PROCESS FOR PULVERIZING COAL TO ULTRA FINE SIZE

Inventor: George W. Switzer, Jr., Reading, Pa.
Filed: Jan. 29, 1973
Appl. No.: 327,877

U.S. Cl. 241/18, 241/24, 241/48
Int. Cl. B02c 21/00
Field of Search 241/16, 18, 19, 24, 25, 241/29, 31, 38, 41, 42, 48

References Cited
UNITED STATES PATENTS
1,385,447 7/1921 Hamilton .................................................. 241/18
1,576,335 3/1926 Kreisinger .............................................. 241/18 X
1,628,609 5/1927 Newhouse .............................................. 241/18 X
2,430,085 11/1947 Spencer et al ........................................ 241/19 X
3,397,845 8/1968 Muller ................................................... 241/48 X

ABSTRACT
A process for pulverizing coal to ultrafine size of a few microns, comprising conveying the coal through successive pulverizers with an inert gas, separating the ultrafine coal from the inert gas, cooling and recycling the inert gas and producing make-up inert gas by water scrubbing and alkaline or monoethanolamine scrubbing boiler flue gases to remove particulate, carbon dioxide, thereby leaving essentially nitrogen inert gas. Control of the final ultrafine particle size is achieved by regulation of the flow of conveying gas through the final pulverizer. Reject material streams are taken from the pulverizers to improve the quality of the product pulverized coal, which reject streams are burned in a furnace so as to recover their heat value.

15 Claims, 2 Drawing Figures
PROCESS FOR PULVERIZING COAL TO ULTRAFINE SIZE

This invention relates to a process for pulverizing coal to ultrafine size.

While attempts have been made in the past to pulverize coal to such size, these have not been successful, either because of the very high consumption of power for the process, the impurities of the resultant product, or the insufficiency of the comminution for effective use.

An object of the present invention is to provide a novel method for pulverizing coal to smaller ultrafine sizes than heretofore obtained and with higher efficiency and optimum purity.

The largest single use of coal is as a fuel in utility and industrial boilers. In both instances, the larger steam generation units burn the coal in the pulverized form. Nominal particle sizes of coal as fired are 74 microns for bituminous coal and 44 microns for anthracite. These finenesses achieve efficient combustion characteristics while still permitting collection of the ash particles before emission of the flue gas to the atmosphere.

Various types of pulverizers are used to achieve the finenesses desired and each type has been empirically developed to a high degree of efficiency for the purpose intended. Pulverization to particle sizes finer than stated might improve combustion efficiency slightly but at the expense of pulverizer power requirements and difficulty of ash separation. Accordingly there has been no development of pulverizing equipment to produce finer particle sizes in large amounts. Some equipment has been developed to produce much finer particle sizes, but due to high power consumption, low output, and high cost, are economical in processing only relatively higher value products, such as cosmetics, pharmaceuticals, and foodstuffs. However, a number of processes and uses are in development which would benefit significantly through the use of large quantities of coal of much finer particle sizes than used heretofore. Pulverizing coal to a particle size of less than 10 microns would have, among many, the following immediate uses: 1. water and liquid waste purification; 2. direct burning in combustion turbines; 3. suspension in liquids to produce colloidal fuels; 4. as a raw material for the production, by further processing, of submicron particles; and 5. as a feed stock for gasification processes facilitating direct methanation of carbon.

Besides the direct uses of ultrafine coal, pulverizing to smaller than 10 microns particle size will permit, in the process, removal of substantial portions of inorganic ash and pyritic sulfur. In combustion processes using the 1 to 10 micron sizes or substantially smaller sub-micron sizes, the environmental effects of the products of combustion would be considerably reduced. With such "cleaner" fuel in fine particle size, the way is opened for employing combustion techniques which would minimize formation of NOx products in the combustion gases emitted into the atmosphere. Use of these techniques is not now feasible in pulverized fuel combustion.

An object of the present invention is to provide a novel process (including essential components) for the comminution of large quantities of coal to pure, ultrafine particle sizes in the range of 1 to 10 microns.

Other objects and advantages will become more apparent from a study of the following description taken with the accompanying drawings wherein:

FIGS. 1A and 1B, taken together show, schematically, a process for pulverizing coal to ultrafine size in accordance with the present invention.

Referring to FIGS. 1A and 1B, lump or run-of-the-mine coal as received in dumper 1 is crushed in crusher 2 to a nominal maximum size of approximately 1 inch, then passed through magnetic separator 6 and pipe 4 and dried with inert boiler flue gases in flash coal driers 5. The dried coal is stored in coal bunks 7 from which it is fed, at a controlled rate, through gas lock feeders 8, to the coarse (74 microns) pulverizer 9. Conditioned inert gas is introduced through pipe 24 into the control feeder, pressurizing the pulverizer circuits and spaces and causing a flow of inert gas through the coal from and in the bunker 7, thus purging the spaces between coal lumps of air.

The coal is conveyed from the coarse pulverizer 9, pipe 15, through cyclone separator 11 and through the fine pulverizer or reductor mill 12 by conditioned inert gas 16a to pipe 16 and the ultrafine product filters 17 where the ultrafine material is placed in storage bunkers for end use.

The inert gas separated from the product is passed through pipe 18 and cooled by gas cooler 19, separator 20, compressed by compressor 21, and returned through separator 22 and pipe 24 to the pulverizer inlet. A portion of this inert gas separated from the product is passed through pipe 52, compressed to a higher pressure by compressor 53 for operation of the filters 17 and returned to the main inert gas stream in the filters.

Losses of inert gas will occur through leakage, backflow into the bunks 7 and entrainment in the product. To replace these losses, inert gas is made from the boiler flue gases used to dry the raw coal. Steps in the preparation of this inert gas consist of water scrubbing in water scrubber 42 to cool the wet flue gas flowing through pipe 26 and remove particulates, alkaline scrubbing by scrubber 47 to remove gaseous sulfur compounds and scrubbing with monoethanolamine in M.E.A. scrubber 32 to remove carbon dioxide. The remaining gas is essentially pure nitrogen.

More detailed descriptions of the several subsystems follows:

STORAGE, PREPARATION AND HANDLING SYSTEM

Coal is received either directly from a mine, by means of a belt conveyor, or in rail cars if the plant is located remote from the mine. Even if the plant is located adjacent to a mine and the rotary car dumper 1, yard locomotive and a portion of the car dumper house could be eliminated, it may be economically prudent to install complete rail car facilities. This would improve reliability of the raw material supply and also facilitate the opportunity for taking advantage of favorable purchasing opportunities.

Upon receipt, the coal is taken to the crusher house 2 where it is crushed to nominal 1 inch size and conveyed to a junction point where the coal can be diverted into one of two streams. The first (3) of the two streams permits the coal to be moved to a ground level storage pile from which the coal is transferred by bulldozers to a main storage pile. The main storage pile will
create a permanent reserve capacity within the plant area to be used in the event the raw material supply is interrupted for any reason.

The second stream 4 carries the coal through flash dryers 5 where external moisture is removed and through magnetic separators 6 where steel parts, such as nuts, bolts, etc., are removed and finally discharged it into elevated bunkers 7.

**COMMINUTION SYSTEM**

A controlled amount of the dry coal is fed by gravity from the storage bunkers through gas lock feeders 8 to conventional bowl roller or ball pulverizing mills 9 where it is reduced to a 74 micron size. In the pulverizing process, some of the pyrites are removed through pipe 10. Upon being discharged from the pulverizers, the coal is fed through pipe 15 and cyclone separators 11 into high speed impact type reductor mills 12 where it is comminuted to some predetermined size between 1 and 10 microns. Within the reductor mill, the coal is subjected to centrifugal forces which permit removal of additional inorganic ash and pyrites through pipe 13.

As coal is reduced from a nominal size of 1 inch to a product of 100 percent less than some size in the range of 1 to 10 microns, there is a tremendous increase in the exposed surface area of the comminuted material. Along with the increase in surface area there is a very marked increase in the activity of the coal and if size reduction takes place in an air atmosphere, the explosive limits with respect to temperature and/or spark energy may be realized inside the mechanical grinder. Therefore, to provide for safety of operations, the coal will be transported under positive pressure in the comminution system by inert gas, such as nitrogen.

The gas will be introduced into the system at the gas lock feeders 8.

The micron sized particles are then pneumatically carried by means of the inert gas 16a through pipe 16 to fabric bag-type dust collectors or filters 17. Here the particles continuously separated from the carrying inert gas are discharged into product storage hoppers or conveyed to process equipment depending upon the application.

**INERT GAS SYSTEM**

To optimize the balancing between investment and operating costs, the inert gas will be recycled with make-up added to the system to compensate for losses. The inert gas which is approximately 99.5 percent nitrogen and 0.5 percent carbon dioxide (molar composition on a dry basis) enters the reductor mills 12 from pulverizer 9 at approximately 38°C. The entering gas will be water saturated. A relatively small portion of the gas flowing to the inlet side of the mill backflows through the coal feeder line from the coal bunkers and is vented to the atmosphere. By using inert gas for maintaining a slight positive pressure in the coal bunkers, the quantity of air entering the system along with the coal feed is minimized. The quantity of gas flowing through the reductor mills 12 is established based on the speed and physical dimensions of the mill components, the characteristics of the classifying gas with respect to the density and viscosity, and the characteristics of the comminuted product with respect to particle size and specific gravity. The flow rate of gas to each of the mills will be measured and controlled to insure proper flow distribution. As the inert gas and coal passes through the mill 12, a considerable percentage of the horsepower required to drive the mill is converted to heat with a resultant rise in temperature of the processed material. A portion of the heat is expended in vaporizing inherent moisture from the coal material. The system is designed so that the inert gas and comminuted coal leave the mill through pipe 16 at approximately 130°C and, based on complete drying of the coal which enters the mill as an assumed inherent water content of six weight percent, the dew point of the existing gas is approximately 80°C.

The gas leaving the bag filters 17 is passed, by pipe 18, through a heat exchanger or gas cooler 19 and is cooled from approximately 130°C by heat exchange with cooling water. As the cooling of the gas will result in partial condensation of water vapor, a phase separator 20 will be provided downstream of the cooler to remove condensate from the system. Subsequently, the effluent gas from the separator will be boosted in pressure by an electric motor driven centrifugal compressor 21 from a suction pressure of a few inches water column to a discharge pressure, downstream of the compressor aftercooler, of approximately 6 psig. Since additional condensation of water vapor occurs in the compressor aftercooler, a phase separator 22 will be provided for removal of this condensate prior to recycling the gas to the inlets of the mills. Supplemental drying of the compressed gas will not be required since the quantity of water removed from the stream by cooling and partial condensation will be sufficient to reject the entire quantity of water picked-up by the gas from the comminuted coal in the reductor mills 12. A portion of the gas stream which was used for removal of surface moisture in the flash coal dryers 5 will be taken from the flue gas circuit downstream of the particulate (42) and sulfur dioxide removal equipment (47) and will be used to provide the make-up to the inert gas recycle system.

Flue gas in pipe 26 containing approximately 21 percent carbon dioxide and 79 percent nitrogen (molar composition on dry basis) and water saturated will be compressed by compressor 46 from a few CM water column to a discharge pressure, downstream of the compressor aftercooler, of approximately 6 psig. Condensate will be removed from the stream, by separator 30, after leaving the compressor aftercooler, and the gas, free of entrained water, will pass through pipe 31 upwardly through a column where it will be scrubbed by MEA scrubber 32 by a 15 percent solution of mono-ethanolamine (MEA) flowing downward in the column. Within the scrubber column, the MEA reacts with the carbon dioxide at approximately 38°C to form a water soluble salt. The gas leaving the MEA scrubber 32 through pipe 33, which will be approximately 99.5 percent nitrogen and 0.5 percent carbon dioxide (dry basis), will enter pipe 24 and the inert gas recycle circuit upstream of the reductor mills.

The carbon dioxide rich MEA solution leaving the bottom of the MEA tower through pipe 35 is pumped through a heat exchanger 36 and the temperature is raised to approximately 100°C. The heated solution is sent to the upper section of a stripping tower 37 and flows downwardly contacting hot vapors from the reboiler. Steam in pipe 50 will be used to supply the heat of vaporization of tower 37, indicated in dash outline required to generate sufficient boil-up vapors to strip the carbon dioxide from the rich MEA. Condensate
passes through pipe 51. The carbon dioxide vapor leaving the top of the tower 37 contains a portion of the vaporized MEA solution. This MEA is recovered by passing the hot vapor mixture through a condenser and returning the condensate to the stripping tower. The carbon dioxide is rejected to the atmosphere at 38. The hot carbon dioxide free, lean MEA, flows from the reboiler section of the stripping column and is cooled by heat exchange with the rich MEA. The cool lean MEA solution is then pumped back by pump 39 to the absorber tower, thus completing the cycle.

The use of nitrogen produced from this flue gas as a classifying gas in the mill is desirable because it is essentially free of oxygen and it provides for safety of operation. The flow rate of gas required for this purpose is approximately twice that which is available from the flash dryer system. Therefore, the gas flowing through the mills will be recycled and only the quantity of gas required for make-up (5 percent of the recycle stream) will be processed for carbon dioxide removal for addition to the recycle circuit.

BOILER PLANT AND AUXILIARY SYSTEMS

In order to supply heat for moisture removal, inert gas to make up system losses, regenerate MEA solution, and to heat the building, a pulverized coal-fired steam boiler 41 is installed. Slightly less than theoretical air will be used in the combustion so as to exclude oxygen in the flue gases. The boiler will be equipped to bypass, variably, some of its steam generating surface so as to vary the temperature of the flue gas flowing in pipe 62 to the flash coal dryer 5 to accommodate variations in the moisture in the incoming raw coal. Flue gas leaving the flash dryers through pipe 26 will be scrubbed by scrubbers 42 with water 43 to remove heat and particulate matter, then with a solution of sodium hydroxide in scrubber 47 to remove sulfur gases. A portion of the flue gases will then enter the MEA inert gas system through pipe 31. The carbon dioxide is removed from the flue gas because its greater density would increase windage power in the mills. The remaining larger portion of the flue gas not needed for the inert gas system will be exhausted to the atmosphere. As previously noted, it has been cleaned of particulate and sulfur gases and contains only carbon dioxide and nitrogen. The flue gases leaving the flash dryer will be saturated with moisture at a temperature approaching 90°C, and it is desirable to reduce this moisture before entering the MEA scrubber 32. Accordingly, the liquid from the water scrubber 42 which follows the flash dryer will be cooled in a mechanical draft cooling tower 45.

The boiler 41 will generate steam for regenerating MEA solution and for space heating and general plant use. By adjustments of the portion of boiler gases bypassing steam generating surface and the firing rate of the boiler, variations of steam demand and moisture content of the raw coal can be accommodated.

In the water scrubber 42, the particulate matter from the flue gas will be removed. The liquid will pass through a settling tank before being pumped through the cooling tower 45. The settling sludge consisting of flyash and fine coal particles will be air-dried and recycled into the coal entering the boiler’s pulverizers. Leaving the water scrubber 42, the flue gas passes through the sulfur-dioxide removal scrubber 47. In this scrubber, the sulfur dioxide is absorbed into a dilute sodium hydroxide solution, converting the solution to sodium sulfite, and sodium bisulfite.

The sulfite and bisulfite are converted back to sodium hydroxide in a coagulator reactor by the addition of calcium hydroxide. The precipitate from the reactor is calcium sulfite which is pumped as a sludge to settling beds or dewatered in mechanical equipment for dewatering or disposal areas.

In an effort to effect additional efficiencies, the heaviest particles and pyrites from the 74 micron coal in the product pulverizers are conducted through pipes 10 and 13 and burned in the boiler 41.

RECYCLED COOLING TOWERS

In the reductor plant are several sources of heat which must be continuously removed. The main source are water jackets of the mills, circulating gas coolers to remove moisture emanating as inherent moisture of the coal, MEA coolers, and bearing oil coolers of the mills. Therefore, the plant includes a cooling water supply 56 and return system 60 circulating through a heat exchanger 19. Only clean water circulates through this system.

Rejection of the heat to the atmosphere is accomplished by a mechanical draft cooling tower 57. The cooled liquid from the cooling tower is pumped through the heat exchanger 19, mentioned above, and the heated cooling tower water from this exchanger is returned to the cooling tower.

Thus it will be seen that I have provided a highly efficient process and apparatus for pulverizing coal to ultrafine particle size of less than 10 microns so as to enable subsequent use of the pulverized coal in various processes, such as that involving direct methanation of coal when in powdered form, and other applications enumerated above.

While I have illustrated and described several embodiments of my invention, it will be understood that these are by way of illustration only and that various changes and modifications may be contemplated in my invention and in the scope of the following claims.

I claim:

1. A process of pulverizing coal to ultrafine size of a few microns, comprising conveying the coal through pulverizing means together with an inert gas, separating the pulverized ultrafine size coal from said inert gas, cooling and recycling said inert gas through said pulverizing means, producing makeup inert gas by scrubbing boiler flue gases to remove particulate matter and carbon dioxide, thereby leaving essentially nitrogen inert gas, and introducing said makeup inert gas in said pulverizing means.

2. The process recited in claim 1 wherein said scrubbing includes water scrubbing to remove heat and particulate matter and alkaline scrubbing to remove sulfur gases.

3. The process recited in claim 1 wherein said scrubbing includes water scrubbing to remove heat and particulate matter and monoethanolamine scrubbing to react with carbon dioxide to form a water soluble salt.

4. The process recited in claim 1 wherein said coal is pulverized in a plurality of successive steps and the quantity of inert gas is selectively adjusted between any two steps.
5. The process recited in claim 4 wherein control of the final ultrafine particle size is achieved by regulation of the flow of conveying inert gas through the final pulverizer.

6. The process recited in claim 1 wherein reject material streams are taken from said pulverizer means to improve the quality of the product pulverized coal and wherein said reject streams are burned in a furnace recovering the heat value of the reject material to a useful purpose.

7. The process recited in claim 1 wherein reject material streams taken from said pulverizer means to improve the quality of the product pulverized coal and the reject material is processed by oxygen deficient combustion and said scrubbing to remove or recover sulfur, sulfur oxide gases, or sulfur salt by-products.

8. A process for pulverizing coal to ultrafine size, comprising reducing the size of the coal particles to an ultrafine size of a few microns, introducing an inert gas and flowing it with said ultrafine coal particles, separating said inert gas from said ultrafine coal particles, processing flue gas from a stream generator by water scrubbing to remove heat and particulate matter, thence passing the water-scrubbed flue gas through an alkaline scrubber to remove sulfur gas, and finally removing carbon dioxide from the resultant gas so as to leave essentially nitrogen, and adding said nitrogen to said inert gas to replenish losses thereof.

9. The process recited in claim 8 wherein said coal is first crushed to about 1 inch size, then coarse pulverized to about 74 micron size, and finally pulverized to a particle size of between about 1 and 10 microns.

10. The process recited in claim 8 wherein said carbon dioxide is removed by scrubbing said gas, after removal of sulfur, with monoethanolamine.

11. The process recited in claim 8 wherein said flue gas is passed through said coal particles before reduction to ultrafine size.

12. Apparatus for pulverizing coal to ultrafine size, comprising a coarse pulverizer for grinding the coal particles to about 74 micron size, means for reducing said coal particles to less than 10 micron size, means for introducing an inert gas into a stream of said pulverized coal and flowing the mixture to said reducing means, and means for separating the resultant ultrafine coal particles from said inert gas, in combination with a steam generator having flue gases which are passed through the coal to dry it before pulverization, a water scrubber for removing heat and particulate matter from said flue gases, an alkaline scrubber for removing sulfur from said flue gases, means for removing the carbon dioxide from the resultant gases so as to leave essentially only nitrogen, and means for introducing said nitrogen into the stream of said inert gas stream to replenish losses thereof.

13. Apparatus for pulverizing coal to ultrafine size, comprising a coarse pulverizer for grinding the coal particles to about 74 micron size, means for reducing said coal particles to less than 10 micron size, means for introducing an inert gas into a stream of said pulverized coal and flowing the mixture to said reducing means, means for separating the resultant ultrafine coal particles from said inert gas, said carbon dioxide being removed by scrubbing with a monoethanolamine solution, together with a stripping tower fed by steam from said steam generator, and a heat exchanger and pump for heating and circulating the carbon dioxide and monoethanolamine solution, whereby the hot vapors in said stripping tower will strip the carbon dioxide therefrom and permit it to escape into the atmosphere.

14. Apparatus for pulverizing coal to ultrafine size, comprising a coarse pulverizer for grinding the coal particles to about 74 micron size, means for reducing said coal particles to less than 10 micron size, means for introducing an inert gas into a stream of said pulverized coal and flowing the mixture to said reducing means, and means for separating the resultant ultrafine coal particles from said inert gas, said last named means being a filter, a gas cooler, separator and compressor being in series relationship with said filter to return inert gas therein at higher pressure and lower temperature and remove condensate.

15. Apparatus for pulverizing coal to ultrafine size, comprising a coarse pulverizer for grinding the coal particles to about 74 micron size, means for reducing said coal particles to less than 10 micron size, means for introducing an inert gas into a stream of said pulverized coal and flowing the mixture to said reducing means, and means for separating the resultant ultrafine coal particles from said inert gas, said last named means being a filter, a gas cooler, separator and compressor being in series relationship with said filter to return inert gas therein at higher pressure and lower temperature and remove condensate, together with a by-pass line for drawing some of the effluent inert gas from the series circuit and recycling it into said reducing means.

* * * * *