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

QUARTERLY TECHNICAL PROGRESS REPORT NO. 3
March 16, 1980 - June 15, 1980

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

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ENERGY & MINERALS RESEARCH COMPANY
964 East Swedesford Road, P. O. Box 389
Exton, PA 19341

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ABSTRACT

During the third quarter, work focused on design and development of the dual roller comminution apparatus, based on operation and evaluation of the cylinder segment test apparatus. Tests of the dual roller will be conducted during the next quarter.

Determinations of the degree of preferential liberation of pyrite and ash inclusions was conducted with results that clearly demonstrate this ultrasonic effect. In preliminary tests, 67% of the pyrite and at least 21% of the ash inclusions were liberated and were amenable to settling collection in the -10 micron size range. Larger scale testing is being conducted to expand the data base and better quantify the degree of preferential liberation.

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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 -10 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.

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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 -10 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.

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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.

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III. EXPERIMENTAL WORK

During the third quarter, experimental work was conducted in the following areas: experimental demonstration of the pyrite liberation potential of ultrasonic comminution; simulation of ultrasonic auger-type grinding; and modification of the ultrasonic cylinder segment apparatus to determine effect of surface finish on comminution.

Test data indicate that 67% of the pyrite and at least 21% of the ash portions were liberated and are amenable to settling for selective separation. This demonstration of effect indicates the potential of ultrasonic comminution to provide the pyrite and ash liberation benefit predicted by theory.

A simulation of tapered-auger grinding was performed using the compression mode. The coal was ground in successively thinner layers and then screened. Results show only a slight increase in the number of fines over those produced using the standard compression mode.

The cylinder segment apparatus was dismantled and the moving plate reground. Two surface finish roughnesses were tested with minimal effect on grinding size results. This has a positive economic implication for process scale-up as well as dual roller apparatus design.

A. Pyrite and Ash Liberation

Utilizing the cylinder segment apparatus and a portion of the HGI 86 coal employed for previous Phase I testing, an experiment was designed and conducted to preliminarily measure the degree of selective pyrite and ash liberation associated with ultrasonic comminution, in comparison to reference values determined on a sample of unground coal.

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The initial step was evaluation of the pyrite and ash levels in the unground coal. The Phenanthroline iron determination method was used as an indicator of pyrite level. While the absolute accuracy of this method is affected by the trace levels of other metals in the coal, accuracy should be sufficient to indicate relative liberation of pyrite in various size categories.

Ash content is determined by standard combustion techniques and "ashing".

Following determination of base line values for pyrite and ash in a small unground coal sample, a sample was ground ultrasonically and sized (in the -200+325 mesh and -325 mesh ranges and within the -325 category to the -10 micron range). The iron and ash analyses can then indicate the occurrence of selective liberation and the size of any liberated inclusions. (For example, if the iron and ash percentages are identical in all size categories, there is a high probability that these inclusions had remained homogeneously mixed within the coal; if, however, a given size-category sample contains a higher percentage of inclusions than another or than the base line sample, the indication is that preferential liberation of inclusions is occurring and that the inclusion size is within this size category while the comminuted coal is smaller.)

Particle size analysis within the -325 mesh size category is conducted by the sedimentation method; the more dense ash and pyrite inclusions settle faster than coal particles of the same size.

The results of this test procedure with the HGI 86 coal are included in Table 1. The data indicate that significant preferential liberation is occurring with ultrasonic comminution and that the inclusions are predominantly in the -325 mesh range, although the increase in percentage of iron and ash in the -200+325 mesh area indicates a substantial portion of the inclusion distribution is in this range. Significant decrease in iron and ash percentage in the 10 micron size range strongly suggests

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Table 1

PYRITIC IRON AND ASH ANALYSIS OF ULTRASONICALLY COMMUNUTED* COAL

<u>HGI-86 Coal Sample</u>	<u>w/o Total Iron</u>	<u>w/o Ash</u>
Bulk Unground (Control)	0.300	4.1
<u>Size Category</u>		
-200+325 Mesh	0.416	4.6
-325 Mesh	0.456	4.5
-10 microns	0.100	3.2

*Test conducted with cylinder segment apparatus.

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that the majority of the inclusions were liberated from the comminuted coal and were amenable to separation by sedimentation.

Further testing for pyrite beneficiation will be conducted on the three coals, PSOC 275, 688 and 769, received from Penn State University.

B. Auger Simulation

Utilizing the compression mode apparatus, 100 gms of PSOC-688 (HGI 97.5) was subjected to successive grindings. A 100-gm sample was collected through 6 mesh (approximately -3360 microns), ultrasonically ground in 2.2-gm units, then passed through 14 mesh (-1410 microns). This sieved sample was then ultrasonically treated again (in 1.6-gram units) and screened through an 18-mesh sieve (-1000 microns). In the last step, the entire sieved sample was ultrasonically ground for the third time (in 1-gm units) and screened successively through 200 and 325 mesh sieves, with screening results as follows:

<u>Size Range</u>	<u>w/o</u>
+200 mesh	65
-200+325 mesh	9
-50+15 micron	21
-15+10 micron	3.6
-10+7 micron	1
-7 micron	0.4 .

The -325 mesh fines were then subjected to sedimentation analysis. Results show a slight increase in -10 micron fines over single-pass standard compression apparatus testing. Since the method used fairly well simulates auger grinding, it is apparent that such a process is not markedly superior to the cylinder segment simulating dual-roller grinding, and therefore evolution of the dual roller concept will proceed.

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C. Surface Finish vs. Micron Size

In order to determine roller surface finish requirements and sensitivity of fine comminution to surface finish of the dual-roller comminution elements, a series of tests was conducted on the cylinder segment apparatus. For these tests, the surface of the moving plate of the apparatus was refinished first to a 100-150 microinch RMS finish, then to 300-350 microinch. Samples of PSOC-769 and 275 were ground with each surface finish and the weight percent fines in the -50 micron range determined for each test.

As evident in Table II, surface finish in this range does not appear to produce marked differences with the materials investigated.

This preliminary finding has implications for production scale-up economics as well as for the design of the dual roller apparatus, since a 300 microinch finish is much more economically attainable in roll machining than is a 100-microinch RMS finish.

IV. EXPERIMENTAL DESIGN

The design of the dual-roller apparatus has been modified to additionally simulate roller operation against an activated flat plate (Figures 1 and 2). Mechanical design has been reviewed and apparatus stiffness and alignment improved based on test experience with the cylinder segment apparatus.

The mechanism of effect in ultrasonic comminution is mechanical fatigue due to the tension/compression cycle to which the coal is subjected by the driven surface in contact with the coal. To couple ultrasonics, the coal particle must be "clamped" by the nip between rollers and nip gap affects size of particles generated. This gap is reduced by the amplitude of radial motion of the ultrasonically excited roller, further reducing

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TABLE II

ULTRASONIC COMMINUTION BY CYLINDER SEGMENT APPARATUS WITH
DIFFERENT PLATE SURFACE FINISH

<u>Surface Finish</u>	<u>Size Range (microns)</u>	<u>PSOC-275 (HGI 57) w/o Sample</u>	<u>PSOC-769 (HGI 109) w/o Sample</u>
100-150 microinch	-50+20	7.1	15.3
	-20+10	2.1	6.0
	-10	1.0	2.8
300-350 microinch	-50+20	6.9	15.5
	-20+10	2.2	6.3
	-10	1.1	3.1

Figure 1

SIDE VIEW SCHEMATIC OF DUAL-ROLLER APPARATUS

Figure 2
TOP VIEW SCHEMATIC OF
DUAL-ROLLER APPARATUS

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the size of particles generated. Thus the nip gap and the radial motion amplitude of the ultrasonically excited roller combine to define the particle size generated.

In the dual-roller mode, the ultrasonic coupler and flat plate simulator are removed axially and maintained out of contact with the ultrasonically excited drive roll.

The 7"-diameter passive drive roll is supported on bearings in a structure that can be precisely adjusted to optimize coal nip gap dimension and uniformity as required for maximum production of -10 micron coal fines.

The 2.75"-diameter ultrasonically activated drive roll and the passive drive roll are rotated by a common drive motor, with provision to operate them synchronously at speeds up to 350 RPM (of the excited drive roll) and to introduce a slight variation in relative speed, for minor "slippage" to allow determination of the relative contribution of the attrition mechanism to ultrasonic comminution.

The ultrasonically excited roller (Figure 2) is supported on bearings connecting the support frame to a pair of force-insensitive transducer supports designed to minimize ultrasonic energy loss through the bearing into the rigid support structure. Transducer excitation of the roll may provide either standing or traveling wave operation as controlled by the configuration of the ultrasonic load employed at the opposite end of the excited roll. Both modes will be tested.

A metered flow of coal samples will be introduced evenly across the 6½-inch nip distance and the resulting fines collected in a pan designed to receive only coal particles passing through the nip, and not to collect any particles that may avoid the nip by coming off the ends of the roll.

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For testing of the roller-on-flat-plate configuration, the ultrasonic coupler-flat-plate may be adjusted axially to establish the optimum nip gap and then maintain gap uniformity. The plate may be excited by the flat plate excitation transducer and the drive roll rotated at a variety of speeds representing various degrees of slip or attrition. Alternatively, the drive roll may be ultrasonically excited and the flat plate operated in a passive mode.

Thus, the apparatus design is versatile and is of sufficient scale to provide quantitative data on the coal comminution modes planned for investigation.

The system represents the next logical step and is based upon test experience with the cylinder segment array now in use. With improved mechanical stiffness, nip geometry control, and a nip length on the dual-roller apparatus nearly four times that of the cylinder segment tester, fines generation should increase markedly.

V. FUTURE WORK

- Conduct further tests on PSOC and HGI 86 coals;
- Complete fabrication and assembly of dual-roller apparatus;
- Conduct tests on dual-roller equipment;
- Optimize final apparatus and begin Phase II experimental runs.