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DOE/PC/40268-T4
(DE84013203)

INVESTIGATION OF PYRITE AS A CONTRIBUTOR TO SLAGGING IN EASTERN BITUMINOUS COALS

Quarterly Progress Report for the Period January 1—March 30, 1984

June 1984

Work Performed Under Contract No. AC22-81PC40268

Foster Wheeler Development Corporation
Livingston, New Jersey

Technical Information Center
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United States Department of Energy

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INVESTIGATION OF PYRITE AS A CONTRIBUTOR TO SLAGGING IN EASTERN BITUMINOUS COALS

Quarterly Progress Report 10

January 1 through March 30, 1984

Prepared for

Pittsburgh Energy Technology Center
U.S. Department of Energy
Pittsburgh, Pennsylvania

By

Richard W. Bryers
Program Manager

June 1984

Contract DE-AC22-81PC40268
FWDC No. 9-41-3210

FOSTER WHEELER DEVELOPMENT CORPORATION
12 Peach Tree Hill Road, Livingston, New Jersey 07039

Section 1

INTRODUCTION

Slagging of utility steam generator furnaces while firing Eastern Bituminous coals has been attributed to the pyritic iron in the coal ash. Investigators have also learned that coals with similar pyritic levels fired in furnaces of similar design do not always produce the same degree of slagging. Since separation of pyrite from other mineral matter does occur in some coals and since the physicochemical behavior upon heating the pyrite and pyrite mixed with other mineral matter or coal may be quite different, the degree of furnace slagging may possibly be attributed to the size and orientation of the pyrite in coal in addition to its concentration level.

The objective of this program is to examine slags formed as a result of firing coals with varying concentration levels, size distribution, and orientation of pyrite with regard to mineral matter in the coal in a laboratory furnace.

The program tasks are:

Task 1 -- Selection of eight candidate coals

Task 2 -- Chemical characterization of the coal samples and identification of the pyrite size, distribution, and orientation with respect to other mineral matter and concentration levels

Task 3 -- Testing 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 sample

Task 5 -- Influence of coal beneficiation on furnace slagging

Task 6 -- Analysis of data and identification of parameters influencing the contribution of pyrite to slagging problems

Work was to begin on characterizing the mineral content of the remaining two coals of the original suite of eight coals to be tested. Combustion tests were to be performed on each coal and the deposits generated were to be analyzed. A third combustion test was to be performed on a coal blended with pyrites to determine the impact of the weight percent of liberated pyrites on slagging. Unfortunately, there was a cost overrun, primarily due to excessive cost of fuel selection, at the beginning of the contract. The scope of work described above represents that portion of the original scope not covered by the original budget. Delays in approval of funding the uncompleted portion of the original scope of work prevented further progress on the contract.

While awaiting approval of further funding, two coals were selected by FWDC and purchased by DOE. The analysis of the two fuels; i.e., Illinois No. 5 Gallatin County, Illinois and Lower Kittaning Clarion County, Pennsylvania, appear in Tables 1 and 2.

Examination of the morphology of furnace slag deposited in the 100 lb/hr combustor, as well as industrial furnace, revealed reoccuring crystals of iron of pyrite origin on the surface of the deposit, as shown in Figures 1 through 4. The cubic, octahedron and cubic/octahedron crystals are similar in size and structure to pyrite crystals occasionally found in coal. Their origin as pseudomorphs or crystals formed during combustion could give some insight as to the method of transport to the surface. Therefore, there appears to be

some merit in characterizing the morphology of pyrites within the coal. Samples of Illinois No. 5 and Lower Kittaning coals were examined in the raw and polished state using SEM and EDAX analysis.

Figures 5, 6, 7, 8 and 9 illustrate several types of mineral forms found in Illinois No. 5 and Lower Kittaning Clarion County, Pennsylvania coal. The photomicrographs of the Illinois No. 5 coal illustrate small pyritic veinlets and fracture filling perpendicular to the coal layers. Within the coal layers are bands of mineral particles 4μs and less in size. Each particle is a discrete mineral specie; thus, silica, kaolinite, pyrites, etc. The fracture filling perpendicular to the coal layers are frequently filled with pure calcite. Pyrite lines either side of the calcite at the interface. This pyrite is forced to the fracture surface during the coalification process. No crystalline forms of pyrites were uncovered in the Illinois coal.

Although crystalline forms of pyrites are not generally found in high sulfur coal, large bands of cubic/octahedron crystals were uncovered in the Lower Kittaning Clarion County coal, illustrated in Figure 4. On at least one occasion, this coal was responsible for iron enriched deposits on the convection pass tubes. All coals are now being examined petrographically for mineral forms.

Mineral analysis on all bulk and fractionated coal samples of the coal tested to-date are being performed by Drs. Cecil and Dulong of the United States Geological Survey in Reston, Virginia. Table 3 summarizes the results completed to-date.

Figure 10 is the revised milestone schedule and status report as of March 1984.

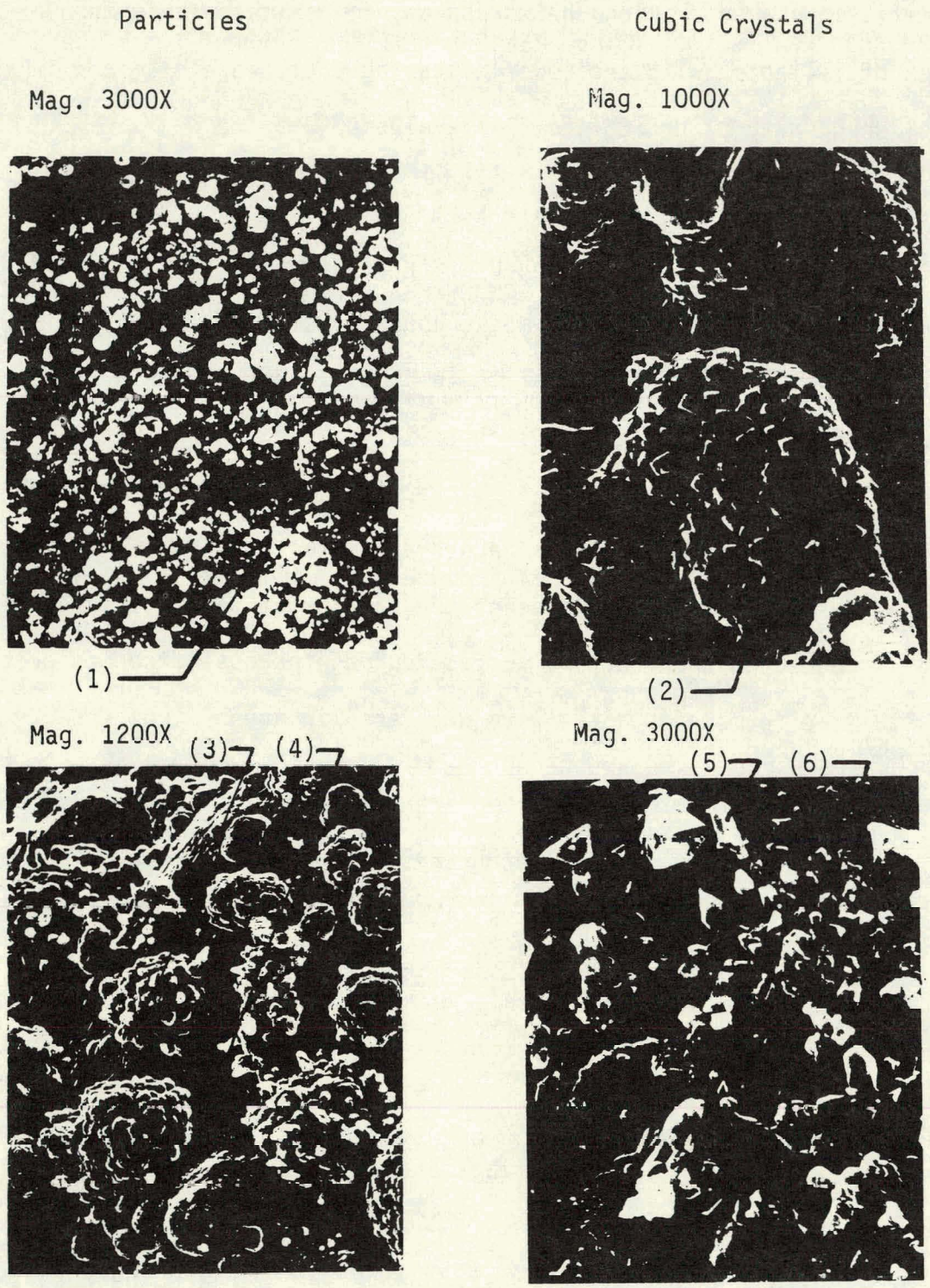
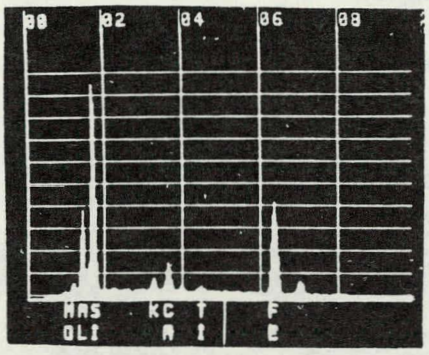
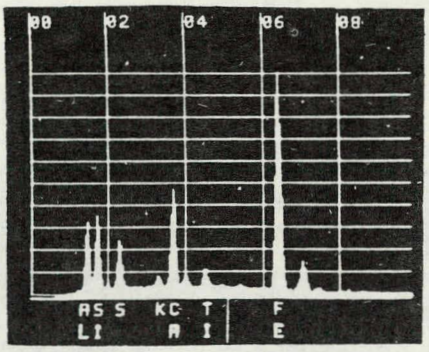


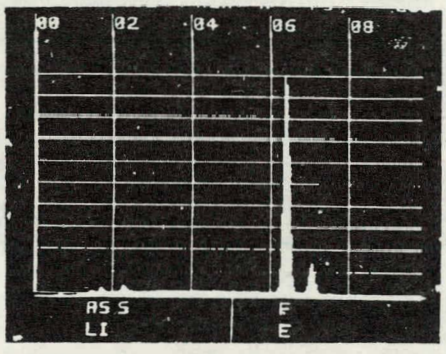
FIGURE 1 Morphology of Various Types of Iron Crystals and Particles Deposited on Slag Surface



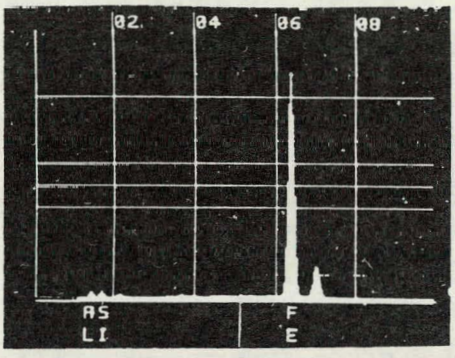
Surface Containing
Small Particles (1)



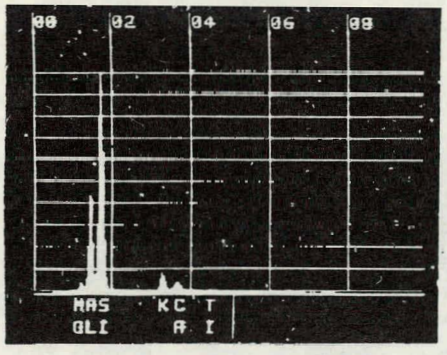
Cubic Crystals (2)



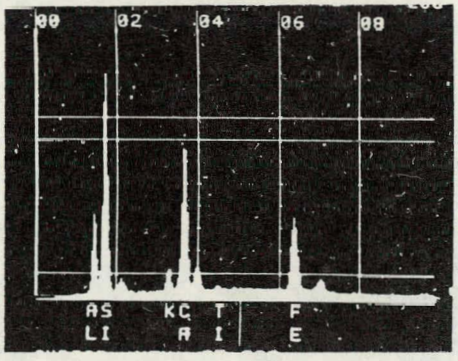
Pyrite Derived
Agglomerates (3)



Assorted Octagonal
Crystals (5)



Matrix (4)

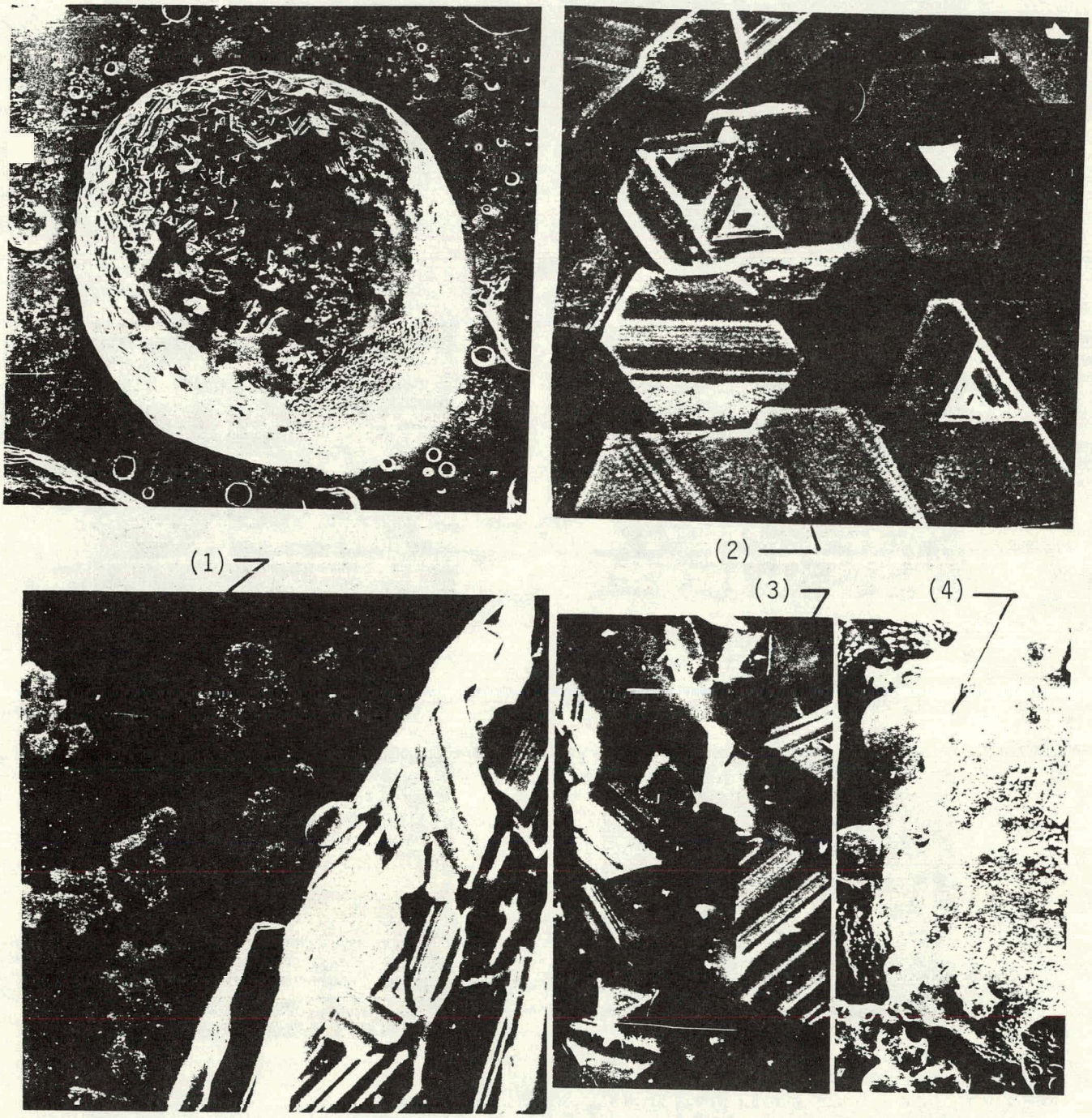


Matrix (6)

FIGURE 2 EDAX Scan of Various Types of Iron Crystals and Particles Deposited on Slag Surface

Gas Pore Formed by SO_3 - Mag. 120X

Pyrite Derived Crystals - Mag. 600X



Mag. 1500X

Pore Surface

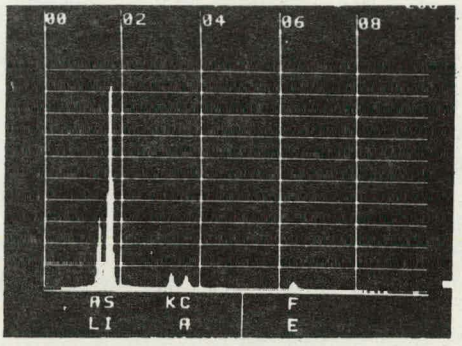
Mag. 1500X

Octahedron Crystals

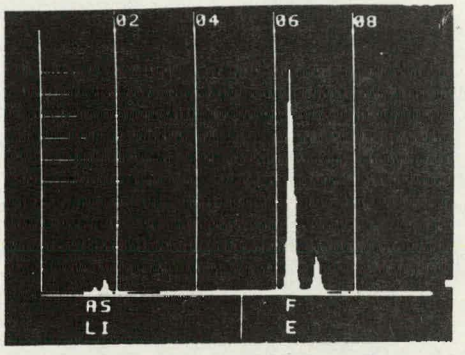
Mag. 300X

Slag Surface

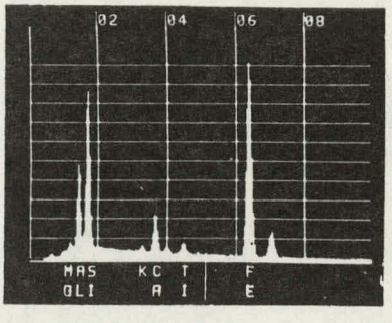
FIGURE 3 Assorted Pyrite Derived Crystals Formed in Gas Pores and on the Slag Deposit Surface



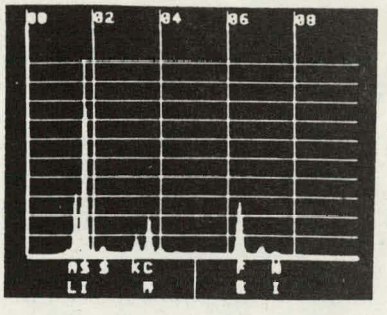
Slag Matrix (1)



Pyrite Derived
Crystal (2)



Octahedron
Crystals (3)



Slag Surface (4)

FIGURE 4 EDAX Scan of Assorted Pyrite Derived Crystals
Formed in Gas Pores and on the Slag Deposit Surface

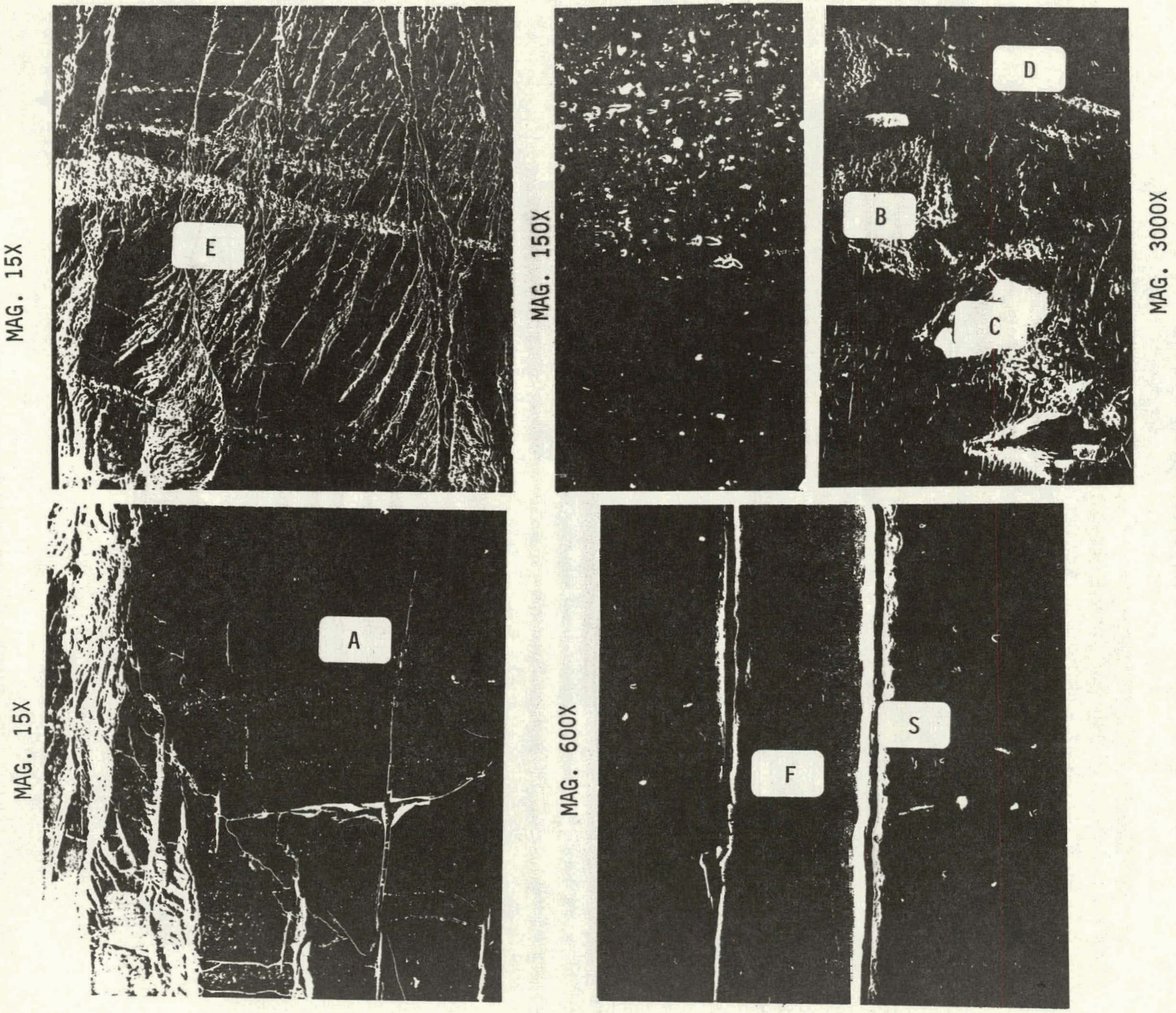
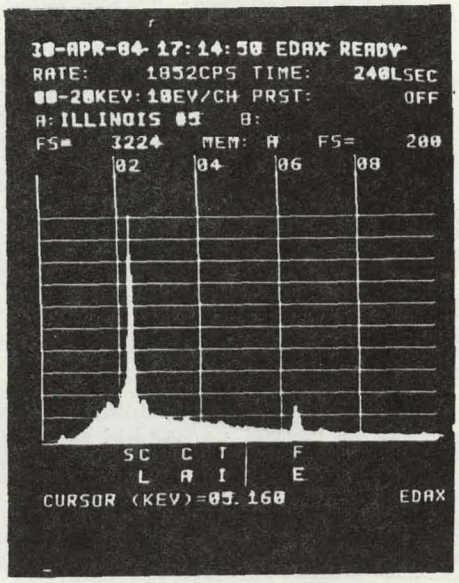
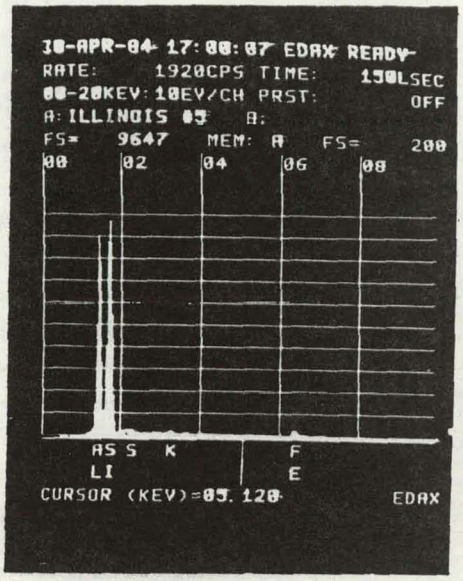


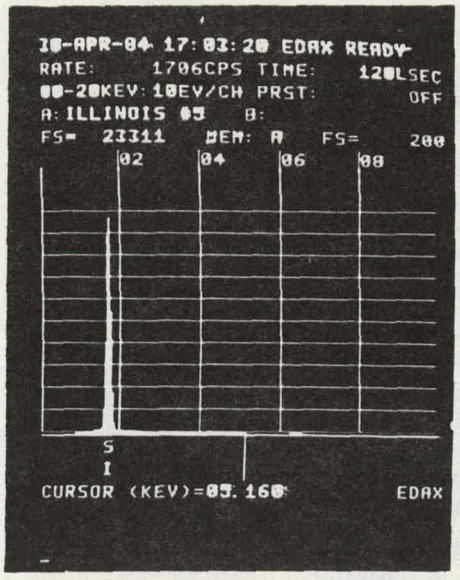
FIGURE 5 SEM Microphotographs of Various Forms of Pyrites, Quartz and Calcite in Illinois No. 5



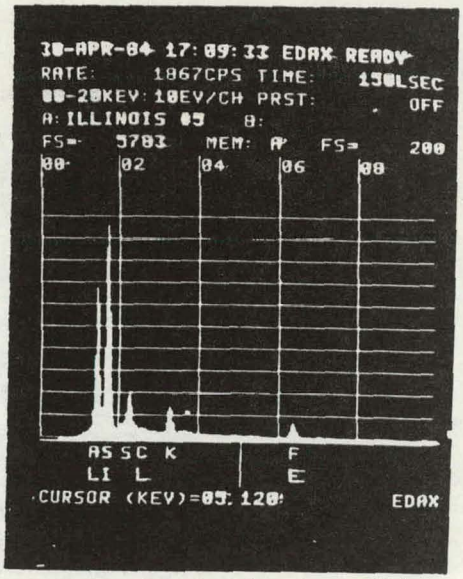
Black Clear Surface Marked (A)



Mineral Inclusion (B)

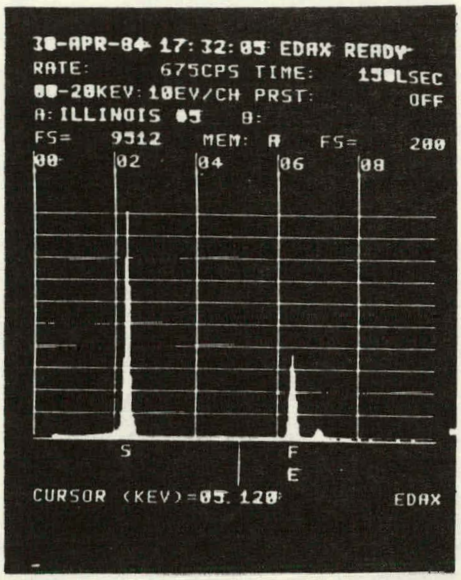


Mineral Inclusion (C)

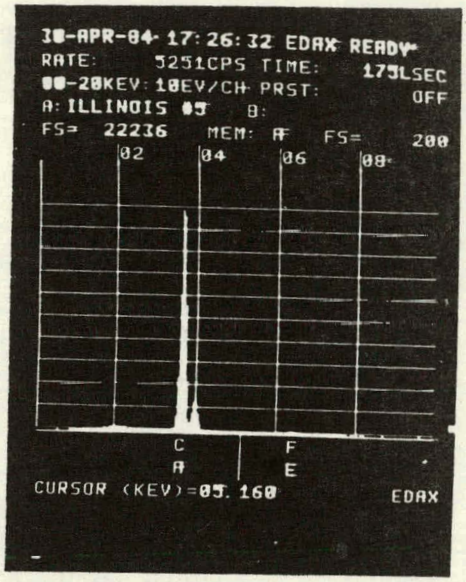


Mineral Inclusion (D)

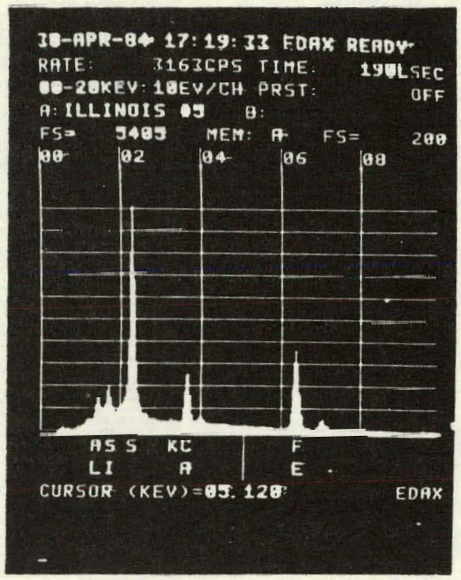
FIGURE 6 EDAX Scan of Quartz Clay and Pyrite Inclusions



Veinlet (E)



Mineral (F) in
Coal Fissure



Coal Mineral
Interface at (S)

FIGURE 7 EDAX Scan of Quartz Clay and Pyrite Inclusion

Raw Coal

Polished Coal

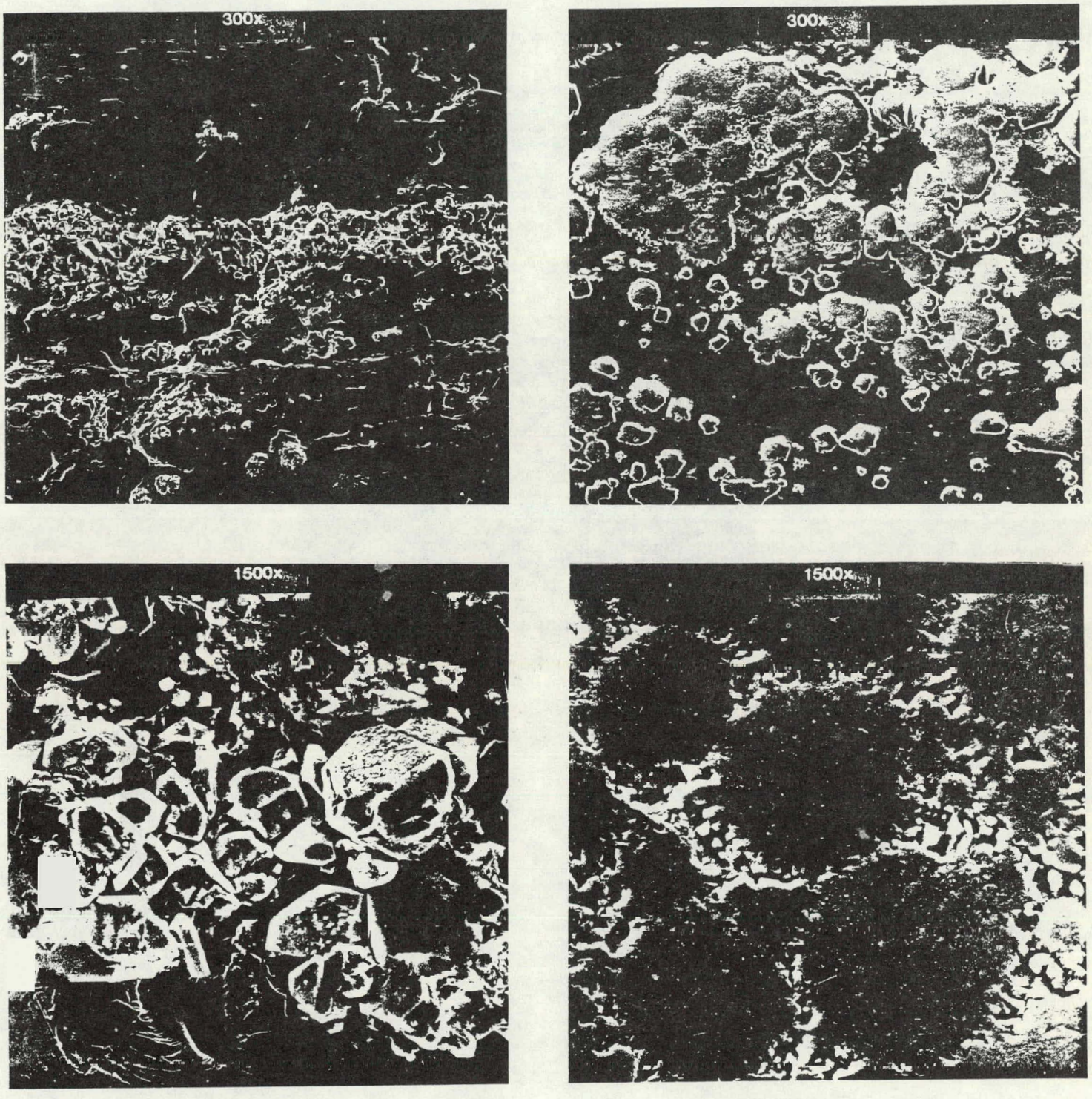


FIGURE 8 Lower Kittaning Pennsylvania Coal Showing Cubic-Octahedron Crystals

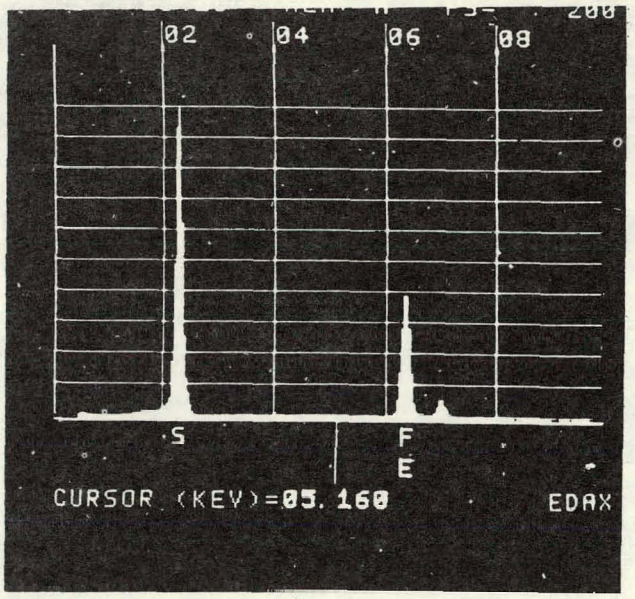


FIGURE 9 EDAX Scan of Pyrites in Lower Kittaning Coal

FIGURE 10

U.S. DEPARTMENT OF ENERGY

DOE Form CR-535 (1-78)

MILESTONE SCHEDULE AND STATUS REPORT

1. Contract Identification	2. Reporting Period	3. Contract Number
Investigation of Pyrite as a Contributor to Slagging in Eastern Bituminous Coals	1/84 through 3/84	DE-AC22-81PC40268

4. Contractor (name, address)	5. Contract Start Date	6. Contract Completion Date
Foster Wheeler Development Corporation 12 Peach Tree Hill Road Livingston, New Jersey 07039	October 1, 1981	March 31, 1984

7. Identification Number	8. Reporting Category (e.g., contract line item or work breakdown structure element)	9. Fiscal Years and Months: 1983 O N D J F M A M J J A S; 1984 O N D J F M A M J J A	10. Percent Complete a) Planned	10. Percent Complete b) Actual
Task 1	Selection of Coals			
Task 2.0	Characterization of Coals			
2.1	Illinois No. 6			
2.2	Kentucky No. 4			
2.3	Upper Freeport			
2.4	Lower Freeport			
2.5	Kentucky No. 9			
2.6	Pittsburgh No. 8 - PA.			
2.7	Pittsburgh No. 9 - W.VA.			
2.8	To Be Selected			
Task 3.0	Combustion Tests			
3.1	Coal No. 1			
3.2	Coal No. 2			
3.3	Coal No. 3			

11. Remarks

12. Signature of Contractor's Project Manager and Date	13. Signature of Government Technical Representative and Date
Richard W Byers 6/19/84	

FIGURE 10 (Cont'd)

U.S. DEPARTMENT OF ENERGY

DOE Form CR-535 (1-78)

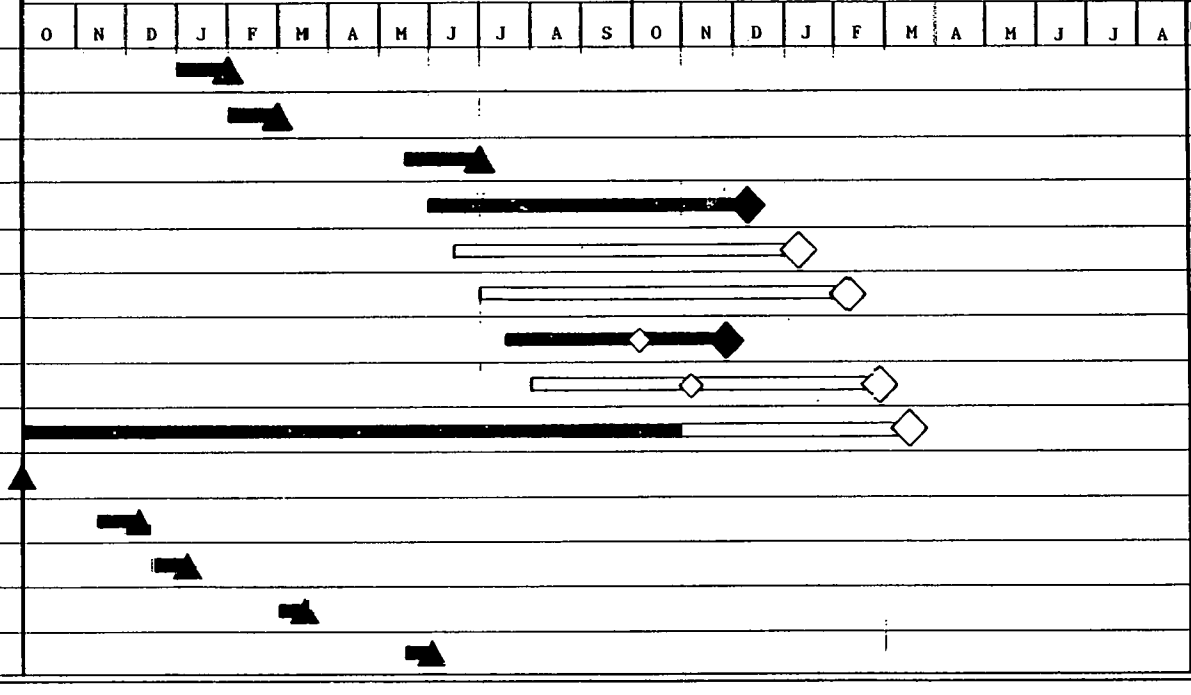
MILESTONE SCHEDULE AND STATUS REPORT

FORM APPROVED OMB NO. 1910-0104

1. Contract Identification	2. Reporting Period	3. Contract Number
Investigation of Pyrite as a Contributor to Slagging in Eastern Bituminous Coals	1/84 through 3/84	DE-AC22-81PC40268

4. Contractor (name, address)	5. Contract Start Date	6. Contract Completion Date
Foster Wheeler Development Corporation 12 Peach Tree Hill Road Livingston, New Jersey 07039	October 1, 1981	March 31, 1984

7. Identification Number	8. Reporting Category (e.g., contract line item or work breakdown structure element)	9. Fiscal Years and Months	10. Percent Complete a) Planned	10. Percent Complete b) Actual
3.4	Coal No. 3 -			
3.5	Coal No. 4			
3.6	Coal No. 5			
3.7	Coal No. 6			
3.8	Coal No. 7			
3.9	Coal No. 8			
3.10	Washed Coal			
3.11	Coal/7 or 8 Plus Pyrites			
Task 4.0	Analysis of Slag Deposits			
4.1	Combustion Test No. 1			
4.2	Combustion Test No. 2			
4.3	Combustion Test No. 3			
4.4	Combustion Test No. 4			
4.5	Combustion Test No. 5			



11. Remarks

12. Signature of Contractor's Project Manager and Date	13. Signature of Government Technical Representative and Date
Richard W. Byers 6/19/84	

FIGURE 10 (Cont'd)

U.S. DEPARTMENT OF ENERGY

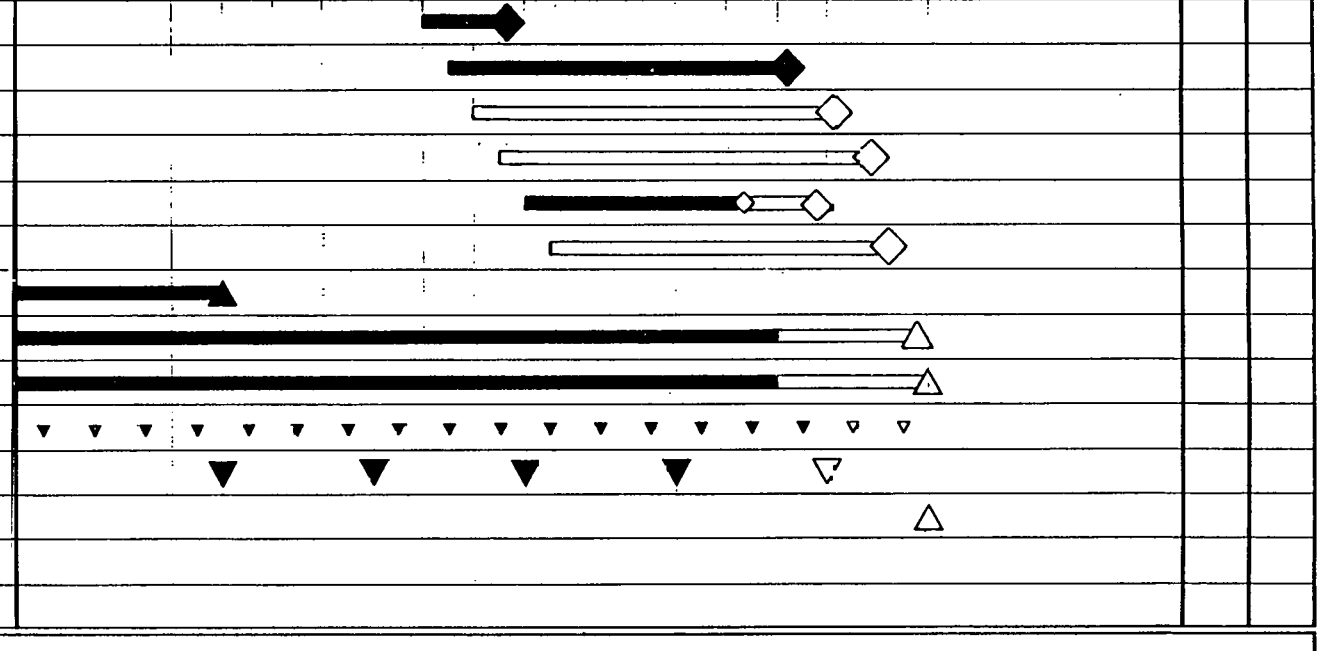
DOE Form CR-535 (1-76)

MILESTONE SCHEDULE AND STATUS REPORT

1. Contract Identification	2. Reporting Period	3. Contract Number
Investigation of Pyrite as a Contributor to Slagging in Eastern Bituminous Coals	1/84 through 3/84	DE-AC22-81PC40268

4. Contractor (name, address)	5. Contract Start Date	6. Contract Completion Date
Foster Wheeler Development Corporation 12 Peach Tree Hill Road Livingston, New Jersey 07039	October 1, 1981	March 31, 1984

7. Identification Number	8. Reporting Category (e.g., contract line item or work breakdown structure element)	10. Percent Complete a) Planned	10. Percent Complete b) Actual
4.6	Combustion Test No. 6		
4.7	Combustion Test No. 7		
4.8	Combustion Test No. 8		
4.9	Combustion Test No. 9		
4.10	Combustion Test No. 10		
4.11	Combustion Test No. 11		
Task 5	Washability Study		
Task 6	Evaluation of Data		
Task 7.0	Program Management		
7.1	Monthly Reports		
7.2	Quarterly Reports		
7.3	Final Report		



11. Remarks

12. Signature of Contractor's Project Manager and Date	13. Signature of Government Technical Representative and Date
Michael W Bigio 6/19/84	

TABLE 1

FUEL ANALYSIS - ILLINOIS NO. 5

FOSTER WHEELER DEVELOPMENT CORPORATION

FUEL ANALYSIS

SAMPLE DESCRIPTION: Illinois No-5 Gallatin Co Illinois

CHARGE NO. 9-41-3210-R270 DATE 4-18-84 LAB.REF.NO. 840303

****

AIR DRY LOSS,% Nil

EQUILIBRIUM MOISTURE,%

	As Rec'd	Dry
PROXIMATE ANALYSIS		
Fixed Carbon	41.37	43.43
Vol. Matter	30.51	32.03
Ash	23.38	24.54
Moisture	4.74	
Total	100.00	100.00
ULTIMATE ANALYSIS		
Carbon	58.22	61.12
Hydrogen	3.63	3.81
Oxygen	5.05	5.30
Nitrogen	1.20	1.26
Sulfur	3.78	3.97
Ash	23.38	24.54
Moisture	4.74	
Total	100.00	100.00
H.H.V.,BTU/lb	10,313	10,826
Sulfate S	0.03	0.03
Pyritic S	1.94	2.04
Organic S	1.81	1.90

REACTIVITY INDEX Deg. C

ACTIVATION ENERGY cal/g-mol

HARDGROVE INDEX

FREE SWELLING INDEX

SPEC. GRAV.

VISCOSITY

ASH FUSION TEMPERATURE, Deg. F

	Red.	Oxid.
Initial Deform.	2030	2200
Soft.Temp.Sph.	2100	2300
Soft.Temp.Hem.	2130	2340
Fluid Temp.	2240	2450

REMARKS:

ANALYST

APPROVED: GABRIEL P LANTOS

TABLE 2

FUEL ANALYSIS - LOWER KITTANING

FOSTER WHEELER DEVELOPMENT CORPORATION

FUEL ANALYSIS

SAMPLE DESCRIPTION: Characterization of Lower Kittaning Clarion Co Pa

CHARGE NO. 9-41-3210-R280 DATE 6-13-84 LAB.REF.NO. 840368

****

AIR DRY LOSS,% 3.26

	As Rec'd	Dry
PROXIMATE ANALYSIS		
Fixed Carbon	47.53	49.39
Vol. Matter	34.02	35.36
Ash	14.68	15.25
Moisture	3.77	
Total	100.00	100.00
ULTIMATE ANALYSIS		
Carbon	66.48	69.09
Hydrogen	4.92	5.12
Oxygen	4.86	5.05
Nitrogen	1.34	1.39
Sulfur	3.95	4.10
Ash	14.68	15.25
Moisture	3.77	
Total	100.00	100.00
H.H.V.,BTU/lb	12,002	12,472
Sulfate S	0.30	0.31
Pyritic S	2.56	2.66
Organic S	1.09	1.13

EQUILIBRIUM MOISTURE,%

REACTIVITY INDEX Deg. C
ACTIVATION ENERGY cal/g-mol

HARDGROVE INDEX 54.

FREE SWELLING INDEX

SPEC. GRAV.

VISCOSITY

ASH FUSION TEMPERATURE, Deg. F

	Red.	Oxid.
Initial Deform.	1902	2390
Soft.Temp.Sph.	1957	2508
Soft.Temp.Hem.	1997	2522
Fluid Temp.	2125	2566

REMARKS:
Dulong's=12999Btu/lb

ANALYST

APPROVED: GABRIEL P LANTOS

TABLE 3 MINERAL ANALYSIS DATA GENERATED BY U.S. GEOLOGICAL SURVEY FROM LOW TEMPERATURE ASH

COAL	KENTUCKY NO. 11	ILLINOIS NO. 6	KENTUCKY NO. 9	UPPER FREEPORT
Bulk	Quartz 33 Pyrite 31 Illite 17 Kaolinite 10 Calcite 5 Siderite 1 Feldspar 3	Quartz Kaolinite Pyrite Illite Feldspar	Pyrite 31 Quartz 27 Kaolinite 15 Illite 10 Calcite 14 Feldspar 2 Heulandite-Clinoptilolite 2	Quartz 36 Kaolinite 21 Pyrite 18 Illite 15 Calcite 8 Siderite 1 Feldspar 1
Float 1.30	Quartz 33 Pyrite 27 Kaolinite 18 Illite 14 Calcite 4 Feldspar 3 Siderite 1	Quartz 25 Calcite 23 Kaolinite 21 Pyrite 19 Illite 9 Marcasite 2 Feldspar 1	Pyrite 48 Calcite 44 Marcasite 3 Quartz 3 Kaolinite 2	Pyrite 27 Quartz 22 Kaolinite 20 Illite 16 Siderite 7 Calcite 5 Feldspar 2
Float 1.80	Kaolinite 38 Quartz 28 Illite 17 Pyrite 16 Feldspar 1	Quartz 38 Kaolinite 24 Illite 19 Pyrite 15 Feldspar 2 Apatite 1	Quartz 26 Pyrite 22 Heulandite-Clinoptilolite 21 Kaolinite 11 Apatite 6 Calcite 5 Illite 5	Pyrite 34 Kaolinite 30 Quartz 21 Illite 14 Siderite 1 Calcite < 1 Feldspar < 1
Float 2.85	Being Analyzed	Quartz 30 Pyrite 21 Calcite 21 Kaolinite 14 Illite 8 Feldspar 3 Apatite 2	Quartz 33 Pyrite 24 Heulandite-Clinoptilolite 24 Kaolinite Apatite 3 Illite 5 Calcite 3	Quartz 40 Pyrite 20 Illite 17 Kaolinite 14 Calcite 5 Feldspar 2 Siderite 2

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