ENERGY & MINERALS RESEARCH COMPANY

EFFICIENT ULTRASONIC GRINDING: A NEW TECHNOLOGY FOR MICRON-SIZED COAL

QUARTERLY TECHNICAL PROGRESS REPORT NO. 1
September 15 - December 15, 1979

by W. B. Tarpley, Jr.
P. L. Howard
G. R. Moulder

January 9, 1980

Work performed under Contract No. DE-AC02-79ER10466
For U. S. DEPARTMENT OF ENERGY

ENERGY & MINERALS RESEARCH COMPANY
964 East Swedesford Road, P. O. Box 389
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Table of Contents

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Abstract

During the first quarter, preliminary testing demonstrated the ability of ultrasonically enhanced comminution to increase fraction of -200 mesh particles by 100 to 500% over mechanical grinding alone. Modification of the preliminary ultrasonic comminution process to include cycles of ultrasonic activation followed by removal of fines has shown a significant increase in the production of -325 mesh particles (-44 microns) with substantial fractions in the -20 micron and -10 micron ranges.

Efforts to characterize coal samples have yielded a correlation between Hardgrove Grindability Index (HGI) and susceptibility to ultrasonic comminution. This information, along with other considerations and data relating to the cost effectiveness of industrial ultrasonic comminution, will be used to select coal samples for the Phase II experiments.

While several preliminary equipment configurations have been used, their purpose has been mainly to verify the mechanism of ultrasonic comminution and to secure design information for the concepting and fabrication of the optimized laboratory apparatus for Phase II testing. On this basis a "nip" configuration has been selected to insure contact throughout the ultrasonic activation period and prevent coal particle compaction.

Project Description

The objective of this project is to demonstrate on a laboratory scale the technical feasibility and economic promise of efficiently applying ultrasonic energy to the production of 2-7 micron coal fines. Such a system could overcome the inherent inefficiency and economic penalty of mechanical grinding, while producing better size uniformity in the product. An additional benefit associated with the mechanism of ultrasonic effect is the possibility of selective liberation of ash and pyrite inclusions.

I. INTRODUCTION

Coal processing has become an increasingly important industry as America continues conversion efforts from petroleum to coal. In order to provide coal with combustion performance approximately equivalent to oil or gas, much finer particle sizes will be needed than the conventional plant grind size (75% -200 mesh).

Conventional grinding techniques cannot economically meet this goal. A new comminution technology, ultrasonic grinding, can offer a solution. Because it operates by methods not common to those of conventional grinding systems, it is expected that ultrasonics can significantly enhance grinding efficiency in the 2-7 micron range needed for various types of processing and "clean coal" applications.

The mechanisms of ultrasonic grinding appear to be:

- Very rapid (10-60 kHz) vibratory promotion of fatigue fracture;
- Promotion of stress corrosion;
- Preferential energy delivery to discontinuities;
- Prevention of small particle shielding by larger ones;
- Cavitation and preferential shear in damp or paste media.

These mechanisms all appear beneficial in producing the desired particle size range by a process entirely amenable to high volume production and at dramatically decreased energy requirements.

II. EXPERIMENTAL PLAN

The program is following the steps outlined below:

Phase I

A. Conduct preliminary ultrasonic comminution tests using existing laboratory equipment.

B. Design and fabricate laboratory-scale ultrasonic comminution apparatus.

C. Using selected samples of candidate coal, conduct experimental runs with and without ultrasonic activation.

D. Evaluate samples produced for particle size distribution and generate Phase II apparatus design data.

Phase II

A. Optimize laboratory comminution equipment.

B. Conduct sufficient experimental runs and evaluation to:

1. estimate maximum requirements of ultrasonic energy to produce ultrafine coal particles;
2. estimate production equipment requirements;
3. demonstrate repeatability of ultrasonic effect;
4. determine if selective fragmentation of coal inclusions occurs.

III. PRELIMINARY WORK

Preliminary experiments in ultrasonic comminution of coal were conducted during the first quarter of this program. Samples of coals having four different Hardgrove Grindability Indices were screened to -6+8 mesh sizes and tested. The apparatus, shown in Figure 1, comprised a 20-kHz transducer, a tuned half-wave adaptor section, and a retaining cup to hold the coal samples to be comminuted. The cup maintained pressure on the coal sample during activation to assure contact between the bulk coal and the ultrasonic coupler by hydraulically imposing a steady force of 1085 lbs. on the coal-containing cup. Each sample consisted of ten grams of coal sized to -6+8 mesh. The transducer was activated at 20 kHz with an input power of 150 watts for a fixed period of two seconds. As expected, the actual amount of power transferred into the coal sample during that time was considerably lower, due to system losses inherent in the non-optimized breadboard comminution apparatus.

The four candidate coals had Hardgrove Grindability Indices of 45, 55, 86 and 93. Each of the four coal types was subjected to four ultrasonic activation tests as well as an unactivated control test. For these initial runs, post-test coal sizing was accomplished simply by screening to determine the percentages of +18, -18+100, -100+200, and -200 mesh particles. Table I summarizes the data. From these results, it appears that the apparatus to be designed for laboratory scale tests should assure maintained contact between the ultrasonically excited element and the fractured or comminuted coal throughout the comminution period, and therefore a nip configuration (as in a roller-roller or roller-table or its equivalent) will be used. The "breadboard" apparatus used was only intended to generate data on the relative correlation of grindability and ultrasonic activation. Obviously, the full advantage of ultrasonic comminution will rely on rapid removal of generated fines (i.e., the desired ultrafines in the 2 to 7 micron size range)to prohibit their subsequent inhibition of further production of fines. Even in this

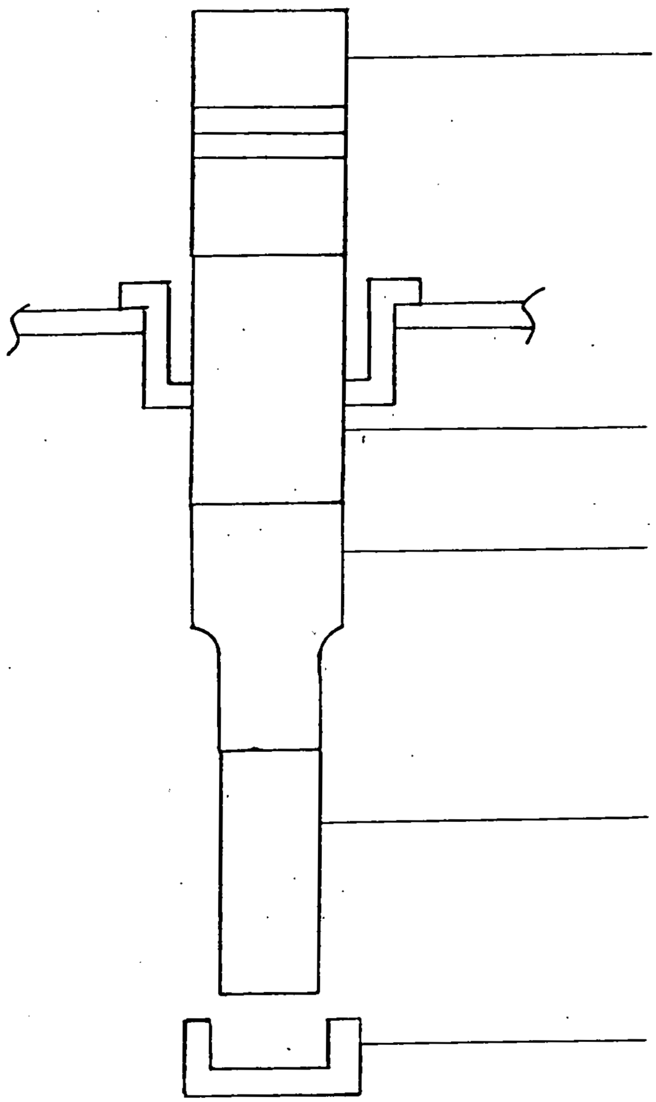

Figure 1

SCHEMATIC OF PRELIMINARY

COMPRESSION-MODE COMMINUTION APPARATUS

Table I

PRELIMINARY ULTRASONIC COMMINUTION TESTING

ON FOUR SAMPLE COALS

	Coal Sample 1-HGI 45		Coal Sample 2-HGI 55		Coal Sample 3-HGI 86		Coal Sample 4-HGI 93	
	U/S Activation	No Ultrasonics	U/S Activation	No Ultrasonics	U/S Activation	No Ultrasonics	U/S Activation	No Ultrasonics
Final Size Distribution (%) (Mesh Size)								
+18	76	93	75	88	58	81	58	78
-18 +100	20	6	20	10	30	16	30	17
-100 +200	2	1	2.5	1	10	2	5	2
-200	2	0	2.5	1	2	1	7	3

preliminary demonstration, however, the data indicate that comminution below the 100 mesh level and especially below the 200 mesh level is greatly enhanced by the application of ultrasonic energy. (Typically, such application enhances selective comminution by a factor of at least 100% and as much as 500%, as measured by weight percentage of -200 mesh particles generated.) In addition, it is evident that while all samples benefited from comminution, the effect increased with increasing HGI.

In a second experiment, a method of removing the fines as well as subjecting the coal to more extensive ultrasonic comminution was evolved. This more efficient system generated a high percentage of -325 mesh particles, and permitted more complete analyses of particle size distribution in this range. Two samples of coals having HGI's of 45 and 93 respectively were comminuted utilizing the apparatus shown in Figure 1. The test conditions of the previous experiment (contact force of 1085 lbs. and ultrasonic treatment duration 2 secs.) were maintained for this experiment. A 10-gram sample of HGI 93 was tested first. The resultant particles were screened through a 200-mesh sieve. After screening, the +200 mesh fines were again ultrasonically comminuted. Each sample was subjected to this cycle of ultrasonic comminution and screening ten times to insure separation of -200 mesh fines and permit more efficient comminution of the larger particles. All the -200 mesh fines were then ultrasonically comminuted and sieved through a 325 mesh screen. The -325 mesh fines were analyzed by sedimentation to determine the distribution of particle size. A sample of HGI 45 coal was similarly treated (Table II) to produce the same weight of -325 fines that resulted from tests of the HGI 93 coal. Again the -325 mesh fines were analyzed by sedimentation to determine the distribution of particle size. The particle size distribution in the size range below 100 microns (150 mesh) was essentially the same for both HGI coal samples tested.

The basic ultrasonic effects involved in coal comminution suggest that some potential for selective liberation of inclusions such as pyrites

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Quarterly Technical Report #1

Table II

PARTICLE SIZE DISTRIBUTIONS FOR ULTRASONICALLY COMMINUTED COAL SAMPLES

Micron Size	HGI 93 w/o Fines	HGI 45 w/o Fines
-100 (150 mesh)	85.5	100
-50	67.9	90.4
-30	39.7	44.5
-20	21.8	19.2
-15	15.2	12.8
-10	8.5	8.1

may exist. Microscopic examination of the coal samples comminuted in this experiment revealed agglomerations which were pyritic in nature (Figure 2). The size of the agglomerations was +200 mesh, suggesting that they may have occurred during the ultrasonic comminution. This evidence tends to support a possible benefication effect associated with ultrasonic comminution.

IV. LABORATORY SCALE APPARATUS DESIGN AND PRIMARY COAL SAMPLE SELECTION

A. Experimental Apparatus Design

Design effort has been completed for an ultrasonically activated cylinder segment for use in determining the relative effectiveness of comminution apparatus configurations for the laboratory scale experiments to be conducted in Phase II (Figure 3). The two primary candidate configurations under consideration are a dual roller and the single roller-flat plate. The apparatus shown in Figure 3 simulates and will supply design data for comparative evaluation of both configurations under consideration. The cylinder segment will be ultrasonically activated in the axial mode. Coal samples will be introduced into the apparatus and drawn across the face of the ultrasonically activated cylinder segment simulating a nip configuration in order to generate fines without the disadvantage of possible compaction. To further evaluate the dual roller configuration the surface plate will be radiused to match the cylinder segment and a rocking motion will be induced. Design parameters are flexible enough to allow considerable change in the apparatus, if required, to select the optimum configuration for Phase II laboratory scale testing.

B. Candidate Coal Selection

As noted, testing of the ultrasonic fine grinding technique is being conducted in two stages. Preliminary testing (Phase I) to

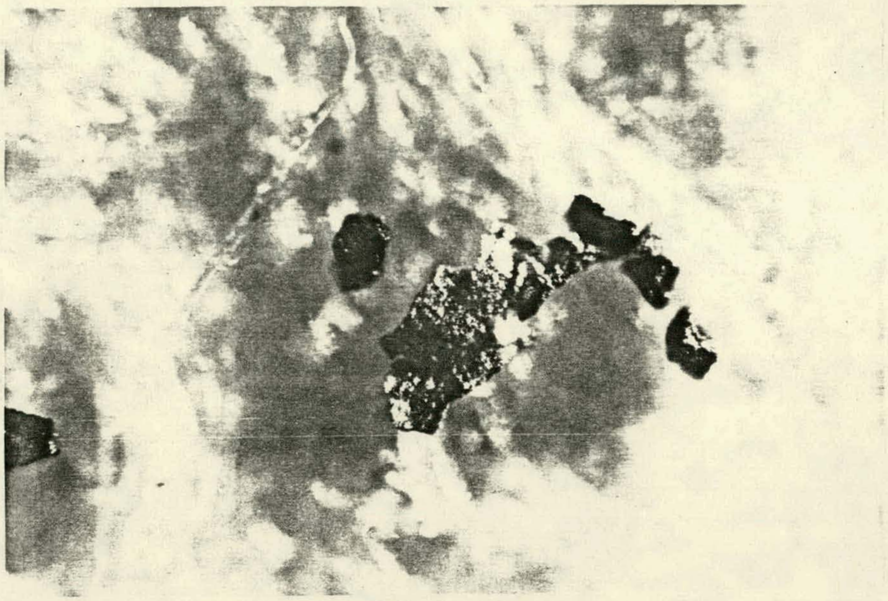

Figure 2

PHOTOMICROGRAPHS OF -200 MESH COAL PARTICLES

AFTER ULTRASONIC COMMINUTION (50X MAGNIFICATION)

Note the large (660µ x 280µ) central agglomerate, characterized by light areas indicative of pyrites, in contrast to smaller (100µ) coal particles.

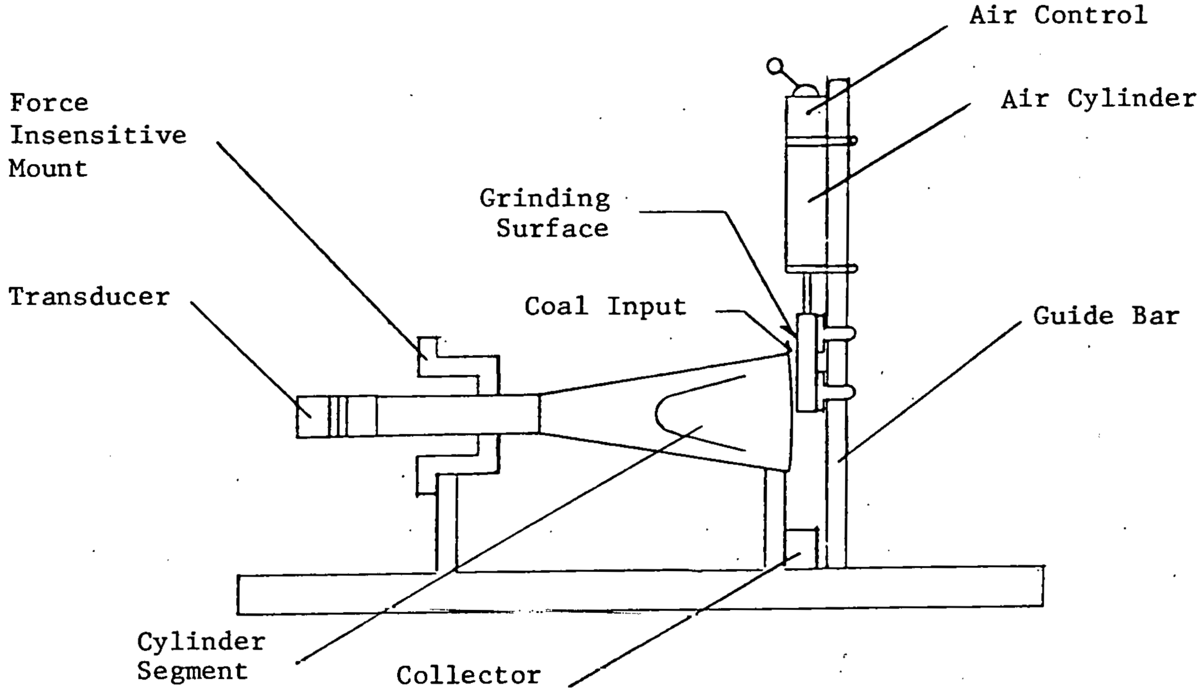

Figure 3

PHASE I - ULTRASONIC COMMINUTION APPARATUS obtain apparatus design information and sensitivity to coal HGI is being conducted on small samples of four coals having markedly different grindabilities, but which have not been otherwise well characterized. Once preliminary testing has been completed, experiments with the improved laboratory scale ultrasonic fine grinding apparatus will be conducted. Two representative, well-characterized, coals available in sufficient quantity (several hundred pounds) to permit a significant extent of testing will be selected and used in this experiment.

Selection of these coal samples is planned on the following criteria:

1. Steam grade coal is preferred over metallurgical coal since the most beneficial application of the ultrasonic fine grinding technique would be in the power generation industry;

2. A widely used coal seam is preferred since the test program results will then be more directly applicable;

3. One fairly low and one fairly high HGI coal should be selected to fully establish the degree of ultrasonic grinding enhancement achievable;

4. Coals with average or above average content of ash and inorganic sulfur should be selected to permit some measure of the degree of "selective" grinding (inclusion liberation) occurring during testing.

Based on these criteria, a current list of candidate coals includes:

a. Pittsburgh Seam - nominal characterization:

HGI - approximately 60

Ash Content - 8-10% (dry)

Inorganic Sulfur Content - 1-2% (dry);

b. Illinois #6 Seam - nominal characterization:

HGI - approximately 55

Ash Content - 9-12% (dry)

Inorganic Sulfur Content - 0.9-1.5% (dry);

c. Lower Freeport Seam - nominal characterization:

HGI - approximately 90

Ash Content - 19-21%

Inorganic Sulfur Content - 1.8-2.5% (dry).

Other representative coals are being evaluated by review of the Penn State Coal Data Bank. Final recommendation on candidate coals is expected during the next quarter.

After acquisition, the actual sample batches of the selected coals will be carefully characterized prior to testing.

V. FUTURE WORK

A. Complete fabrication and assembly of Phase I ultrasonic comminution apparatus.

B. Acquire selected samples of candidate coals, characterize and prepare for testing.

C. Conduct tests of activated cylinder segments and generate Phase II apparatus design data.

D. Depending on the evaluation of ultrasonically comminuted coal samples, lay out design parameters for Phase II apparatus.