

# Coal Technology '82

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& Conference

VOLUME 5  
INDUSTRIAL/UTILITY APPLICATIONS

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VOLUME I

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VOLUME II

DIRECT COMBUSTION

VOLUME III

SYNTHETIC FUELS

VOLUME IV

INDUSTRIAL/UTILITY  
APPLICATIONS

VOLUME V

(KEYNOTE SESSION IS INCLUDED IN VOLUME I)



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# VOLUME V

## TITLE

## PAGE NUMBER

### INDUSTRIAL/UTILITY APPLICATIONS SESSIONS

#### DIRECT COAL UTILIZATION/RETROFIT

"MICRONIZED COAL AS AN ALTERNATE FUEL  
FOR OIL AND GAS FIRED BOILERS" 7  
T.A. MORRIS, G. HAIDER, BABCOCK & WILCOX  
COMPANY, A.E. MARGULIES, G.F. MOORE, STONE  
& WEBSTER ENGINEERING CORPORATION, R.J. WEST,  
GULF STATES UTILITIES COMPANY

"TWO-STAGE SLAGGING COMBUSTORS FOR 23  
UTILITY AND INDUSTRIAL BOILER APPLICATION"  
GOPAL KADAGATHUR, BRUCE L. LEVY, STONE &  
WEBSTER ENGINEERING CORPORATION

"TRW'S ENTRAINED SLAGGING COAL COMBUSTOR" 37  
J.C. STANSEL, CHIEF ENGINEER, COMBUSTION &  
GASIFICATION MAJOR PROJECTS, R. BRUCE GERDING,  
DIRECTOR OF DEVELOPMENT, MAJOR PRODUCTS,  
TRW ENERGY DEVELOPMENT GROUP

"THE WORMSER GRATE INSTALLATION AT IOWA 55  
BEEF'S PLANT IN AMARILLO, TEXAS"  
ALEX WORMSER, WORMSER ENGINEERING, INC.,  
WALTER BECKWITH, IOWA BEEF PROCESSORS, INC.

#### FLUIDIZED BED COMBUSTION I

"THE DESIGN AND OPERATION OF LURGI'S 84 MW<sub>t</sub> 72  
CIRCULATING FLUID BED (CFB) BOILER IN  
LUENEN, WEST GERMANY"  
T. LUND, MANAGER, BUSINESS DEVELOPMENT, LURGI  
CORPORATION, DR. L. PLASS, H. BEISSWENGER, DR. G.  
DARADIMOS, LURGI CHEMIE UND HUTTENTECHNIK GMBH

"FLUIDIZED BED COMBUSTION OPERATING 92  
EXPERIENCE AT THE GREAT LAKES  
DEMONSTRATION PLANT"  
JOSEPH R. COMPARATO, H. H. VROOM, III,  
COMBUSTION ENGINEERING, INC.

"INDUSTRIAL FLUIDIZED BED COGENERATION 109  
SYSTEM AT THE SHELL NEDERLAND RAFFINADERIJ  
EUROPOORT TANK FARM"  
W.R. KELLY, MANAGER, H.J. FRUH, MANAGER, SYSTEMS  
ENGINEERING, J.M. ROURKE, PROJECT MANAGER,  
S.R. MOORE, MANAGER, START-UP OPERATION,  
CONTRACT OPERATIONS DEPARTMENT, FOSTER  
WHEELER BOILER CORPORATION

"PERFORMANCE OF A FLUIDIZED BED BOILER PLANT" 127  
ALBERT M. LEON, DIRECTOR THERMAL TECHNOLOGY,  
DORR-OLIVER INC.

TITLEPAGE NUMBER

"THE COAL FIRED COGENERATOR USING  
AN AIR HEATER AFB COMBUSTOR"  
S. MOSKOWITZ, CURTISS-WRIGHT CORPORATION

NOT AVAILABLE

FLUIDIZED BED COMBUSTION II

"THE BFGOODRICH PYROFLOW FBC BOILER  
PROJECT"

NOT AVAILABLE

STANLEY B. FARBSTEN, THE BFGOODRICH  
COMPANY, GEORGE BENDA, ILLINOIS DEPARTMENT  
OF ENERGY & NATURAL RESOURCES, ALBERT P.  
GRAFF, PYROPOWER CORPORATION

"RECOVERING LOST MEGAWATTS USING FLUIDIZED  
BED COMBUSTION"

137

A.M. DONALDSON, FUELS TECHNOLOGY GROUP  
SUPERVISOR, T. E. STINGFELLOW, PROCESS ENGINEER,  
STEARN-ROGER ENGINEERING CORPORATION

"UTILIZATION OF CIRCULATING FLUID BEDS IN AIR  
TURBINE COGENERATION"

157

JAMES S. DAVIS, STRUTHERS WELL CORPORATION,  
WILLIAM W. YOUNG, STRUTHERS THERMO-FLOOD  
CORP., L. JAMES SWEET, STRUTHERS WELLS U.K.

"ATMOSPHERIC FLUID BEDS WITH TWO STAGE  
REACTION DEVELOPED FOR COMBUSTORS AND  
GAS PRODUCERS"

177

P.B. CAPLIN, TECHNICAL DIRECTOR, THE ENERGY  
EQUIPMENT COMPANY LIMITED

COAL LIQUID MIXTURES

"COAL-WATER SLURRY AS AN ALTERNATE FUEL"  
ROLF D. MANFRED, PROJECT MANAGER, FLUIDIZED  
COMBUSTION & ALTERNATE FUELS PROGRAM,  
COAL COMBUSTION SYSTEMS DIV., ELECTRIC  
POWER RESEARCH INSTITUTE

NOT AVAILABLE

"COAL-WATER SLURRY PILOT PLANT"  
RICHARD PASSMAN, DIRECTOR, ARC-COAL  
OPERATIONS, ATLANTIC RESEARCH CORPORATION

NOT AVAILABLE

"FORMULATION & HANDLING CHARACTERISTICS OF  
COAL WATER MIXTURES"

NOT AVAILABLE

RICHARD C. DONNELLY, OCCIDENTAL  
RESEARCH CORP.

INDUSTRIAL FUEL/CO-GENERATION

"COGENERATION AND COAL GASIFICATION -  
AN OPPORTUNITY FOR UTILITY/INDUSTRIAL  
SYNERGY"

197

M.S. BROWN, PROJECT MANAGER, M. GINIGER,  
PROJECT ENGINEER, EBASCO SERVICES INCORPORATED,  
J.P. LIKSTUTIS, PROJECT MANAGER, ENVIROSPHERE  
COMPANY



TITLEPAGE NUMBER

"COAL AND PETROLEUM COKE MIXTURES AS  
BOILER FUEL"

215

HENERY A. HAMANISHI, SENIOR ENGINEER,  
ROYCE J. HOLLAND, DISTRICT ENGINEERING  
MANAGER, MORRISON-KNUDSON CO., INC.

"APPLICATION OF A SAWDUST GASIFIER TO  
PRODUCE LOW-BTU GAS FROM LIGNITE AT  
A TEXAS BRICK PLANT"

245

EARL J. JONES, P.E., MANAGER OF SERVICES,  
ELGIN-BUTLER BRICK COMPANY, E.P. HAMILTON  
III, Ph.D., P.E., PRESIDENT, E.P. HAMILTON AND  
ASSOCIATES, T.F. EDGAR, Ph.D., P.E., PROFESSOR,  
THE UNIVERSITY OF TEXAS AT AUSTIN

COAL AND PETROLEUM CORE MIXTURES AS  
 FUELS  
 ROYCE A. HOLLAND, SENIOR ENGINEER, SENIOR LECTURER  
 ROYCE A. HOLLAND, DISTRICT ENGINEER, SENIOR LECTURER  
 MANAGER, MONROE-KNUDSEN, INC., NEW ORLEANS, LA 70112

APPLICATION OF A SAWDUST-BARRIER TO CHLORINE GAS  
 PROTECTIVE LOW-STU GAS-TIGHT LIGNITE AT  
 A TEXAS BRICK PLANT  
 EARL J. JONES, JR., MANAGER OF SERVICES  
 BRICK-OUTER BRICK COMPANY, 2534 HAMILTON ROAD, WILSON, TX  
 75090  
 EARL J. JONES, JR., PRESIDENT, BRICK-OUTER BRICK COMPANY, 2534  
 HAMILTON ROAD, WILSON, TX 75090  
 ASSOCIATES, THE ENGINEERING & PROFESSIONAL & TECHNICAL  
 THE UNIVERSITY OF TEXAS AT AUSTIN, AUSTIN, TEXAS 78712

RECOMMENDATION FOR A SAWDUST-BARRIER TO CHLORINE GAS  
 PROTECTIVE LOW-STU GAS-TIGHT LIGNITE AT  
 A TEXAS BRICK PLANT  
 EARL J. JONES, JR., MANAGER OF SERVICES  
 BRICK-OUTER BRICK COMPANY, 2534 HAMILTON ROAD, WILSON, TX  
 75090  
 EARL J. JONES, JR., PRESIDENT, BRICK-OUTER BRICK COMPANY, 2534  
 HAMILTON ROAD, WILSON, TX 75090  
 ASSOCIATES, THE ENGINEERING & PROFESSIONAL & TECHNICAL  
 THE UNIVERSITY OF TEXAS AT AUSTIN, AUSTIN, TEXAS 78712

UTILIZATION OF FLUORINATING FLUID BEDS IN THE  
 THERMAL DECOMPOSITION OF  
 JAMES S. DAVIS, STRUTHERS WELLS CORPORATION  
 WILLIAM W. YOUNG, STRUTHERS WELLS CORPORATION  
 CORP., L. JAMES SWEET, STRUTHERS WELLS CORP.

ATMOSPHERIC FLUID BEDS WITH TWO STAGE  
 REACTION DEVELOPED FOR COMBUSTION OF  
 GAS PRODUCERS  
 F. R. CARLIN, TECHNICAL DIRECTOR, THE SWEET  
 EQUIPMENT COMPANY LIMITED

### COAL LIQUEFICATION

COAL-WATER SLURRY AS AN ALTERNATE FUEL  
 COAL-WATER SLURRY, PROJECT MANAGER, FLUIDIZED  
 COMBUSTION & ALTERNATE FUEL PROGRAM,  
 COAL COMBUSTION SYSTEMS DIV., ELECTRIC  
 POWER RESEARCH INSTITUTE

COAL-WATER SLURRY PROJECT MANAGER  
 RICHARD P. BROWN, DIRECTOR, COAL-WATER  
 OPERATIONS, AMERICAN RESEARCH CORPORATION

FORMULATION & HANDLING CHARACTERISTICS OF  
 COAL-WATER MIXTURES  
 RICHARD C. DONNELLY, OCCIDENTAL  
 RESEARCH CORP.

### INDUSTRIAL FUEL COGENERATION

COGENERATION AND COAL GASIFICATION  
 AN OPPORTUNITY FOR THE FUTURE  
 SYDNEY

COAL-WATER SLURRY PROJECT MANAGER, M. COOPER,  
 PROJECT ENGINEER, BRANCO SERVICE INC., CORPORATION  
 L. J. KISTLER, PROJECT MANAGER, BRANCO SERVICE  
 INC.

# "MICRONIZED COAL AS AN ALTERNATE FUEL FOR OIL AND GAS FIRED BOILERS"

BY:

T.A. Morris

G. Haider

BABCOCK & WILCOX COMPANY

A.E. Margulies

G.F. Moore

STONE & WEBSTER ENGINEERING  
CORPORATION

R. J. West

GULF STATES UTILITIES COMPANY



MICRONIZED COAL AS AN ALTERNATE FUEL  
FOR OIL AND GAS FIRED BOILERS

T.A. Morris  
and  
G. Haider  
Babcock & Wilcox Company  
Alliance Research Center  
Alliance, Ohio

A.E. Margulies  
and  
G.F. Moore  
Stone & Webster Engineering Corporation  
Boston, Massachusetts

R.J. West  
Gulf States Utilities Company  
Beaumont, Texas

ABSTRACT

Three micronized coals\* were tested in the Babcock & Wilcox Laboratory Ashing Furnace at approximately 200,000 Btu/hr to determine the feasibility of burning them in boilers designed for oil or gas. Following these tests, one of the three coals was tested in Babcock & Wilcox's Basic Combustion Test Unit at a burn rate of approximately 4 million Btu/hr. These included load and excess air tests and an around-the-clock deposition test. To evaluate the deposition potential, flue gas was diverted through a test section in which the tube size, tube spacing, gas temperature, and gas velocity are similar to those of an oil or gas designed boiler. Results from the first two phases indicate:

- Ash deposition rates on ceramic probes in the Laboratory Ashing Furnace were less for micronized coal than for pulverized coal.
- Fly ash from micronized coal had a finer particle size distribution than fly ash from conventional pulverized coal.
- Combustion performance of micronized coal was superior to pulverized coal.
- Deposits formed on a tightly spaced tube bank when firing micronized coal were removable by sootblowing with air.
- When tubes were blown every hour base deposits (deposits on the tubes immediately after sootblowing) did not increase with time.
- The micronized coal flame was significantly shorter than a pulverized coal flame.

\*In this text, micronized coal is any coal with a top size no greater than 325 mesh (44 microns). For comparison, conventional pulverized coal is considered 70% less than 200 mesh (75 microns) and 98% less than 50 mesh (300 microns).

Test results support a preliminary conclusion that micronized coal would be a feasible substitute fuel in boilers designed for oil and gas, with minimal deratings. Therefore, subsequent planned phases of longer term demonstration testing are justified in industrial and utility boilers.

## INTRODUCTION

Micronized coal is currently being investigated as a substitute fuel for industrial and utility boilers designed for oil and gas. This paper presents the results of the first two phases of a four-phase test and demonstration program [1] for evaluation of micronized coal for application to oil- and gas-fired boilers.

## Background

Oil- and gas-fired boilers for several reasons have smaller furnace volumes than a coal-fired boiler having the same heat input. First, the volume of the firebox in a coal-fired boiler must be greater due to additional heat transfer surface required in this region of the boiler. This additional heat transfer surface helps to lower the gas temperature entering the convective tube banks so that slagging can be controlled by sootblowers. Second, additional firebox volume is required in a coal-fired boiler because of the increased residence time needed for complete combustion of the coal.

Convective heat transfer tubes in coal-fired boilers must be spaced much farther apart than in oil- and gas-fired boilers to reduce the tendency for bridging by ash deposits between adjacent tubes. Thus, if an oil- or gas-fired boiler were to be converted to conventional pulverized coal, the convective heat transfer surface would have to be replaced with tubes spaced farther apart or the boiler would have to be operated with a significant derating of plant capacity.

The large amount of ash present in coal would probably necessitate further modifications to an existing oil-designed boiler. A hopper would have to be added to the bottom of the furnace to collect large ash and slag as they fall. With increased ash loading in the convective passes, more ash would be deposited on these tubes. Therefore, additional sootblowers would have to be provided and used more frequently than they would if oil were being fired. If the boiler was designed for firing natural gas, sootblowers would have to be added with the new tube bank. Since the ash loading in the boiler would be much higher with coal than with oil or natural gas, the tail-end particulate cleanup system (baghouse, electrostatic precipitator) would have to be added if designed for natural gas firing.

In many cases, the cost of equipment modifications and/or the amount of derating would be so substantial that conversion to conventional pulverized coal could not be justified economically. If some of the previously mentioned modifications could be reduced or eliminated by firing micronized coal in boilers designed for oil and gas firing, then micronized coal could be a viable substitute for oil or gas.

Micronized coal is being examined as a potential substitute fuel for oil- and gas-designed boilers because preliminary tests have indicated that the finer grinding (1) increases the burning rate of coal to permit completion of combustion in the relatively smaller furnaces of oil- and gas-fired units, and (2) reduces the mean particle size of the ash particles produced during combustion so that they follow flow streams around the tightly spaced tubes of these boilers [2, 3].

## Phase I Description - Fuels Characterization and Laboratory Ash Furnace Tests

During Phase I, fuel chemical and physical analyses were performed and then fuel combustion tests were conducted in the Babcock & Wilcox (B&W) Laboratory Ashing Furnace (LAF) located at B&W's Research Center in Alliance, Ohio [4]. This small furnace was designed to produce fly ash with properties similar to ash from an industrial or utility steam generator. This testing was performed using three coals, a portion of each ground to a pulverized and a micronized size consist. Table 1 presents a comparison of the three coals tested.

## Phase I Results and Discussion

Evaluation of the potential for ash deposition requires data on the ash deposition rate and the ease of ash deposit removal. Figure 1 presents the comparison of deposition probes exposed to combustion gases for one hour during micronized and pulverized coal testing of West Virginia coal. Deposition rates on the ceramic probes were dramatically less when burning micronized coal than for pulverized coal. This confirms the concept that the smaller ash particles will follow the gas stream around the tubes.

The results of fly ash sintering strength tests indicate that deposits from micronized coals, if left on tubes for the same time, would be harder to remove than those from pulverized coal. Since the deposit rates for micronized coal are slower, deposit buildup may be controlled with sootblowing, as is done for pulverized coal.

The decreased deposition rates observed in the above tests confirm less impingement of ash particles on the tubes. This should result in lower rates of tube erosion with micronized coal than with pulverized coal, at equivalent boiler capacities.

Another concern of deposition was that ash particles would agglomerate into larger particles during combustion. Table 2 presents the comparison of the mass mean particle sizes of micronized and pulverized coals and fly ash produced from burning each coal. Ash particles from micronized coal were finer than those from pulverized coal.

TABLE 2

Comparison of Mass Mean Particle Sizes of Pulverized and Micronized Coal and Fly Ash from Each

Origin of Coal	Mass Mean Particle Size, Microns			
	Pulverized Coal	Fly Ash	Micronized Coal	Fly Ash
West Virginia	43.67	37.73	7.76	5.12
Ohio	48.00	39.98	8.32	4.25
Indiana	53.72	7.53	6.98	4.03

The relatively finer ash from pulverized Indiana coal may be due to the fine mineral matter distribution in the coal. However, the deposit on the probe from pulverized Indiana coal was comparable to the deposit of pulverized West Virginia and Ohio coals even though the Indiana pulverized coal fly ash was finer. The reason for this behavior is

TABLE 1

MOISTURE, PROXIMATE, ULTIMATE AND SULFUR FORMS ANALYSES,  
CALORIFIC VALUES FOR PARENT COALS,  
ASH ANALYSES AND ASH-FUSION TEMPERATURES

	Indiana Parent Coal		Ohio Parent Coal		West Virginia Parent Coal	
	As Received	Dry	As Received	Dry	As Received	Dry
Total Moisture, %	13.0	---	5.2	---	4.8	---
Proximate Analysis, %						
Moisture	13.0	---	5.2	---	4.8	---
Volatile Matter	37.7	43.4	38.1	40.2	28.6	30.1
Fixed Carbon	41.2	47.3	48.1	50.7	62.5	65.6
Ash	8.1	9.3	8.6	9.1	4.1	4.3
Ultimate Analysis, %						
Moisture	13.0	---	5.2	---	4.8	---
Carbon	62.0	71.2	70.2	74.0	79.5	83.5
Hydrogen	4.5	5.1	4.9	5.1	4.8	1.29
Nitrogen	1.03	1.18	1.55	1.64	1.23	1.29
Sulfur	3.24	3.73	2.16	2.28	0.75	0.79
Ash	8.1	9.3	8.6	9.1	4.1	4.3
Oxygen (Difference)	8.13	9.49	7.39	7.88	4.82	5.22
Total	100.00	100.00	100.00	100.00	100.00	100.00
Sulfur Forms, % as S						
Pyritic	0.76	0.87	0.74	0.78	0.01	0.01
Sulfate	0.50	0.57	0.17	0.18	0.02	0.02
Organic (Difference)	1.98	2.29	1.25	1.32	0.72	0.76
Total	3.24	3.73	2.16	2.28	0.75	0.79
Gross Calorific Value						
Btu/lb	11,100	12,760	12,540	13,230	14,000	14,710
Btu/lb. (M&A Free)*	-----	14,080	-----	14,550	-----	15,380

TABLE 1 (CONT'D)

MOISTURE, PROXIMATE, ULTIMATE AND SULFUR FORMS ANALYSES,  
CALORIFIC VALUES FOR PARENT COALS.  
ASH ANALYSES AND ASH-FUSION TEMPERATURES

	Indiana Parent Coal	Ohio Parent Coal	West Virginia Parent Coal
Ash Analysis (Spectrographic), %			
Silicon as SiO <sub>2</sub>	43.53	50.58	44.87
Aluminum as Al <sub>2</sub> O <sub>3</sub>	20.34	24.62	27.85
Iron as Fe <sub>2</sub> O <sub>3</sub>	22.02	17.16	13.06
Titanium as TiO <sub>2</sub>	0.96	1.10	1.17
Calcium as CaO	4.06	1.13	3.39
Magnesium as MgO	0.77	0.62	1.16
Sodium as Na <sub>2</sub> O**	0.46	0.39	1.02
Potassium as K <sub>2</sub> O**	2.41	1.99	2.11
Sulfur as SO <sub>3</sub>	4.40	1.11	4.08
Phosphorus as P <sub>2</sub> O <sub>5</sub>	0.61	0.39	0.54

## Ash-Fusion Temperatures, °F

Atmosphere	Red.	Oxid.	Red.	Oxid.
A (I.D.)	2,000	2,380	2,310	2,610
B (S.T., Sp)	2,090	2,490	2,500	2,670
C (S.T., HSp)	2,130	2,520	2,520	2,690
D (F.T., 1/16")	2,260	2,560	2,570	2,720
E (F.T., Flat)	2,570	2,650	2,750+	2,750+

## NOTES:

\*Moisture and ash free

\*\*By flame photometer



unclear; however, it may be related to the lower ash fusion temperature and higher slagging index of Indiana coal (See Table 3).

TABLE 3

Ash-Fusion Temperature and Slagging Index for Ash  
Prepared from Test Coals

Coal	Ash-Fusion Temperatures	Slagging Index
	Hemispherical Temperatures (HT) in Reducing Atmosphere, °F	Calculated From Elemental Analysis of Ash
West Virginia	2520	0.22
Ohio	2470	0.64
Indiana	2130	1.75

The fact that smaller particles will require less time to burn than larger particles is due to the larger surface area for combustion per unit mass. Table 4 shows the ignition temperatures and burnout temperatures obtained from burning profiles of the micronized and pulverized coals.

TABLE 4

Ignition Temperatures and Burnout Temperatures  
of Micronized and Pulverized Coals

Coal	Ignition Temperature		Burnout Temperature	
	Approx., °F		Approx., °F	
	Micronized Coal	Pulverized Coal	Micronized Coal	Pulverized Coal
West Virginia	600	600	1500	1800
Ohio	470	590	1410	1650
Indiana	430	510	1290	1400

The ignition temperatures and burnout temperatures were generally lower with micronized coal. This indicates that the intensity of combustion of micronized coal will increase. This increased intensity will shorten combustion times further.

The possibility that the micronized coal particles would agglomerate in the feed system to the combustor was considered. The particle size distribution of micronized coal passing through the feed system proved that agglomeration was not occurring.

The bulk of the accumulated data supports a conclusion that conversion to micronized coal, instead of pulverized coal, will require less boiler modification and/or less boiler derating. Therefore, scaled-up tests in the Basic Combustion Test Unit (BCTU) followed.

Phase II Description - Small Scale Combustion/Deposition Testing

The Phase II testing took place in B&W's 4 million Btu/hr BCTU. The coal was fired in the BCTU in a batch mode. A small test section was added to the existing BCTU furnace through which the flue gas was diverted. This test section was designed to simulate a superheater section of boilers designed for oil and gas firing. Tubes were 2-inch

O.D. on 3-inch centers. Gas velocities through the tubes were approximately 100 ft/sec at nominal load. The tubes were air-cooled, and surface metal temperatures could vary up to 1000°F. An air sootblower was installed for tube cleaning.

Phase II testing was performed using West Virginia Sewell No. 1 coal. This was the same West Virginia coal that was tested in the Phase I LAF testing.

Figure 2 illustrates the mass fraction distributions of the intermediate and ultrafine micronized coals tested in the BCTU. It appears as if there is very little difference between these two samples; however, by calculating the number distributions from the mass fraction distributions and by plotting them on a histogram, definite differences in the samples appear, as shown in Figure 3.

The mass mean diameters were 8.3 and 9.4 microns for the ultrafine and intermediate micronized coal samples, respectively. The Sauter mean diameters were 4.8 and 6.7 microns for the finer and coarser micronized coal samples, respectively.

The Phase II testing consisted of a 64-hour, around-the-clock deposition test plus a series of parametric combustion tests using coal micronized to an intermediate fineness. In addition, some limited testing was performed using coal micronized to an ultrafine consistency. For comparison, some testing was performed using conventional pulverized coal.

The initial testing was performed using pulverized coal. Five parametric tests were planned for this grind, but before these could be completed, the deposition test section plugged with ash as shown in Figure 4. This occurred within seven hours after starting up on pulverized coal. Tube temperatures (surface metal temperature) during this period ranged from 400 to 600°F.

The coal ground to intermediate fineness was then tested under different excess air and load conditions in the BCTU. Figure 5 shows the relationship of NO emissions with load for the intermediate fineness coal. The increase in NO<sub>x</sub> emissions with load is due to the higher furnace temperature and increased turbulence resulting in better fuel/air mixing.

The coal micronized to intermediate fineness was then tested in the BCTU for 64 hours continuously. The tubes were blown with compressed air every hour, and photographs were taken before and after soot blowing. Tube metal temperatures averaged around 900°-1000°F for these tests. The hourly sootblowing provided controllable deposition, as shown in Figure 6. Occasionally, the coal would hang up in the feed hopper, suddenly free itself, and then start feeding again. When this happened, the coal feed rate would increase briefly and level out shortly. This, in turn, would increase the tube surface temperature about 100° to 200°F. A few times, the tube metal temperatures exceeded 1200°F due either to a coal surge or loss of a compressor supplying cooling air to the tubes. These high metal temperatures increased the deposition rates drastically. However, after the temperatures leveled out, the air sootblowing again cleaned the tubes quite well. The base deposit did not appear to grow over the extended test (i.e., the sootblowing seemed to clean the tubes to the same degree each time).

Although limited testing was performed with the ultrafine micronized coal, a very interesting observation was made with regard to its performance. During some shakedown tests with this ultrafine coal, the stack

oxygen concentration was reduced to low levels (about 0.5 - 1.0 percent by volume). When firing conventional pulverized coal in the BCTU, these low oxygen levels would result in a very smokey furnace and a dirty stack. However, when firing the ultrafine micronized coal under these conditions, the stack gas was very clean and the rear of the furnace was very clear.

As expected, the flames of the conventional pulverized and the flames of the coal micronized to intermediate and ultrafine consistency were visibly different. The flame of ultrafine micronized coal was very short. It extended from the burner about 2-4 feet down the furnace (to about one-half of the furnace length). This flame was very bright orange to white, and one could look into the flame from the back of the furnace and see the coal impeller and various parts of the burner; however, not as clear as the blue flame from natural gas. The increased brightness was due to the more intense combustion (more heat release per unit volume) than is typically seen with conventional pulverized coal. Because the coal particles are smaller and the surface where combustion reactions can occur is significantly larger, the particles burn in a shorter time. The flame of the conventional pulverized coal was not as clear and it occupied the entire furnace.

The flame from the coal micronized to intermediate fineness was not as bright as the flame from the ultrafine micronized coal. Occasionally, parts of the burner could be seen through the flame, but usually only a bright halo around the impeller could be seen through the orangish flame. This flame occupied a large percentage of the furnace region, but not as much as the pulverized coal flame.

#### CONCLUSIONS

The LAF test results support the contention that ash deposition rates, ash impingement on tubes and combustion times will be less for micronized coal than for pulverized coal. The results, though not completely conclusive, indicate that equipment modifications and/or plant derating will be significantly less in converting to coal if micronized coal is used instead of pulverized coal.

The shape of the flame when firing intermediate micronized coal in the BCTU was slightly different from a conventional pulverized coal flame; it did not occupy the entire furnace. The flame from the ultrafine micronized coal was significantly shorter.

The deposits formed on the tightly-spaced tube bank in the BCTU when firing micronized coal to an intermediate consistency were removed by sootblowing with air. During the 64-hour continuous test, tubes were blown every hour, and base deposits (deposits on the tubes immediately after sootblowing) did not appear to increase with time. However, longer duration testing in full size boilers is required to confirm these test results and address the question of erosion.

## REFERENCES

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