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TECHNICAL PROGRESS REPORT

for the First Quarter

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POC-SCALE TESTING OF A DRY TRIBOELECTROSTATIC SEPARATOR FOR FINE COAL CLEANING

by

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ABSTRACT

The Pittsburgh Energy Technology Center (PETC) developed a triboelectrostatic separation (TES) process which is capable of removing mineral matter from coal without using water. A distinct advantage of this dry coal cleaning process is that it does not entail costly steps of dewatering which is a common problem associated with conventional fine coal cleaning processes. It is the objective of this project to conduct a series of proof-of-concept (POC) scale tests at a throughput of 200-250 kg/hr and obtain scale-up information. Prior to the POC testing, bench-scale test work will be conducted with the objective of increasing the separation efficiency and throughput, for which changes in the basic designs for the charger and the separator may be necessary. The bench- and POC-scale test work will be carried out to evaluate various operating parameters and establish a reliable scale-up procedure. The scale-up data will be used to analyze the economic merits of the TES process.

During the past quarter, a number of project tasks have been initiated. All documents required for project startup (i.e., work plans, management plans, etc.) have been submitted to DOE for approval. A bench-scale TES unit and an apparatus for studying tribocharging mechanisms have been designed and are currently being fabricated. One of the three coal samples to be used for bench-scale testing has been acquired.

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INTRODUCTION

Numerous advanced coal cleaning processes have been developed in recent years that are capable of substantially reducing both ash- and sulfur-forming minerals from coal. However, most of the processes involve fine grinding and use water as cleaning medium; therefore, the clean coal products must be dewatered before they can be transported and burned. Unfortunately, dewatering fine coal is costly, which makes it difficult to deploy advanced coal cleaning processes for commercial application.

As a means of avoiding problems associated with the fine coal dewatering, the Pittsburgh Energy Technology Center (PETC) developed a dry coal cleaning process, in which mineral matter is separated from coal without using water. In this process, pulverized coal is subjected to triboelectrification before being placed in an electric field for electrostatic separation. The triboelectrification is accomplished by passing a pulverized coal through an in-line mixer which is made of copper, whose work function lies in-between those of carbonatious material (coal) and mineral matter. Thus, coal particles impinging on the copper wall loses electrons to the metal, thereby acquiring positive charges, while mineral matter impinging on the wall gains electrons to acquire negative charges. The triboelectrostatic separation (TES) process has been tested successfully on bench-scale. The results obtained at PETC showed that is capable of removing more than 90% of the pyritic sulfur and 70% of the ash-forming minerals from a number of eastern U.S. coals. It is necessary, however, to test the process on a proof-of-concept scale so that appropriate scale-up information is obtained. Furthermore, it is necessary to increase the throughput of the TES process by improving the design for the electrostatic separation system.

OBJECTIVES

It is the objective of the project to further develop the triboelectrostatic separation (TES) process developed at the Pittsburgh Energy Technology Center (PETC) through bench- and proof-of-concept scale test programs. The bench-scale test program is aimed at studying the charging mechanisms associated with coal and mineral matter and improving the triboelectrification process, while the POC-scale test program is aimed at obtaining scale-up information. The POC-scale tests will be conducted at a throughput of 200-250 kg/hr. It is also the objective of the project to conduct cost analysis based on the scale-up information obtained in the present work.

Specific objectives of the work conducted during the first quarter were: i) to complete project planning, ii) to procure necessary coal samples, iii) to design an apparatus for studying triboelectrification mechanism with an objective of maximizing separation efficiency, and iv) to design an efficient electrode system to maximize throughput.

WORK DESCRIPTION

Task 1: Project Planning

The project work plan was prepared and submitted to the DOE for approval. This document provided a detailed description of the test programs, experimental procedures, analytical methods, and reporting guidelines that would be utilized to ensure the successful completion of the proposed work. Drafts of several other technical/management project plans were also submitted at this time. These included the management plan, milestone schedule/plan, reporting schedule/plan, labor plan, cost plan, and hazardous substance plan. Final approval of the project work plan by DOE is pending.

Task 2: Sample Acquisition

Three coal samples were chosen for the bench-, prototype-, and POC-scale test work.. These include a Pittsburgh No. 8 seam coal, Elkhorn No. 3 seam coal and a Wyodak coal. The Pittsburgh No. 8 coal was chosen for its large reserve base and relatively high pyritic sulfur content, while the Elkhorn No. 3 seam coal was chosen for its potential for producing superclean coals. The Wyodak coal is a western low-sulfur subbituminus coal. This coal was chosen because triboelectrostatic separation (TES) is one of the few benefication methods that may be used for upgrading subbituminus coals.

For bench-scale testing and characterization, one 55 gallon drum of the Pittsburgh No. 8 coal sample was delivered on January 25, 1996. The other two coal samples will be delivered when the bench-scale test work on the Pittsburgh coal is complete. The Pittsburgh coal sample was a run-of-the-mine coal obtained from CONSOL Inc. No assays have been done to date.

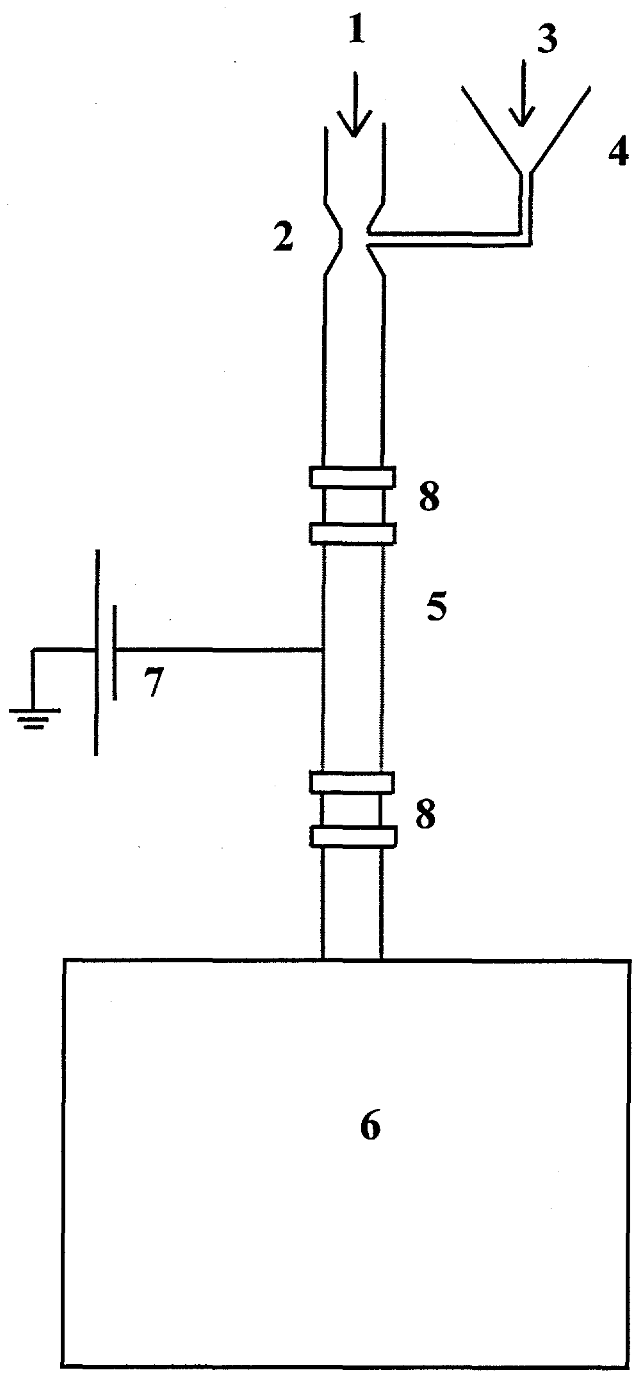
Task 3: Bench-Scale Testing

During the past quarter, extensive studies were made on three major aspects of the project, namely, i) design of tribocharger and charge measurement device, ii) design of bench-scale triboelectrostatic separator, and iii) design of POC test unit. The first two are considered to be part of Task 3, while the last is part of Task 4.1. A key person involved in the discussions was Dr. Anatoly Mesenyashin, Professor, Head, Laboratory of Electrical Separation, Mechanical Treatment Institute, St. Petersburg, Russia. He is the author of a book entitled, "Electrical Separation in Strong Electric Fields," and is recognized as the leader in electrostatic separation.

Charger Design and Charge Measurement

There are two important components in designing a triboelectrostatic separator. One is the charger and the other is the separator. An efficient charger will increase separation efficiency, while the separator will be important in determining throughput. In the present work, a static mixer will be used as the charging device. As particles flow through a static mixer in a gas stream, they are subjected to particle-particle and particle-wall collisions. When two particles of different work functions collide with each other, electrons move from the surface of the particle of low work function (coal) to the surface of the particle of high work function (mineral matter). As a result, coal particles become positively charged, while mineral matter becomes negatively charged. The charge density of the particles may vary depending on the relative abundance of the coal and mineral matter present in the feed stream. The particle-to-wall collision will also produce charges on the particle surface. Particles whose work function is lower than that of the wall will be positively charged, while those of higher work functions will become negatively charged. Thus, the selection of the material from which the in-line mixer is constructed is very important in the charging mechanism. This will be particularly the case when processing low-ash and low-sulfur coals. Copper is frequently used because its work function lies between that of coal and mineral matter.

In the present work, another important variable will be introduced. A potential will be applied to the in-line mixer so that the work function of the material can be varied. This technique will be useful for maximizing the charge difference between the coal and the mineral matter, thereby



1. Compressed Nitrogen Gas
2. Venturi Tube
3. Pulverized Coal
4. Hopper
5. Static in-line Mixer
6. Charge Measuring Device
7. External Circuit
8. Plexi-glass Sleeves

Figure 1. Bench-Scale Tribocharger

maximizing the separation efficiency. If indeed the triboelectrification mechanism can be controlled by controlling applied potentials, it will be possible to construct in-line mixers from wear-resistant materials such as chrome steel, which should be substantially more durable than copper.

Figure 1 is a schematic representation of an apparatus designed to charge particles using an in-line mixer and to measure the charge of the particles. In the charging section, compressed nitrogen gas (1) will be passed through a venturi tube (2) so that it draws the pulverized coal (3) stored in the hopper (4) into the gas stream. As the feed coal passes through the in-line mixer (5), the feed coal and mineral matter will be subjected to particle-particle and wall-particle charging mechanisms as described above. The charged particles will then pass through the charge-measuring device (6) located below the in-line mixer. The potential of the in-line mixer will be controlled by an external circuit (7). The in-line mixer will be insulated from the rest of the system by means of Plexiglas sleeves (8) to minimize short-circuiting. Details of the charge measuring device will be described in the next quarterly report.

Variables to be studied include structural parameters of the static mixer charger (i.e., construction material, geometry, and element configuration) and four operational parameters (i.e., air velocity, solids concentration, particle size, and applied potential).

Bench-Scale Triboelectrostatic Separator

Many electrostatic separators are based on passing charged particles through an electric field so that positively charged particles are collected on the negative electrode (cathode), while negatively charged particles are collected on the positive electrode (anode). One serious problem associated with this method of separation is that throughput capacity is limited by the rate at which the charged particles are collected on the electrode surface, which in turn is limited by the surface area of the electrodes involved. Furthermore, there are particles that are not collected by the electrodes and bypass the collection system.

The bench-scale triboelectrostatic separator to be used in the present work has radically different design features that will eliminate the limitations associated with conventional electrostatic separators. As shown in Figure 2, a laboratory hammer mill (1) will be used to pulverize the feed coal and charge the particles. The mill discharge is collected in a chamber (2) and passes through a flow straightner (3), so that the coal particles enter the electric field created between the two rotating drum electrodes (4). The electrodes are designed to provide a non-uniform electric field. The force (F) of attraction between a charged particle and an electrode surface may be given by the following relationship:

$$F \propto \frac{dE}{dH}$$

in which E is the field strength and dE/dH represents the field gradient. The gradient can be controlled by changing the curvature of the drum electrodes. Although Figure 2 shows that the two drums have the same curvature, electrodes of unequal diameter will also be tested as a means of maximizing the field gradient. As the particles pass through the electric field, positively charged particles will be directed toward the cathode, while negatively charged particles move toward the anode. Based on photographs taken by Finseth and his colleagues at DOE (Doney *et al.*, 1995), clouds of particles are split into two streams in a non-uniform electric field, one consisting of positively charged particles and the other of negatively charged particles. Therefore, the separator shown in Figure 2 will rely on separating particles based on a volume split rather than collection on

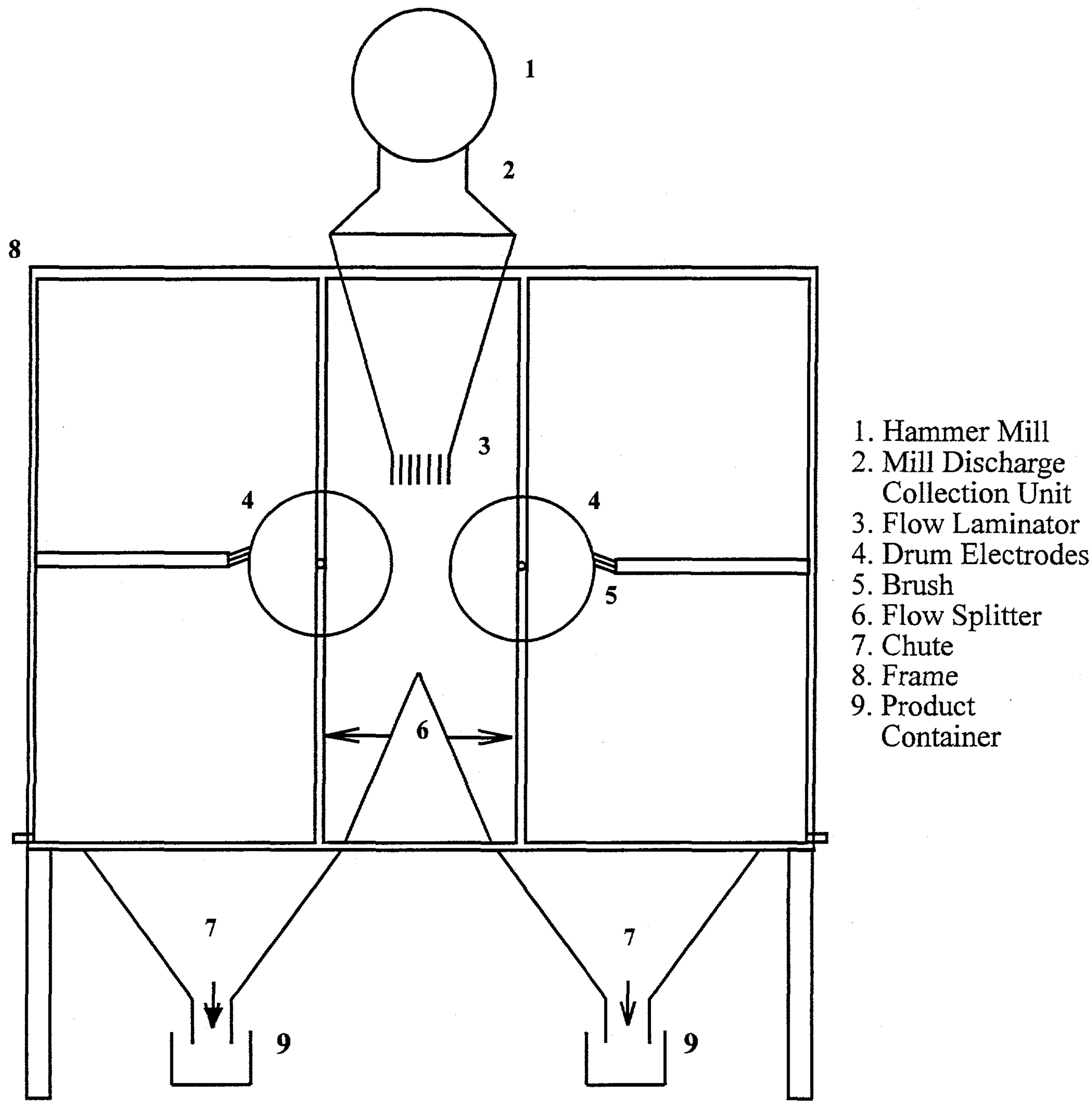


Figure 2. Bench-Scale Triboelectrostatic Separator

electrode surfaces. This will greatly increase the throughput of the separator. Obviously, some of the particles may be collected on the drum surface; however, they can be readily removed by rotating the drums against brushes (5). The splitter (6) located below the electrodes is designed to control the flow split. By moving the splitter from side to side, it will be possible to control the product grades. The positively and negatively charged particles separated as such will be collected in two separate product containers (7). An important advantage of the proposed design is that there will be no bypass (or middlings) products which need to be recycled.

For the reasons presented above, the laboratory separator will have a high throughput capacity. It is possible, however, that the separation efficiency may be lower than the case of collecting particles directly on the surfaces of electrodes. Therefore, laboratory tests may be run in multiple stages, and the results will be used for obtaining grade vs. recovery curves. Other process variables to be tested will include feed rate, particle size distribution, electric field strength, flow split, splitter location, etc.

Note here that a coal sample is directly fed to the separator from the mill. The reason is that the particles may be sufficiently charged in the mill during the process of comminution. Indeed, milling may provide the most efficient means of charging particles in practice. Nevertheless, some of the bench-scale test work will also be conducted by using in-line mixers as a charging device, as described in conjunction with Figure 1.

SUMMARY

During the first quarter, project planning was completed and all required documents were submitted to DOE for approval. One of the three coal samples to be used for the proposed bench-scale TES program was acquired, and characterization/analysis of this sample will be carried out during the next quarter. Major accomplishments achieved during the current reporting period include: i) design of an experimental apparatus for studying triboelectrification mechanism, ii) design of an external potential control system to control the triboelectrification mechanism, and iii) design of a bench-scale triboelectrostatic separator which is capable of maximizing throughput.

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