the next and more efficiently bring the fuel up to or near ignition temperature. The present invention incorporates several previously related inventions to improve the heat content and cleanliness of the fuel, thus reducing fuel flow rate, ash, CO₂, CO, NOₓ, sulfur, mercury, chlorine, particulate and other emissions, for the same or higher energy output.
Process Flow Chart

Raw Coal 101

Raw coal crusher 102

Fluidized gravity separator 106

Pulverizer 107

Kiln for removal of effluent 108

Finished coal/biomass product delivered to boiler

Biomass 104

Biomass shredder 105

Fig. 1
Block Diagram of the Coal-Biomass System

Fig. 2
Fig. 3a

Motor driven shredder (motor not shown)

202

201 Biomass input

328

326a

327 Cutting blades

329 Biomass output

327
Fig. 3b
Motorized pulverizer
(Motor not shown)

Fig. 3d
Fig. 3e
SYSTEM AND METHOD FOR CLEANING
COAL AND BIOMASS IN EFFICIENT
INTEGRATION WITH FUEL DELIVERY TO A
BOILER

FIELD OF INVENTION

[0001] Recently, there has been an increasing effort to burn
fossil fuels such as coal and biomass more effectively to
reduce emissions and costs. While the global combined heat
and power industry utilizes more coal and biomass than any
other fuel, the need for clean coal has been mandated and
incorporated in numerous National and International pollu-
tion standards in order to prevent health hazards, acid rain,
and climatic impact. The present invention describes methods
for integration of several solid fuel cleaning technologies
with standard processes for preparation of solid fuel and its
delivery to the boiler. The present invention provides for
better efficiency and reduction of heat loss by ordering the
system in steps that sequentially utilize higher temperatures
for preparation of the fuel prior to combustion, in order to help
presently existing solid fuel power stations operate efficiently
while lowering emissions from these plants.

BACKGROUND

[0002] The art of coal preparation has been part of the coal
industry and coal fired boilers since the rise of coal as an
inexpensive fuel during the Industrial Revolution. Initially
based on crushing to desired size, preparation technology
became more automated with the use of specific gravity tech-
nology first suggested by Archimedes in 300 BC. The 19th
century breaker washed coal in a water solution maintaining
a specific gravity of between 1.16 and 1.22 to cause the fuel to
float while the rock and other non-fuel ash would separate by
sinking. More modern techniques include dry separation and
the use of fluidized beds to produce similar segregation of fuel
and non-fuel based on the specific gravity of each. These
separation techniques have been deployed to reduce sulfur in
some coals. The prior art of coal preparation has thus been
limited to sizing and cleaning through separation or washing.
With the increasingly restrictive pollution control regulation
in the past half-century, research has moved to pyrolysis and
other thermal or chemical technologies to remove hazardous
substances before or during combustion. In many cases these
methods have been energy intensive, inefficient, and costly.

[0003] The history and detailed time-line of coal pyrolysis
are well documented and found in a variety of sources. Details
of a pyrolysis process can be found, for example, in “Kinetic
Studies of Gas Evolution During Pyrolysis of Subbituminous
Coal,” by J. H. Campbell et al., a paper published May 11,
1976 at the Lawrence Livermore Laboratory, Livermore,
Calif. Numerous issued U.S. patents describe methods for
the reduction of sulfur in coal, for example, U.S. Pat. No. 7,056,
359 by Somerville et al. Their process involves grinding coal
to a small particle size, then blending the ground coal with
hydrated lime and water, followed by drying the blend at
300-400 degrees F. U.S. Pat. No. 5,037,450 by Keener et al.
utilizes a unique pyrolysis process for densifying or des-
sulfurizing coal. Here the sulfur and nitrogen content of coal is
again driven off in gaseous form and sequestered for possible
further use.

Furthermore, recent efforts to reduce greenhouse gas
emissions has generated a desire to burn biomass in certain
solid fuel plants. The failure to properly prepare biomass for
combustion in a boiler designed for coal has led to power
output reductions, boiler slagging, additional corrosion, and
increased emissions of many hazards.

SUMMARY OF THE INVENTION

[0004] A system and method is proposed for coal and bio-
mass preparation, cleaning and heating together with and
integrated fuel delivery to the boiler that is more flexible and
more efficient than prior art. All thermal processes for the
cleaning of coal and biomass fuels that are conducted near the
mine or source of fuel are prone to higher costs due to energy
and heat loss in transportation. Furthermore, the vicinity of
combined heat and power boilers is an area that is rich in
waste heat. Therefore, by integrating the fuel cleaning pro-
cesses with the processes necessary to deliver the fuel to the
burner tip in the boiler, there are increased efficiencies.

The system begins with raw coal or biomass delivered to the
coals yard of a boiler or power plant, where it is at ambient
temperature. If the particle size of raw fuel is too big to be
handled properly in the equipment, part of the fuel prepara-
tion requires coal crushing or biomass shredding to manage-
able size. Many power plants have their fuel delivered in the
desired size, but having size management equipment in the
system increases the flexibility to reduce costs through the
utilization of lower cost off-size raw fuel. In the process of
being sized, fuels will have been warmed slightly and the coal
fuels are presented to a fluidized bed gravity separator. This
begins a process of combining coal and biomass into a hom-
geneous fuel as in the prior art detailed in U.S. patent appli-
cation Ser. No. 12/483,620, System and Method for Obtain-
ing Combinations of Coal and Biomass Solid Fuel Pellets of
High Calorific Value. This unit should use the gas with waste
heat as an air source for fluidizing the bed. The use of waste
heat in this part of the system reduces moisture while upgrad-
ing the heat value of the fuel, providing savings in transporta-
tion, milling, fuel consumption, ash management, and
emissions of CO₂, CO, SOX, and NOX. Within the gravity
separator the equipment should be managed for separation of
non-fuel ash from the biomass and coal fuels. Through care-
ful balancing of the separator parameters, there will be
removal of certain heavier kernels of fuel that contain high
levels of non-combustible materials, sulfur and mercury. This
part of the system processing will further increase tempera-
ture and the calorific value of the fuel and generate further
savings in materials handling, fuel consumption, ash manage-
ment, and emissions of CO₂, CO, SOX, NOX, and mercury.

The fuel will exit the separator at 10-40 degrees C. above
ambient temperature.

After separation, the system calls for pulverization of the fuel.
Pulverization is a normal on site process for all pulverized
coal boilers, but the present invention produces savings
because each unit of calorific value in input fuel consists of a
reduced quantity of drier, warmer, lower ash fuel that costs
less to pulverize. The pulverizer reduces particle size, and
increases the temperature through friction. The pulverizer
temperature increase of the fuel may be 10-20 degrees C.

The next step in the system is the subsequent invention is to
deliver the hot pulverized fuel to a rotary kiln. Such kiln is not
a normal part of prior art power plant boiler operations. In
the kiln the fuel is in a rotating chamber between two airlocks
that permit the elevation of the temperature of the hot, cleaner,
pulverized fuel above the temperature at which the fuel would
otherwise combust if there were sufficient oxygen present. At
these temperatures, residual moisture is vaporized as well as
chlorine, mercury, arsenic, selenium and other heavy metals traces. These vapors of potential hazards are removed and sequestered with small amounts of reagents such as activated carbon or lime, so that there can be no danger of their emission from the power plant combustion cycle. On exiting the rotary kiln, the fuel in the range 200-300 °C, just below the ignition temperature of most coals. This fuel product is free of chlorine, importantly eliminating alkalis from the fuel, and any biomass that has been added. Absence of alkalis prevents reduction of the melting point of ash and helps eliminate slagging of the boiler walls and tubes through ash fusion. In addition, dioxins and furans, which are complex chlorine based hazardous emissions that are formed during combustion in the presence of chlorine, cannot be formed when the chlorine has been removed before combustion. The system supports the addition of a higher percentage of a wide range of biomass fuels as they are combined in a homogenous mixture with coal that presents to the burner tip a single higher-grade fuel.

When the fuel thus prepared and cleaned is then delivered to the boiler, it will have better ignition and burn more cleanly with lower ash, and lower emissions of particulate, CO₂, CO, SO₂, NOₓ, mercury, hydrochloric acid, dioxins, furans and heavy metals. This system is efficient in the utilization of heat, and delivers to existing boilers an engineered coal fuel that reduces the costs of operations and maintenance in both combustion and post combustion treatment, for the same level of energy output.

**BRIEF DESCRIPTION OF THE FIGURES**

**[0005]** FIG. 1 is a process flow chart showing how raw coal and raw biomass fuels are received and reduced to appropriate size in a crusher or shredder as required, and mixed together on a fluidized bed gravity separation device driven with hot flue gases from the power plant flue stock. The output of reduced size, drier, reduced ash fuel moves to a pulverizer where it is further homogenized and milled to the required powder size for the boiler nozzles. The pulverized fuel is then transferred to a kiln with airlocks that permit heating to 200-400 degrees. The fuel is then delivered to the boiler in the normal fashion.

**[0006]** FIG. 2 shows a block diagram of the system of the present invention is shown where the pulverizer, 208, and the boiler, 210, are equipment normally found in a fluidized coal generating station, with the shredder, 202, crusher, 207, and gravity separator, 204, and the kiln, 205, are positioned on opposite sides of the pulverizer, thus integrating the system with the power plant fuel preparation process in order to better manage heat and efficiencies.

**[0007]** FIG. 3a shows the detail of a biomass shredder in which biomass fuel is chopped into regular sized pieces to aid in materials handling and mixing with coal.

**[0008]** FIG. 3b shows the detail of a coal crusher in which coal fuel is crushed to regular sized pieces to aid in materials handling and mixing with biomass.

**[0009]** FIG. 3c shows the fluidized bed gravity separator that separates ash and other minerals from fuel in order to increase calorific value and reduce ash and emissions.

**[0010]** FIG. 3d shows a pulverizer in which the fuel is reduced in size to a powder that can be blown with air through a nozzle for ignition in the boiler.

**[0011]** FIG. 3e shows the rotary kiln in which the fuel is treated to vaporize moisture and other hazards including chlorine, mercury, arsenic and selenium in order to complete the fuel cleaning prior to combustion.

**DETAILED DESCRIPTION OF THE INVENTION**

**[0012]** The present invention describes a system and method for cleaning coal and biomass fuel in a process that is integrated with pulverization fuel prior to being blown into a pulverized coal (PC) boiler. The system places certain equipment in the fuel delivery path both before and after the pulverizer.

FIG. 1 is a system flow chart diagram at the site of the boiler showing how raw coal 101 enters a crusher 102 to be reduced in size; while raw biomass 104 enters a shredder 105 to be reduced in size. The size-reduced fuels flow from the crusher 102 and the shredder 105 to a fluidized-bed gravity separator 103. In the separator 103, the coal and biomass are mixed, heated with flue gas from the boiler flue stack, and heavy materials with high ash and mineral content are separated and removed from the fuel. The cleaned fuel is transferred to the pulverizer 106 where it is further mixed, further heated, and milled to a fine powder. The fuel exiting the pulverizer is transferred through an airlock to the kiln 107 where it is further heated to remove effluent gases. The cleaned and pre-heated fuel 108 exits the kiln through second airlock is then delivered to the boiler combustion chamber.

FIG. 2 is a block diagram of the integrated system for cleaning and drying of coal and biomass fuel. Biomass, 201, enters shredder, 202, to be reduced in size and gently heated due to friction, prior to delivery to the gravity separator, 204. Raw coal, 206, enters the crusher, 207, to be reduced in size and gently warmed due to friction, prior to deliver to the gravity separator, 204. The gravity separator has an internal fluidized bed, not shown here, through which hot flue gas flows, mixing, agitating, heating and drying the raw fuel. The gas flow agitation of the solid material causes it to perform like a fluid in the precipitation and separation of heavier material through the force of gravity. The agitation on the precisely sloped fluidized bed causes heavier material, which is laden with non-fuel ash and minerals such as mercury, salt, and sulfur, to be separated from the rest of the fuel, thus cleaning it of certain effluent. The cleaned, dried, and heated fuel is delivered to a pulverizer, 208 where the biomass and coal are further mixed and ground into a fine powder suitable for air blown injection into a boiler ignition nozzle. The pulverization increases the temperature through additional friction and further dries the material. The cleaned, dried, heated, mixed, and pulverized fuel is delivered through an airlock, not shown, to the rotary kiln, 205, where it is further mixed and heated in an anaerobic environment to a temperature of 200-400 °C. In order to remove any latent moisture that as water vapor is ducted from the pulverizer end of the kiln using technology based on U.S. patent application Ser. No. 12/788,346 Novel Off-Gas System for Coal and Biomass Pyrolysis. Other non fuel substances such as mercury, chlorine, arsenic, selenium, and sulfur, that are vaporized in the kiln are ducted off the distal end of the kiln and sequestered with lime and activated carbon. Sequester operation not shown. The fuel is then discharged through an airlock and ready for delivery to the furnace, 210.

FIG. 3a is a representation of a motor driven shredder (motor not shown), 202, into which raw biomass, 201 is fed through various means such as gravity, input hopper or the like, 326a. A materials handling device such as a conveyor, 328, moves the biomass through the shredder while a set of cutting blades,
that may be of variable suitable dimensions for the different species of biomass. The motor (not shown) rotates the cutting blades and the cutting action reduces the size of the biomass to a size of 5 cm or less, prior to further treatment. The shredded biomass exits through an output flange, 329. FIG. 3b shows a crusher, 207 used to reduce the raw coal, 206 to a smaller and more uniform size. The raw coal is delivered to the device and conveyed through it via gravity or a moving belt, 302. A motor (not shown) articulated a piston or rollers, 303 that crushes the material. The crushed coal, 301 exits the crusher via an exit flange, 304. Shredded biomass and crushed coal in particle size of 5 cm or smaller, are delivered to FIG. 3c that shows a fluidized-bed gravity separator, with an outer frame and shell 310 and a porous bed, 311 inside the shell. Raw fuel that has been sized mixes as it enters the input flange, 312. While the fuel is on the bed, hot flue gases from the boiler flue stack is blown in through port, 314. The bed is precisely aligned. When the hot flue gases agitate the fuel, the fuel is dried, further mixed, and separated between lighter and heavier material. The heavier fuel particles, with higher concentrations of ash and emission precursors fall off the fluidized bed and exits via flange, 315. The cleaner, drier, mixed fuel exits the separator at the output flange, 313 for delivery to a pulverizer.

FIG. 3d shows a motor driven pulverizer, 333, in which the fuel enters at the top, 331. Rolling cones, 332 driven by a motor (not shown) rotate and mill the fuel particle size into small, fine powder of 50 microns or less, suitable for injection into a boiler through a nozzle, exits the bottom of the pulverizer, 335, from where it is delivered to the fuel hopper of a rotary kiln.

FIG. 3e shows a rotary kiln, 340, in which an externally heated core chamber, 344, that is turned by a motor (not shown), inside the kiln shell, 342. Fuel enters a fuel hopper, 341 and then continues through an airlock, 345, that passes fuel into the kiln core, 344, but does not permit excess air to enter. Inside the kiln, the fuel is heated by electric or gas elements, not shown, outside the kiln core to a temperature that vaporizes residual moisture and emission precursors. These emission precursor vapors, including mercury, chlorine, heavy metals, nitrogen, and sulfur exit the kiln chamber at flange 347 and are directed to a scrubber (not shown) that sequesters these vapors with water and/or reagents. The residual moisture, as water vapor is drawn off the kiln through a flange (not shown) at the opposite end of the kiln from flange 347. The cleaner, drier, hotter fuel, 348, passes through an airlock, 346 and exits the kiln at flange 343. The fuel is then presented with air pressure through a nozzle into a boiler combustion zone where it burns more cleanly, and efficiently.

Having described my invention, I claim:

1. A system located at the site of a boiler for obtaining clean coal and biomass, the system comprising: a boiler, said boiler an integral part of a power plant, said boiler having a flue stack for the release of hot flue gases and an input nozzle for the combustion of solid fuel; raw coal and biomass, further comprising means for the receipt of said raw coal and biomass at site of said boiler; a crusher located at the site of said boiler with means for loading and crushing said coal; a shredding device located at the site of said boiler with means for loading and shredding said biomass; a fluidized-bed gravity separation device located at the site of said boiler, said device receiving and mixing said coal and biomass from said crusher and said shredder respectively together with hot flue gas from said boiler; a pulverizer located at the boiler site with means for receiving coal and biomass from said gravity separation device, said pulverizer further powdering said coal and biomass mixture emanating from said gravity separator; a rotating heated kiln located at the site of said boiler with means for receiving coal and biomass from said pulverizer, and means for transferring said coal and biomass from said pulverizer to said kiln; said kiln further comprising thermal means for removal of hazardous effluent gases evolved from said coal and biomass in said heated kiln, further comprising means for transferring pyrolyzed coal and biomass from said kiln to said input nozzle of said boiler.

2. A system as in claim 1 wherein said boiler comprises an input boiler nozzle, said nozzle receiving said coal and biomass mixture from said kiln.

3. A system as in claim 1 wherein hazardous effluent gases evolving from said coal and biomass mixture in heated kiln are selected from the group of gasses consisting of chlorine, mercury, arsenic, selenium and heavy metals, further said kiln system comprising means for capturing and sequestering said gasses.

4. A system as in claim 1 wherein said fluidized gravity separation device receives hot flue gasses from said power plant stack to mix, heat and dry said coal and biomass from said crusher and said shredding device respectively while separating the heavier and lighter mass of mixed coal and biomass.

5. A system as in claim 1, wherein said pulverizer receives said coal and biomass mix from said fluidized gravity separator.

6. A system as in claim 5 wherein said pulverizer comprises means for sizing coal and biomass content mix, said pulverizer further comprising means for the delivery of its contents into said input of said kiln.

7. A system as in claim 6 wherein the contents of said kiln are heated, said contents further exiting from said kiln in the temperature range of 200-300 C.

8. A system as in claim 7 wherein the exiting heated contents of said kiln enter said nozzle of said boiler.

9. A method for receiving and sizing coal and biomass at the site of a power plant, followed by cleaning the coal and biomass from major pollutants, the method comprising the steps of: loading the delivered coal into a raw coal crusher; loading the delivered biomass into a biomass shredder followed by transferring said coal and biomass content into a heated fluidized-bed gravity separator; transferring said crushed coal and shredded biomass contents from said gravity separator to a pulverizer; transferring the contents from said pulverizer to a pyrolyzing kiln for heating and removing contaminants from said coal and biomass content at a predetermined elevated temperature; transferring said heated contents from said kiln to a boiler, said boiler having a stack emitting hot flue gasses.

10. The method of claim 9 wherein said crusher provides a means for breaking said coal into smaller pieces in the size range of 5 cm or smaller.

11. The method of claim 9 wherein said shredder includes means for cutting said biomass into suitable sizes of 5 cm or less for said pulverizer.

12. The method of claim 9) wherein said fluidized gravity separator mixes said coal and said biomass from said crusher and shredder with said boiler flue gases for injection to a pulverizer, said pulverizer comprising means for further com-
bining and powdering said mixed coal and biomass content into smaller particles of coal and biomass.

13. The method of claim 12 wherein said powdered particles are in the range of 50 microns or smaller.

14. The method of claim 9) wherein said heated kiln receives said mixed coal and biomass particles from said pulverizer, said heated kiln further comprising means for removing and sequestering unwanted contaminants from said coal and biomass mixture.

15. The method of claim 14 wherein said contaminants are at least one of contaminants selected from the group of contaminants consisting of chlorine, mercury, nitrogen, sulfur, arsenic, selenium, and other heavy metals.

16. The method of claim 15) wherein the temperature of said heated decontaminated coal-biomass output from said kiln is in the range of 200-300 °C.

17. The method of claim 9 wherein said boiler comprises an intake nozzle for receiving said coal and biomass contents from said heated kiln.

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