Micropulverization and Drying of Lignite Coal

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A Technical Report

by

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and
Robert B. Ross

Submitted to:

The Mississippi Mineral Resources Institute
University, MS 38677

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Abstract

This report describes combined micropulverization and drying of lignite coal. Heated air or steam is used as the grinding medium in a fluid energy mill type pulverizer. Average product sizes are less than 10 microns in diameter. Also described is a hot-water drying technique which results in a very dry, high heating value product.

It has been found that a coal type fuel with a mean particle size of about 10 microns can be burned in a boiler originally designed for oil or natural gas with minimum slagging of the heat transfer surfaces. There is an estimated 35 billion tons of recoverable lignite coal in the Gulf Coast region. This region has many oil and gas boilers which are used in industry and consume a significant portion of the nation's total energy usage. A lignite water slurry is one form being considered as a retrofit fuel.

The report gives the results of combined pulverization and drying and of hot-water drying. Detailed analyses of the products from each drying temperature are included. It is found that the inherent moisture content can be reduced from an initial 40% to less than 15% which is crucial for satisfactory slurry production.

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CHAPTER 1

INTRODUCTION

The present instabilities in both costs and supply of oil and gas, coupled with the inevitable increase in costs give strong incentives for the conversion of oil and gas-fired boilers to coal. The five general classifications of coal are: peat, lignite, subbituminous, bituminous, and anthracite. These classifications of coal are arranged in an ascending order of carbon content and age. The United States has an estimated ultimate resource of 2.9 trillion metric tons of coal. Of this ultimate resource 182 billion tons are economically recoverable (1).

During the 1970's the Gulf Coast region (Texas, Louisiana, Arkansas, Tennessee, Mississippi, and Alabama) accounted for approximately 50 percent of the nations natural gas use and 31 percent of the nations total energy use. This region also contains an estimated 35 billion tons of lignite coal in depths of less than 200 feet. Therefore, the use of lignite coal as a retrofit fuel for this region is attractive (2).

The quality of the Gulf Coast lignites can vary significantly even within individual mining areas and seams. However, generalized regional trends increase in quality from east to west. Typical as-mined analyses of Gulf Coast lignites show a range of 30 to 50 percent moisture content and 8 to 21 percent ash content (2).

Deposits mined to date have been ideally suited to surface strip mining since they occur in laterally continuous seams, 5 to 15 feet thick, in shallow overburden. Land reclamation conditions are ideal due to the flat to moderately rolling terrain with high to moderate rainfall (2).

At present the three primary methods of burning coal are pulverized coal firing, cyclone firing, and stoker firing. Pulverized coal furnaces are in widest use among utilities and represent the most modern use of this fuel. Cyclone furnaces were introduced because of their ability to burn coals having low ash fusion temperatures and to recover a high percentage of the coal ash as slag instead of allowing it to escape the combustion section and form deposits on boiler tube surfaces. Stoker firing is generally limited to small applications (2).

There are many oil and gas boilers in use today without the capability to burn conventional pulverized coal because of the problems associated with tube slagging. To resolve these problems would generally not be cost effective because of the major modifications and or deratings involved. However, many of the problems of retrofiting boilers for coal usage can be alleviated by using a very finely ground coal (3).

Micropulverized coal is a very finely ground (100% less than 44 microns) coal. Conventional pulverized coal particles, due to their larger size tend to impact and deposit on boiler tubes. However, due to their small size, micropulverized coal particles tend to follow flow streamlines around the boiler tubes. Therefore, there is less boiler tube slagging associated with the burning of micropulverized coal when compared to that from conventionally ground coal (3).

The special properties of lignite coals influence virtually every aspect of direct combustion. Of primary importance are the high moisture contents, low heating values, and alkaline contents common in lignite coals. High sodium content tends to act as a fluxing agent for ash particles which agglomerate and melt on tube surfaces causing slagging or tube fouling. High moisture content necessitates the use of drying before combustion and can cause feed problems (2).

By permanently reducing the inherent moisture content of lignite, the heating value can be increased significantly yielding a higher grade fuel. Also, if the lignite is ground to an ultrafine powder and made into a coil-oil or water slurry, then the potential exists for using it as a retrofit fuel. This end-point use of the lignite is the reason for investigating the properties of the micropulverized/dried product.

Steam drying has been found to be an effective means of permanently drying lignites. Steam drying by the semi-batch Fleissner process operated commercially in Europe from 1927-1960 (3). Research in the areas of steam and hot-water drying are ongoing at the Grand Forks Energy Technology Center. Hot-water drying is a process for the removal of liquid water from high-moisture coal by heating a coal-water slurry under pressure. The tests conducted at Grand Forks have shown that hot-water drying can produce a product with significantly reduced moisture and sodium content thus yielding a product with a higher heating value and a reduced foulage potential (4).

In the first part of this study, the effect of combined pulverization and drying are investigated. The lignite was ground in a fluid energy attrition pulverizer using either superheated steam or air as the working medium.

Parameters used to describe the test results are the changes that occur in equilibrium moisture, ash, volatile matter, and heating value. In addition, the porosity, particle size, density, and surface characteristics of the pulverized lignite are analyzed.

In the second part of the study the results of hot-water drying tests are given. Lignite which had been ultrafine ground using ambient temperature air was heated under high temperature and pressure in an autoclave. The test results are described in terms of the same set of parameters as indicated above for the combined grinding/drying tests.

CHAPTER 2

MICROPULVERIZATION

Micropulverized coal is characterized as having a maximum size of 44 microns. This product can be produced in most types of grinding mills. However, fluid-energy mills are best suited from a machinery wear point of view. Micropulverized coal has a unique characteristic in that the small particle size provides for rapid combustion and less slagging than conventional pulverized coal when used in an oil or gas boiler (5).

The lignite used was pulverized in cooperation with Ergon, Inc. at their Vicksburg facility. A 100 pound per hour fluid-energy mill was used to grind the lignite. In the mill feed coal is ground by its injection into a vertically flowing vortex. The vortex is generated in a manner which provides differential flow velocities within the vortex and a recirculating flow along the containment walls. The vortex is controlled so that it operates in the central region of the containment thus minimizing abrading action along the walls and allowing recirculation. This abrasion along the containment walls is a major problem with many fluid energy mills. Smaller particles exit through a central outlet at the top of the device while (due to the acceleration effects of the vortex) larger particles are forced into the return flow along the walls. The primary grinding mechanism is the impact of particulate material on itself (6).

The tubes in oil and gas boilers are generally spaced closer than those of conventional coal-fired boilers. Because of this increased surface to flow area ratio, the larger ash particles in conventional pulverized coal will impact the tubes and cause slagging. However as already noted, the very fine ash particles in micropulverized coal or lignite tend to follow the flow streams around the tubes resulting in less slagging and erosion (7).

In addition to the lignite tests described in this paper, other work has been performed on micropulverized coal. Fly ash and combustion/deposition tests were conducted on three different types of micronized coal by Stone and Webster Engineering Corporation in cooperation with Babcock and Wilcox. The three parent coals were all bituminous coals with ash contents ranging from low to high.

The fly ash tests were performed at the Babcock and Wilcox Alliance Research Center. This is a 200,000 BTU/HR test furnace designed to produce fly ash with properties similar to ash from a large utility boiler. Conventional pulverized and micronized grinds of the three test coals were burned in the test furnace. Ceramic probes were inserted at the furnace exit to obtain indications of deposition on superheater tubes and the ash from each coal was collected and analyzed for particle size.

The size of ash particles from micropulverized coal was smaller than that of conventional pulverized coal. The largest ash particle size from micropulverized coal was 14 microns compared to 32 microns top size from conventional pulverized coal. For a given particle distribution the ash from the micropulverized coal was half the size of conventionally ground coal.

Deposits of fly ash on ceramic probes when burning coal ground to micronized and pulverized grinds demonstrated that micronized coal ash particles were small enough to travel with the flue gas around the tubes, while pulverized coal ash particles did not; they impacted and deposited on the tubes.

With data from the ash tests supporting a preliminary conclusion that conversion to micropulverized coal, instead of pulverized coal, will require less boiler derating, scaled-up tests proceeded at B & W's four million BTU/HR Basic Test Combustion Unit (BCTU). The purpose of the scaled-up tests was to investigate the effects of coal particle size on combustion and deposition (5).

The testing was performed using one parent coal sample ground to three degrees of fineness: (1) conventional pulverized grind (70% minus 200 mesh); (2) micropulverized, with a top size of 44 microns; and (3) finer micropulverized with a top size of 15 microns. The mass mean diameters were 9.4 and 8.3 microns for the micropulverized and finer micropulverized products respectively.

The initial testing began using conventional pulverized coal. Five parametric tests were planned for this grind, however the deposition test section became clogged with ash before the tests could be completed. The ash buildup occurred within seven hours after start-up.

The micropulverized coal was then tested in the BCTU for 64 hours continuously. The tubes were blown with compressed air every hour, and photographs were taken before and after soot blowing. The hourly soot blowing provided controllable deposition. Occasionally, the coal would hang up in the feed hopper, suddenly free itself, and then start feeding again. When this happened, the coal feed rate would increase briefly and then level out in a short period of time. This surge in feed rate would increase the tube surface temperature 100-200°F causing a drastic increase in deposition rates. However after the temperatures leveled out, the air soot blowing adequately cleaned the tubes. The base deposits on the tubes did not grow over the extended test.

As expected, the flames of the conventionally pulverized and micropulverized coals were visibly different. Because the particles of the micronized coals are smaller and the surface where combustion takes place is larger than with conventional grinds, the particles burn in a shorter, brighter flame. The increased brightness is due to the more intense combustion than is typically seen with conventional grinds.

The ash furnace tests support the contention that ash deposition rates will be less for micropulverized coal than for conventional pulverized coal. The results, though not completely conclusive, indicate that equipment modifications and or plant derating will be significantly less in converting to coal if micropulverized coal is used instead of pulverized coal. While these tests were performed with bituminous coals, similar trends would be expected with lignites.

CHAPTER 3

EXPERIMENTAL PROCEDURE

The lignite investigated was obtained from a test pit opened by Mississippi State University on land leased by Phillips Coal Company in Panola County, Mississippi. The lignite was from the Claiborne group and was beneath approximately thirteen feet of overburden. The seam was approximately six feet thick. The samples were placed in barrels lined with polyethylene bags prior to pulverization studies at the Ergon laboratory in Vicksburg. The proximate analysis of the as-mined lignite performed by Phillips Coal Company is shown in Table 1. This analysis is shown on an as-received and equilibrium moisture basis.

The equilibrium moisture value is defined as the in-place coal seam moisture value. This moisture value is obtainable in the laboratory by placing a coal sample in a 97% relative humidity environment for a specified period of time. The laboratory results agree well with the actual bed moisture for higher rank coals, however the equilibrium moisture results produced in the laboratory for the lignite investigated are low compared to the actual bed moisture (8). Even though the actual bed moisture is predicted low for this lignite, it is a reproducible property which is used as a basis of comparison.

The lignite was pulverized at the Ergon laboratory with both steam and air used as pulverizing mediums. Temperatures of 250, 325, 400, and 460°F were used with steam as the pulverizing medium. The maximum steam temperature that could be obtained due to the limitations of the steam superheater was 460°F. Temperature runs of 250 and 325°F were planned for the air medium. However, the lignite began to ignite at