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Investigation of Pyrite as a Contributor
to Slagging in Eastern Bituminous Coals

MASTER

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INTRODUCTION

Slagging by eastern coals in industrial furnaces results primarily from pyritic iron in the coal ash. Since it has been learned that coals of similar pyritic levels fired in furnaces of similar design do not always produce the same slagging conditions, and since segregation of pyrites from other minerals does occur when slagging is encountered, slagging must be attributed to the size and orientation of the pyrites in the coal, in addition to their concentration level.

A program is underway to examine slags from coals with varying concentration levels, size distribution, and orientation of pyrite with other mineral matter, when the coals are fired in a laboratory furnace under controlled conditions simulating an industrial furnace.

Evaluation of the contribution of coarse pyrite in coal to furnace-wall slagging will be accomplished in the following steps:

- Task 1--Selection of eight candidate coals.
- Task 2--Chemical characterization of the coal samples and identification of the pyrite size distribution, orientation with respect to other mineral matter, and concentration levels.
- Task 3--Test firing of the candidate coals in a laboratory furnace.
- Task 4--Chemical and physical characterization of the slag and fly ash samples created by the impurities in the coal samples.
- Task 5--Influence of coal beneficiation on furnace slagging (preparation and analysis of washed coal).
- Task 6--Analysis of data and identification of parameters influencing the contribution of pyrite to slagging problems.

Task 1 is presently underway.

Section 2

TASK 1--SELECTION OF EIGHT CANDIDATE COALS

During Task 1 Foster Wheeler will select eight candidate coals with variations in pyrite size and distribution according to the specifications of the Research Plan. The selection will be made after reviewing the specification with such agencies as the DOE Fuel Preparation Laboratory at Bruceton, Pennsylvania; the Pennsylvania State College of Mineralogy and Coal Combustion Laboratory; the Coal Research Department of the University of Kentucky; the Indiana State Geological Survey; and the Illinois Geological Survey. Foster Wheeler will locate the source of each coal, negotiate the coal purchase, and arrange for shipment of the required amount of each coal selected.

The coals will be selected to provide a suitable matrix of pyrite size distribution and concentration, permitting identification of the source of pyrite responsible for slagging. Where possible, coals with previous firing experience in industrial or utility steam generators will be selected. Reports prepared by the Fuel Preparation Laboratory of the Department of Energy at Bruceton, Pennsylvania, on the washability characteristics of eastern bituminous will be used as guidelines in selecting coals, particularly in reference to the distribution of pyrite. Professionals at this Fuel Preparation Laboratory as well as those at Pennsylvania State University College of Mineral Science and Combustion Laboratory, The Indiana State Geological Survey, Illinois Geological Survey, and The Coal Research Center at the University of Kentucky will be consulted.

All coals selected will be eastern bituminous. None will be selected from Illinois, unless there is assurance that contributions by sodium to the

fireside problems are minimal. Three of the coals will have a sulfur level in the range of 3 to 4 percent. Each of these coals will contain approximately 2 percent ± 0.2 percent pyritic sulfur, which is easily washed from the coal. Washability tests should indicate that the pyrite is preferentially concentrated in the coarse size fractions. A simple sink-float test at 2.85 sp gr using bromoform will be performed to indicate the relationship of pyrite to other mineral matter. At least 1.75 percent pyrite should appear in the sink fraction. Ash levels of two of the coals should be between 8 and 12 percent. One coal may be selected with an ash loading in excess of 15 percent. The high ash loading is recommended to illustrate that conventional ASTM ash fusion cones will not reveal the slagging potential of coal when pyrite exists as a mineral separable from the ash. Pyrite separable from the remaining mineral matter should produce the same slagging if particle size concentration and furnace operating conditions are kept constant. Ash chemistry of the three coals should be similar. Alkalies should be at the same level and the silica-to-alumina ratio should be the same. There should be no biasing of results attributed to unusual concentrations of quartz.

Two coals should be selected with total sulfur levels of 3 to 4 percent, pyrite concentration of 2 percent ± 0.2 percent, ash levels of 10 percent, silica-to-alumina ratios of 2:1, and low-alkali concentrations that cannot be washed. Sink-float tests of 2.85 sp gr should reveal virtually no pyrite in the sink fraction.

One washable coal containing 3 to 4 percent sulfur, 2 percent pyritic sulfur ± 0.2 percent, 10 percent ash, low-alkali, and silica-to-alumina ratios of about 2:1, with the pyrite concentrated in the fines, should be selected to demonstrate the influence of pyrite size distribution on its slagging potential.

Two washable coals with two different sulfur levels below 3 to 4 percent (i.e., 1 and 2 percent) and, consequently, with lower level of pyrite should be selected to illustrate the influence of pyrite concentration on slagging. Once again, the ash levels should be held constant (about 10 percent), alkali concentrations should be low, and the silica-to-alumina rates should be about 2:1. Sink-float tests at 2.85 sp gr should reveal a concentration of pyrite in the coarse size fractions. In the event that suitable coals cannot be found, an alternative fuel of higher sulfur concentration may have to be selected to evaluate the affect of concentration level on slagging.

We plan to acquire one sample of 85 to 90 percent pure pyrite extracted from coal in a beneficiation process from the Department of Energy Fuel Preparation Laboratory for blending with a coal of low slagging potential. Approximately 200 lb of the sample will be required.

The distribution of pyrite in the coal will be checked in a candidate fuel in a simple sink-float test at 2.85 sp gr. The candidate coal will be crushed to a fineness equivalent to 50 percent through 200 mesh. The sample will be screened into two size fractions (+100 μ m and -100 μ m.) Each size fraction will be sink floated in a bromoform bath at 2.85 sp gr. The percent by weight of the sink fractions will be recorded, and they will be analyzed for their percentage of pyrite. The percentage of sample found in the sink fractions of the coarser and fine size fractions will determine whether the pyrite is present as a coarse or fine isolated specie.

Section 3

QUARTERLY PROGRESS

At the beginning of the contract the Pittsburgh Energy Technology Center indicated they would like all contractors to select their coals from the list appearing in Table 1. The intent was to simplify the purchase of coals and extend the data basis of any given fuel examined. Unfortunately, the data available for the coals selected was inadequate to make a selection based on the characteristics required and tabulated in Table 2. Identification and selection of specific coals to meet the needs of the test program, described in previous sections, require examination of the ash chemistry, ash fusion temperature, percent sulfur, percent ash, washability data, ash and iron concentration at sink 2.85, mineral content, and forms of iron and sulfur. It would also be desirable to know the particle size distribution of the pyrite and previous operational record in full-scale combustors.

Since the original list did not include the data needed, supplemental sources of information, listed in Table 3, had to be researched to characterize the coal. Unfortunately, due to variability in sampling and variability in scope of analyses, data from different sources do not always agree, and data from one source is rarely complete, making it difficult to accurately characterize any given coal. In view of the problems encountered in characterizing the coals and the very specific needs of the program, the Pittsburgh Energy Research Center relaxed their requirements for coal selection and suggested we pursue a selection of our own.

The sources of data already cited were expanded to include contacts with the State Geological Surveys and Department of Natural Resources. Samples

of candidate coals were requested for analysis in the laboratory, as described in the last paragraph of Section 2. In addition to sink floating, thermal analysis was used to develop combustion profiles of the coal. Where sink 2.85 gravity fractions are too small to analyze for ash sulfur, ash chemistry, and ash fusion temperatures, thermogravimetric analysis (TGA) and differential thermal analysis (DTA) were employed to determine percent ash and the presence of pyrites. Figure 1 illustrates a TGA thermogram and how it can be used to determine percent ash and identify the presence of pyrites. Figure 2 illustrates how pyrite is identified in a DTA thermogram. The preliminary analysis to confirm selection of coals is underway.

Table 4 summarizes the coals presently under consideration. Table 5 summarizes key data justifying the selections. Samples of Kentucky No. 9 from Muhlenberg County, Kentucky; Kentucky No. 11 from Hopkins County, Kentucky; and Tebo from Henry County, Missouri, have arrived in the laboratory and are presently being analyzed. Samples of coals from the remaining locations are presently being sought.

Table 1 Coals Tentatively Selected for AR&TD Programs

<u>%C daf</u>	<u>Rank</u>	<u>Seam</u>	<u>County</u>	<u>State</u>	<u>Reason for Selection</u>
73	lig A	Beulah-ZAP	Mercer	ND	ND Lignite
75	lig A	DRACO	Harris	TX	TX Lignite
76	subb B	Rosebud	Rosebud	MT	DOE/GRI/EPA
78	hvC	Blue	McKinley	NM	GRI
79	hvC	IL #6	Macoupin	IL	GRI
80	hvB	IN #3	Green	IN	DOE, Inactive
81	hvB	#9	Hopkins	KY	Slagging
82	hvC	TEBO	Henry	MO	W. M. W., Slagging
83	hvA	Pittsburgh #8	Washington	PA	DOE/GRI, Slagging
83	hvA	Winifrede	Kanawha	WV	Slagging
83	hvA	L. Millersburg	Warrick	IN	Slagging
85	hvA	Cedar Grove	Logan	WV	Slagging
86	hvA	Black Creek	Jefferson	AL	EPA
88	mv	L. Freeport	Cambria	PA	Slagging, Active
88	lv	U. Kittanning	Somerset	PA	Inactive
89	mv	U. Freeport	Clearfield	PA	Slagging
95	AN	Buck Mountain	Luzen	PA	Anthracite

Table 2 Characteristics of Sample Coals

1. 3-4% Sulfur Coal Moderate Ash Level Coarse Pyrite Size, Isolated Pyrites
2. 3-4% Sulfur Coal High Ash Level Coarse Pyrite Size, Isolated Pyrites
3. 3-4% Sulfur Coal Moderate Ash Level, Isolated Finely Divided Pyrites
4. 3-4% Sulfur, Moderate Ash Level, Pyrite and Ash Mixed
5. 2% Sulfur Coarse, Isolated Pyrites
6. 1% Sulfur, Coarse Isolated Pyrites

Note: Coals 1 and 3 may be used in two tests to illustrate reproducibility with a single coal. It would be preferred that two coals be selected for each category to illustrate similar results with different coals.

Table 3

1. R. F. Abernathy, M. J. Peterson, and F. H. Gibson, "Major Ash Constituents in U. S. Coals," Bureau of Mines, RI 7240, 1969.
2. A. W. Deurbrouck, "Sulfur Reduction Potential of the Coals of The United States," Bureau of Mines, RI 7633, 1972.
3. J. A. Cavallaro, M. J. Johnson, and A. W. Deurbrouck, "Sulfur Reduction Potential of the Coals of The United States," United States Bureau of Mines, RI 8118, 1976.
4. C. V. Richardson and G. F. Nielsen, "Keystone Coal Industry Manual," Mining Informational Services, McGraw-Hill Mining Publications, New York 1981.
5. _____, "An Evaluation of Coal Cleaning Processes and Techniques for Removing Pyritic Sulfur from Fine Coal," BCR, April 1971, Contract No. CPA 70-26.
6. _____, "An Evaluation of Coal Cleaning Processes and Techniques for Removing Pyritic Sulfur from Fine Coal," BCR, February 1970, Contract No. PH 86-67-139.
7. _____, "An Evaluation of Coal Cleaning Processes and Techniques for Removing Pyritic Sulfur from Fine Coal," BCR, September 1969, Contract No. CPA 70-26.
8. _____, "An Evaluation of Coal Cleaning Processes and Techniques for Removing Pyritic Sulfur from Fine Coal," BCR, April 1971, Contract No. CPA 70-26.
9. _____, "Influence of Coal Mineral Matter on Slagging of Utility Boilers," EPRI-CS-1418, Research Project 736, November 1979.
10. Richard A. Glenn, Robert D. Harris, "Liberation of Pyrite from Steam Coals," Journal of the Air Pollution Control Association, August 1962, Vol. 12, No. 8.
11. Richard A. Glenn, Robert D. Harris, "Liberation of Pyrite from Steam Coals," Vol. XXIII, Proceedings of the American Power Conference 1961.

<u>Type</u>	<u>Coal Selection</u>
1. 3-4% Sulfur Moderate Ash Level (10%) (Coarse, Isolated Pyrites) A washable coal with pyrites separable from mineral matter at 2.95 sp gr Tons - 8 Date - March 1, 1982*	Kentucky No. 9, Muhlenberg, Kentucky; Upper Freeport, Indiana County, Pennsylvania
2. 3-4% Sulfur, High Ash Level (20%) (Coarse, Isolated Pyrites) A washable coal with pyrites separable from mineral matter at 2.95 sp gr Tons - 2 Date - June 1, 1982	Tebo, Henry County, Missouri
3. 3-4% Sulfur, Moderate Ash Level (10%) A washable coal in the fine size range with pyrites separable from mineral matter at 2.95 sp gr Tons - 2 Date - September 1, 1982	Meigs Creek No. 9, Belmont or Harrison, Ohio; Kentucky Noll, Hopkins County, W. Kentucky
4. 3-4% Sulfur, Moderate Ash Level (10%) Pyrite and ash mixed - no sink 2.95 gravity fraction Tons - 4** Date - December 1, 1982	Illinois No. 6, Macoupin County, Illinois; Alternates; Kentucky No. 9, Hopkins County, Kentucky; Fire Clay, Kansas
5. 2% Sulfur Coal Washable pyrites, coarse and separable from the ash Tons - 2 Date - October 1, 1982	Pittsburgh No. 8, Harrison, W. Va. Alternate Upper Freeport, Clearfield County, Pennsylvania
6. 1% Sulfur Coal Washable pyrites, coarse and separable from the ash Tons - 4 Date - October 1, 1982	Pittsburgh No. 8, Washington County, Pennsylvania

*Only 2 tons needed at this time.

**This could be a repeat test, or a second coal with a similar specification could be used.

Table 5 Characterization of Select Coals

Class State, County, Seam	% Ash	% S _T	% S _P	Ash Chemistry									Fusion Temp.		
				SiO ₂	Al ₂ O ₃	TiO ₂	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	SO ₃	I.D.	S.T.	F.T.
<u>Class I</u> 3-4% S Kentucky No. 9 Muhlenberg Co., Kentucky	13.78	4.5	2.74	40.9	19.2	0.67	28.0	4.3	1.1	0.54	2.5	2.1	1920	1960	2060
Upper Freeport Indiana Co., Pennsylvania	25.6	3.0	2.4	47.2	25.0	1.0	20.0	1.0	3.0	0.54	2.98	2.3	2140	2310	2820
<u>Class II</u> 3-4% S Tebo Henry Co., Missouri	19.2	5.28	2.88	45.4	15.6	0.7	26.7	6.2	0.6	0.1	1.7	3.0	2000	2050	2360
<u>Class III</u> 3-4% S Kentucky No. 11 Hopkins Co., W. Kentucky or Meigs Creek No. 9 Harrison Co., Ohio	6.8 9.2	4.7 2.3	2.1 1.7	34.3 --	20.6 --	1.1 --	31.3 --	2.5 --	0.5 --	0.3 --	2.3 --	1.2 --	2010 --	2210 --	2360
<u>Class IV</u> 3-4% S Illinois No. 6 Macoupin Co., Illinois Kentucky No. 9 Hopkins Co., Kentucky Fire Clay Crawford, Kansas	12.5 12.3 33.8	5.73 4.6 4.18	2.71 2.6 3.28	41.4 43.7 --	20.3 22.1 --	1.5 1.0 --	23.3 29.0 --	6.8 0.9 --	1.3 0.9 --	0.5 0.2 --	2.1 2.3 --	2.4 0.8 --	1980 2050 --	2020 2140 --	2110 2430

Table 5 Characterization of Select Coals
(Continued)

Class State, County, Seam	% Ash	% S _T	% S _P	Ash Chemistry									Fusion Temp.		
				SiO ₂	Al ₂ O ₃	TiO ₂	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	SO ₃	I.D.	S.T.	F.T.
Class V 2% S															
Pittsburgh No. 8 Harrison, West Va.	9.8	5.13	2.76	26.5	27.0	0.8	47.8	1.7	0.4	0.5	0.8	2.8	1940	2140	2440
Upper Freeport Clearfield Co., Pennsylvania	10.12	2.89	1.69	39.2	27.5	1.05	18.7	4.00	0.34	0.11	0.91	5.00	--	--	--
Class VI 1% S															
Pittsburgh No. 8 Washington Co., Pennsylvania	11.5	1.82	0.38	53.6	24.0	1.20	13.4	0.78	2.73	0.49	1.52	2.60	2330	2370	2450

Table 5 Characterization of Select Coals
(Continued)

Class State, County, Seam	Pyrite Particle Size (Mean)	% Basic	B/A Ratio	Slagging Index	% Fe ₂ O ₃ as FeS ₂	Remarks
<u>Class IV</u> 3-4% S						
Kentucky No. 9 Hopkins Co., Kentucky	--	33.3	0.49	1.2	88	Being considered because of its poor liberation of pyrites.
Fire Clay Crawford, Kansas	--	--	--	--	--	Being considered an alternate, as it appears difficult to wash.
<u>Class V</u> 2% S						
Pittsburgh No. 8 Harrison, West Va.	150μ	51	1.01	2.78	100	--
Upper Freeport Clearfield Co., Pennsylvania	--	24	0.31	.52	100	--
<u>Class VI</u> 1% S						
Pittsburgh No. 8 Washington Co., Pennsylvania	--	18.9	0.23	0.41	71	--

Table 5 Characterization of Select Coals
(Continued)

Class State, County, Seam	Pyrite Particle Size (Mean)	% Basic	B/A Ratio	Slagging Index	% Fe ₂ O ₃ as FeS ₂	Remarks
<u>Class I</u> 3-4% S						
Kentucky No. 9 Muhlenberg Co., Kentucky	--	37.1	0.59	1.6	85	Presently fired at Mill Creek Station. Moderate to severe slagging. Extensive data by EPRI & Penn State.
Upper Freeport Indiana Co., Pennsylvania	--	27	0.375	0.9	57	Presently fired at Homer City. Similar to coals at Keystone & Conemaugh. Examined by Penn State for sticking characteristics. Extensive data on washing characteristics of coal.
<u>Class II</u> 3-4% S						
Tebo Henry Co., Missouri	160μ	35	0.54	1.5	70	Coal was deep cleaned at Bituminous Coal Research.
<u>Class III</u> 3-4% S						
Kentucky No. 11 Hopkins Co., W. Kentucky	22μ	36	0.57	1.19	100	Reported to contain finely divided pyrites. See Figure 4, Table 6.
or						
Meigs Creek No. 9 Harrison Co., Ohio	60μ	--	--	--	--	Reported to contain finely divided pyrites. See Figure 4, Table 6.
<u>Class IV</u> 3-4% S						
Illinois No. 6 Macoupin Co., Illinois	160μ	34	0.51	1.38	100	Presently fired at Labadie Station. Extensive data by EPRI & Penn State.

Table 6 Pyritic Sulfur Reduction at 1.60 Specific Gravity
as Related to Top Size of Coal

Coal Identification		Pyritic Sulfur Weight Percent Raw From Coal	Reduction at 1.60 Float Percent			
Seam	Location, County, State		CTECO 3/8" x 100M	CTECO 14M x 0	BCR 30M x 0	BCR P.C. Grind
Fire Clay	Crawford, Kansas	3.28	36.3	41.7	40.2	58.8
No. 9	Hopkins, Kentucky	2.20	55.5	58.4	30.9	28.6
No. 9	Muhlenberg, Kentucky	2.89	52.5	55.2	37.7	49.5
Tebo	Henry, Missouri	3.06	66.8	76.0	76.8	87.3
Upper Freeport	Indiana, Pennsylvania	1.31	62.8	71.7	78.6	84.7
No. 9	Belmont, Ohio	1.88	45.3	50.0	59.0	74.5
No. 8	Harrison, W. Virginia	--	--	--	--	--
No. 8	Washington, Pa.	--	--	--	--	--
Upper Freeport	Clearfield, Pa.	--	--	--	--	--

**Table 7 Ash Reduction at 1.60 Specific Gravity
as Related to Top Size of Coal**

Coal Identification		Pyritic Sulfur Weight Percent Raw From Coal	Reduction at 1.60 Float Percent			
Seam	Location, County, State		CTECO 3/8" x 100M	CTECO 14M x 0	BCR 30M x 0	BCR P.C. Grind
Fire Clay	Crawford, Kansas	33.8	65.7	66.2	70.8	69.8
No. 9	Hopkins, Kentucky	9.48	45.3	44.9	50.2	54.4
No. 9	Muhlenberg, Kentucky	9.44	31.4	32.8	37.3	51.5

Table 8 Mineral Analysis

[illegible]

TABLE 9
PARTICLE SIZE DATA ON PYRITE IN EXPERIMENTAL COALS
PRIOR TO PULVERIZATION TESTS

COAL	SIZE RANGE, MICRONS	AVERAGE VOLUME OF PARTICLES, CUBIC MICRONS	NUMBER, RELATIVE PERCENT	WEIGHT, RELATIVE PERCENT
No. 11 (W. Kentucky)	< 5	15.6	40.0	0.2
	5—20	1950	55.0	42.5
	20—40	27×10^3	4.9	49.7
	40—75	18.9×10^4	0.1	7.6
	75—150	19.5×10^5	—	—
	150—250	8×10^6	—	—
	> 250	52.5×10^6	—	—
Pittsburgh No. 8 (W. Virginia)	< 5	15.6	25.7	—
	5—20	1950	44.8	1.3
	20—40	27×10^3	17.3	7.0
	40—75	18.9×10^4	9.8	2.8
	75—150	19.5×10^5	2.2	64.7
	150—250	8×10^6	0.2	24.2
	> 250	52.5×10^6	—	—
Meigs Creek No. 9 (Ohio)	< 5	15.6	31.5	0.1
	5—20	1950	60.5	13.3
	20—40	27×10^3	6.8	20.9
	40—75	18.9×10^4	1.0	21.4
	75—150	19.5×10^5	0.2	44.3
	150—250	8×10^6	—	—
	> 250	52.5×10^6	—	—
No. 6 (Illinois)	< 5	15.6	54.2	0.2
	5—20	1950	36.1	1.6
	20—40	27×10^3	6.7	2.4
	40—75	18.9×10^4	2.0	8.6
	75—150	19.5×10^5	0.7	32.4
	150—250	8×10^6	0.3	54.8
	> 250	52.5×10^6	—	—
Tebo (Missouri)	< 5	15.6	81.5	0.1
	5—20	1950	16.1	2.4
	20—40	27×10^3	1.9	3.9
	40—75	18.9×10^4	0.2	2.8
	75—150	19.5×10^5	0.2	29.8
	150—250	8×10^6	0.1	61.0
	> 250	52.5×10^6	—	—

Table 10

—Particle Size and Pyritic Sulfur Data on Pulverized Products

Coal	Mesh	Microns	$\frac{1}{2} \times 0$ -in. HAMMER MILL—ONE PASS				$\frac{1}{2} \times 0$ -in. IMPACT MILL—ONE PASS				$\frac{1}{2} \times 0$ -in. IMPACT MILL—ONE PASS			
			Weight, Percent	Pyritic Sulfur, Weight Percent	Cumulative Weight, Percent	Pyritic Sulfur, Cumulative Weight Percent	Weight, Percent	Pyritic Sulfur, Weight Percent	Cumulative Weight, Percent	Pyritic Sulfur, Cumulative Weight Percent	Weight, Percent	Pyritic Sulfur, Weight Percent	Cumulative Weight, Percent	Pyritic Sulfur, Cumulative Weight Percent
Pittsburgh No. 8 (W. Va.)	+60	>250	0	...	0	...	13.6	2.1	13.6	2.1	1.8	1.6	1.8	1.6
	60 × 100	250-149	7.4	4.2	7.4	4.2	14.9	2.2	28.5	2.2	5.8	1.6	7.6	1.6
	100 × 200	149-74	37.1	3.0	44.5	3.7	24.0	2.8	53.1	2.4	27.2	3.2	34.8	2.8
		>80	19.8	5.0	64.3	4.1	18.8	4.7	71.9	3.0	14.0	5.9	48.8	3.7
		80-40	16.5	2.1	80.8	3.7	12.1	1.8	84.0	2.0	13.0	2.1	62.7	3.4
		40-20	8.4	2.0	89.2	3.5	5.1	1.5	89.1	2.8	19.8	2.1	82.5	3.1
		20-10	4.2	2.3	93.4	3.5	5.7	2.0	94.8	2.7	9.3	1.8	91.8	2.9
		10-0	0.0	2.2	100.0	3.4	5.2	2.1	100.0	2.7	8.2	2.1	100.0	2.9
Tobo (Missouri)	+60	>250	0	...	0	...	11.6	6.4	11.6	6.4	1.5	5.8	1.5	5.8
	60 × 100	250-149	4.0	5.7	4.0	5.7	12.6	4.7	24.2	5.5	0.0	4.6	7.5	4.8
	100 × 200	149-74	33.6	4.6	37.6	4.7	20.7	4.8	44.9	5.1	18.3	4.7	25.8	4.7
		>80	20.8	6.0	58.4	5.3	14.9	8.0	59.8	5.8	10.1	14.7	35.9	7.5
		80-40	9.3	3.7	67.7	5.2	10.3	4.2	70.1	5.0	9.8	9.5	45.7	8.0
		40-20	15.8	3.6	83.5	4.9	14.0	4.4	84.7	5.4	21.7	2.0	67.4	6.0
		20-10	10.4	4.5	93.9	4.8	9.5	4.2	94.2	5.3	10.9	3.7	84.3	5.6
		10-0	6.1	4.9	100.0	4.8	5.8	5.1	100.0	5.3	15.7	5.2	100.0	5.5
No. 6 (Illinois)	+60	>250	0	...	0	...	12.3	6.0	12.3	6.0	1.4	4.3	1.4	4.3
	60 × 100	250-149	6.4	3.1	6.4	3.1	14.5	2.9	26.8	4.3	4.9	2.7	6.3	3.0
	100 × 200	149-74	33.0	3.0	40.0	3.0	20.6	2.9	47.4	3.7	17.8	2.9	24.1	2.9
		>80	12.5	6.0	52.5	3.9	10.2	9.6	57.6	4.7	12.2	9.1	36.3	5.0
		80-40	15.9	2.7	68.4	3.6	18.8	2.9	76.4	4.3	15.0	2.1	51.3	4.2
		40-20	15.4	3.0	83.8	3.5	12.0	2.8	88.4	4.1	24.1	2.9	75.4	3.8
		20-10	8.0	2.9	92.4	3.5	5.7	2.5	94.1	4.0	14.6	3.9	90.0	3.0
		10-0	7.0	4.4	100.0	3.5	5.9	3.0	100.0	4.0	10.0	5.9	100.0	3.2
No. 11 (W. Ky.)	+60	>250	0	...	0	...	8.6	2.8	8.6	2.8	1.1	2.1	1.1	2.1
	60 × 100	250-149	5.6	2.3	5.6	2.3	12.4	2.1	21.0	2.4	4.8	1.8	5.9	1.8
	100 × 200	149-74	38.0	2.0	43.6	2.0	25.6	1.9	46.6	2.1	24.2	2.0	30.1	2.0
		>80	24.1	3.3	67.7	2.5	15.1	3.5	61.7	2.5	7.6	7.0	37.7	3.0
		80-40	10.8	1.5	78.5	2.4	16.2	2.5	77.9	2.5	21.0	2.4	58.7	2.8
		40-20	10.2	2.5	88.7	2.4	12.4	2.6	90.3	2.5	23.3	2.4	82.0	2.7
		20-10	6.2	1.1	94.9	2.3	6.3	2.6	96.6	2.5	10.2	0.7	92.2	2.4
		10-0	5.1	1.0	100.0	2.2	3.4	3.0	100.0	2.5	7.8	0.9	100.0	2.3
Moiga Creek No. 9 (Ohio)	+60	>250	0	...	0	...	10.0	2.9	10.0	2.9	0.9	1.4	0.9	1.4
	60 × 100	250-149	7.7	2.4	7.7	2.4	11.3	0.7	21.3	1.7	3.1	0.9	40.0	1.0
	100 × 200	149-74	43.0	2.5	50.7	2.5	21.5	0.8	42.8	1.3	13.7	1.4	17.7	1.3
		>80	13.9	4.0	64.6	3.0	25.7	3.7	68.5	3.2	22.0	3.3	39.7	2.4
		80-40	12.4	1.8	77.0	2.8	5.8	1.6	74.3	2.1	16.5	1.6	56.2	2.2
		40-20	11.3	1.4	88.3	2.6	12.6	1.5	86.9	2.0	22.4	1.7	78.6	2.0
		20-10	6.4	1.5	94.7	2.6	8.4	1.4	95.3	2.0	11.3	1.4	89.9	2.0
		10-0	5.3	1.0	100.0	2.5	4.7	2.5	100.0	2.1	10.4	2.0	100.0	2.0

Figure 2 Differential Thermal Analysis Thermograms of Low Temperature Ash from Various Raw Coal Gravity Fractions Compared with the 2.85 Sink

FIGURE 3

THERMAL GRAVIMETRIC ANALYSIS
Comparison of raw coal to
pyrites..

Figure 4 Cumulative Size Distribution by Weight of Pyrite in Experimental Coals Prior to Pulverization Tests