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Project Summary

Homer City Multistream Coal Cleaning Demonstration: A Progress Report

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This report gives an overview of ongoing testing and evaluation of the Homer City Coal Cleaning Plant, built to enable the Homer City Power Complex to meet sulfur dioxide (SO_2) emission levels mandated by the Pennsylvania and Federal governments.

The plant was constructed as a result of an extensive comparative evaluation of flue gas desulfurization (FGD) and physical coal cleaning. The Homer City System, The Multistream Coal Cleaning System (MCCS), was chosen as an economical alternative to FGD.

The plant contains circuits for cleaning coarse, medium, and fine coals and for recovering fine and very fine coals. The dominant type of cleaning equipment used in the plant is the dense medium cyclone.

The original "93 plant" configuration was never able to clean coal to the conditions specified in the plant design. An extensive test and evaluation program was begun to identify and correct the causes of plant operating problems. After extensive pilot plant equipment tests and engineering studies were completed, recommendations were made for plant modifications neccessary to correctthe design and operating deficiencies of the plant. Extensive modifications were made to one of two parallel processing trains in the plant (the "B" circuits), and a test program was initiated to evaluate these corrective measures.

The recently modified "B" circuits have not yet met design conditions. Presently, the fine and medium coal circuits are undergoing an evaluation to determine why the cyclones are not operating at predicted levels and to test further proposed corrective actions in actual operation.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The Homer City Power Complex consists of two 600 MW boiler/turbine/generator units and one 650 MW unit, fed primarily from two dedicated mines and from other sources within 30 mi (48 3 km) of the plant.

Units 1 and 2 (600 MW) at the generating station must meet an SO_2 emission limit of 3 7 lb/10^6 Btu (1590 ng/J) mandated by the Pennsylvania Department of Environmental Resources (PA DER). Unit 3 must comply with an EPA New Source Performance Standard (NSPS) limiting SO_2 emission levels to 1.2 lb/10^6 Btu (516 ng/J).

To meet both emission levels using the captive coal reserves on-site, two compliance strategies were initially considered· the first considered a coal cleaning system in Units 1 and 2 and a FGD system for Unit 3; the second, the MCCS, involved constructing and operating a coal preparation plant to produce two grades of compliance coal capable of meeting both emission regulations. Evaluating both strategies led to the conclusion that the MCCS would offer substantial capital, operating, maintenance, effluent disposal, and boiler operating costs savings over FGD.

This report chronicles the history of the MCCS coal preparation plant, describes its design and operating problems, summarizes corrective measures, and provides some preliminary results of tests on the modified portion of the plant.

Coal Preparation Technology

Operations and Equipment

Coal preparation or benefication is used to remove mineral matter from coal. Since the advent of sulfur emission regulations, many development activities have focused on coal desulfurization.

Several different unit operations are used in coal preparation, including size reduction, size classification, coal cleaning, dewatering and drying, and pollution control/waste disposal. Modern commercial coal preparation plants crush coal and separate the particles into several size ranges which may be defined as coarse, medium, or fine. Each size fraction is usually processed in a separate circuit using equipment suitable to the size range and cleaning objectives.

Size reduction liberates mineral impurities and produces the range of sizes needed in subsequent cleaning activities. Size reduction is mechanical: equipment breaks the coal by impaction, compression, splitting, shearing, or attrition. Primary size reduction usually involves rotary breakers or crushers; second and third stages, crushers or mills

Size classification is commonly used to remove fines prior to size reduction and to separate size ranges prior to further processing or sale. The major classification technique is wet or dry screening. The most common screens used in coal preparation are:

— Perforated plate and square-opening wire screens that shake or vibrate.

— Curved stationary screens (sieve bands) to separate fine and intermediate size particles in water slurries.

— Classifying cyclones to separate fine coal particles from coarser fractions.

Coal is most commonly cleaned in equipment that relies on differences in the size, shape, and specific gravity of particles for separating the organic and mineral coal particles.

Jigs remove mineral matter and mining refuse from coarse and intermediate size coal, using hydraulic pressure to stratify a bed of coal.

Wet concentrating (Deister) tables use water to separate or wash intermediate and fine size coal on a vibrating ribbed surface.

Hydrocyclones process a slurry of medium or fine size coal in large quantities at relatively low cost.

Dense medium separators include dense medium vessels and dense medium cyclones. Both types of separators are fed a slurry of sized coal, water, and magnetite. The amount of magnetite can be adjusted to control the separating specific gravity. The vessels are static baths in which the less dense clean coal particles float and the heavier refuse particles sink. The cyclones separate coal and refuse by centrifugal force: the heavier refuse particles are forced to the outside of the cyclone and are removed through the underflow orifice at the cyclone apex; the less dense coal particles are transported to the center of the cyclone where they are removed via the vortex finder as the clean coal overflow. In addition to the vessel or cyclones, the dense medium circuit contains equipment for controlling the slurry density and recovering magnetite for reuse.

Performance Criteria

Several criteria are used to evaluate the performance of coal cleaning equipment and are classified according to the degree to which they depend on the characteristics of the coal being cleaned. Some criteria are dependent, either directly or indirectly, and some are, under certain circumstances, essentially independent. Dependent criteria include: weight yield, Btu recovery, emission parameter (of clean coal), emission reduction, recovery reduction, misplaced material, yield error, and ash error. Independent criteria include: probable error, error area, and imperfection.

Design of the 93 Plant

In 1975, owners of the Homer City Power Complex decided to proceed with the design and construction of a complex coal cleaning system using dense medium cyclones as the primary component of deep coal cleaning for Unit 3 NSPS compliance.

The basic coal cleaning technology initially implemented at Homer City was well established; however, several new process design features and innovations were incorporated into the system including:

— Raw coal crushing was controlled to minimize production of very fine coal.

— Dense medium cyclones, commonly used to perform gravitational cleaning of sized coal, were used to separate coal and ash at smaller particle sizes and lower specific gravity than normally used in commercial practice.

— Scavenging equipment was incorporated in the fine coal processing circuits to recover about 95 percent of the energy in the coal fed to the preparation plant.

— Efficient pollution control devices and methods of residue disposal were used to minimize the environmental impact of coal cleaning. The process water was recirculated to the coal cleaning operation to provide a closed water circuit.

The 93 plant contained circuits for cleaning coarse, medium, and fine coal as well as circuits for recovering fine and very fine coal. The dominant type of cleaning equipment used in the plant was the dense medium cyclone (DMC). Hydrocyclones and concentrating (Deister) tables were used to reclean fine coal from the underflow of the fine-coal, low-gravity DMC circuit. Thickeners were used to close the water circuit and to help recover fine and very fine coal.

The coarse coal, 1¼ x ¼ in. (31.8 x 6.3 mm), was processed through 24 in. (61.0 cm) diameter heavy media cyclones at 1.8 specific gravity (s.g.). The overflow from this separation was screened to remove water, and the resultant material was used as a component of the middling product for Units 1 and 2. The underflow was discarded as refuse.

The medium coal circuit produced two products. The ¼-in. x 9 mesh (6.3 x 2.0 mm), was processed in 14 in. (35.6 cm) s.g. The overflow of this separation (deep-cleaned product) was split; 57 percent was used in the deep-cleaned product, 43 percent in the middling product. The underflow of this separation was reprocessed at 1.8 s.g. to recover usable coal for Units 1 and 2.

The fine coal, 9 x 100 mesh (2.0 x 0.15 mm). was processed in 14 in. (35.6 cm) DMC's after being reclassified to remove any very fine material to avoid an adverse effect on product quality. The underflow was recleaned (using hydrocyclones and Deister tables) and used in the middling product. Material finer than 100 mesh (0.15 mm) was not cleaned, but bypassed to the middling product.

Evaluation and Modification of the 93 Plant

Because of several design and operating problems, the plant never produced the projected quality and quantity of product coal. The three major problems identified with these circuits were:

— Poor water feed to the plant and poor water distribution in the circuits made it impossible to run the plant for any sustained time and maintain conditions needed for proper equipment operation.

— The low gravity DMC circuits failed to achieve design performance even when design operating conditions were attained.

— Magnetite losses in the DMC fine coal cleaning circuits were excessive.

To rectify these problems, a cooperative pilot plant test program was conducted by the Department of Energy (DOE), EPA, and the Homer City owners. Thirty-six tests were conducted on an 8 in. (20.3 cm) DMC with the cyclone operated at a nominal feed rate, at 1.3 s.g. with 9 x 100 mesh (2.0 x 0.15 mm) coal. Statistical evaluation was performed by Bituminous Coal Research, Inc., and the following conclusions characterize cyclone operation at low gravity with fine coal:

— Dense medium cyclone performance improves as particle size of the feed coal increases.

— Cyclone performance, as measured by the dependent criteria and percent sulfur reduction, is statistically related to flow rate level.

— Cyclone performance, as measured by the dependent criteria, is related to the size of the inlet orifice.

— Dense media cyclone performance improves as the percent of coal in the slurry decreases.

— The cyclone operating parameters investigated are, in general, more highly correlated with independent measures of cyclone performance than with dependent or sulfur-based criteria.

— For the test matrix under investigation, cyclone operating conditions corresponding to a 1.5 in. (3.81 cm) orifice size, 120 gpm (454.3 l/s) flow rate, and 7:1 media to coal ratio produced best overall cyclone performance.

In addition to the pilot plant tests, several cleaning plant consultants and engineering firms were requested to survey the existing plant and propose corrective measures.

As a result of these efforts, the "B" side of the 93 plant was extensively modified and started up in 1982.

Although the coarse coal circuit cleaning equipment was not changed, it now processes a minimum coal size of ⅛-in. (3.15 mm) instead of ¼-in. (6.35 mm). The coarse coal is separated at 1.8 s.g. in 24 in. (61.0 cm) cyclones into a middling product and refuse.

The medium coal circuit was changed to process coal in the size range of ⅛-in. x 16 mesh (3.15 x 1.0 mm) instead of ¼-in. x 9 mesh (6.35 x 2.0 mm) and the low gravity DMC underflow is recleaned in hydrocyclones and concentrating tables instead of only in dense medium cyclones.

The major changes in the fine coal circuit involve redefining the coal size from 9 x 100 mesh (2.0 x 0.15 mm) to 16 x 100 mesh (1.0 x 0.15 mm), the use of fifteen 8 in. (20.3 cm) cyclones to replace the former bank of eight 14 in. (35.6 cm) cyclones, the use of a low head static feed tube to stabilize inlet pressure, and the use of special screening devices to eliminate the 100 mesh (0.15 mm) "slimes" before processing.

1982 Plant Performance

In 1982 modifications to solve major operating problems in the MCCS were completed on the "B" circuits within the plant. The program to test the modified "B" circuits has centered around the evaluation of the revised low gravity circuits for cleaning medium and fine/very fine size coal. Testing has included that needed for start-up, conceptual design verification, and performance evaluation of the low gravity modifications. Performance evaluations of the 1982 plant configuration have centered on the medium and fine coal cleaning circuits to improve the quality and yield of the Unit 3 product.

Medium Coal Circuit

Tests were conducted during the start-up period to optimize performance of the 14-in. (35.6 cm) diameter heavy medium cyclones in the medium coal circuit which operates at low specific gravity. The cyclones fell just short of the targeted quantity and quality requirements necessary to meet design conditions for producing compliance coal. In an effort to pinpoint the problem areas within this circuit, an individual cyclone was modified for further testing. This single cyclone within the bank was sampled under various operating conditions to determine the effects of operating parameters on performance. To date, the most dramatic effects in cyclone performance were observed when the plant medium was purged and recharged with fresh E grade magnetite. (Magnetite grade is determined by the weight percent passing a 325 mesh or 0.045 mm screen: B grade is 90 percent passing, E grade is 95 percent passing, and F grade is 98 percent passing the classification point.) Under these conditions, the performance at 1.34 s.g. separating gravity met the design sharpness of separation criteria (i.e., a probable error of 0.03).

Fine Coal Circuit

Optimization testing, including cyclone bank modifications and variation of operating conditions, could not achieve design conditions. As a result, a detailed performance analysis began on a single cyclone within a five cyclone bank. As with the dense medium cyclones above, the most dramatic performance improvement occurred when the plant medium was recharged with fresh magnetite. However,the cyclone did not achieve design performance using fresh magnetite alone. Future testing will be performed to define remedial measures which can be prescribed to achieve design separating efficiency.

Future Testing

Present and future work is aimed at determining why the 8 in. (20.3 cm) dense medium cyclone at the Homer City Coal Cleaning Plant behaves so differently from the pilot plant cyclone tested at the DOE facility. Future plant testing will investigate the effects of cyclone geometry, inlet pressure, cyclone orientation, finer-sized magnetite, medium-to-coal ratio, and coal size distribution on the performance of the 8 in. (20.3 cm) cyclone.

Conclusions

Experience over the past 6 years at the Homer City Coal Cleaning Plant has indicated that fine coal cleaning at low specific gravity is possible, with a good potential for recovering fuel that is remarkably free of ash and pyritic sulfur. To reach full potential, it is necessary to control the feedstock to the cleaning devices, to specially engineer the cleaning devices for their specific coal cleaning function, and to closely control the devices in the plant circuits.

In addition, successful operation of any coal cleaning process depends on the characteristics of the coal reserves to be cleaned. A system that meets coal quality specifications when operating on coal from one reserve may not perform as well when operating with coal from an over- or underlying seam or in a distant part of the same seam.

Future application of coal cleaning to meet extremely low ash and sulfur criteria should be proposed with sufficient lead time to extensively sample the reserve bases proposed for the operation and to test the cleaning efficiency of the low specific gravity device on coal that is representative of the reserve. Plant design should provide accurate classification, sufficient separating equipment capacity, and a system to efficiently by-pass fine coal that cannot be processed. Since it appears that separating efficiency is enhanced using fine magnetite in the system, the magnetite recovery equipment must be optimized for the applications and slurries being processed.

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The complete report, entitled "Homer City Multistream Coal Cleaning Demonstration: A Progress Report," (Order No. PB 84-214 181; Cost: $8.50, subject to change) will be available only from:

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