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**COMBUSTION CHARACTERIZATION OF
BENEFICIATED COAL-BASED FUELS**

QUARTERLY REPORT NO. 1 FOR THE PERIOD MAY TO JULY 1989

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QUARTERLY REPORT

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OBJECTIVE AND SCOPE

This three-year research project at Combustion Engineering, Inc. (CE), will assess the potential economic and environmental benefits derived from coal beneficiation by various advanced cleaning processes. The objectives of this program include the development of a detailed generic engineering data base, comprised of fuel combustion and ash performance data on beneficiated coal-based fuels (BCFs), which is needed to permit broad application. This technical data base will provide detailed information on fundamental fuel properties influencing combustion and mineral matter behavior as well as quantitative performance data on combustion, ash deposition, ash erosion, particulate collection, and gaseous and particulate emissions. Program objectives also address the application of this technical data base to predict performance impacts associated with firing BCFs in various commercial boiler designs as well as assessment of the economic implications of BCF utilization. Additionally, demonstration of this technology, with respect to large-scale fuel preparation, firing equipment operation, fuel performance, environmental impacts, and verification of prediction methodology will be provided during field testing.

Twenty fuels will be characterized during the three-year base program: three feed coals, fifteen BCFs, and two conventionally cleaned coals for the field test. Approximately nine BCFs will be in dry ultra fine coal (DUC) form, and six BCFs will be in coal-water fuel (CWF) form. Up to 25 additional BCFs would be characterized during optional project supplements.

SUMMARY

During the second quarter of 1989, the following technical progress was made.

- ° Shipped 20-ton batches of three feed coals and three microbubble beneficiated products from PETC to CE.
- ° Analyzed each of the six fuel batches from PETC and determined that all were suitable for representative bench-scale and pilot-scale testing.
- ° Completed preliminary coal-water fuel formulations with the microbubble flotation beneficiated products, showing that they can be used to make representative slurries.
- ° Completed pilot-scale combustion tests of the Illinois No. 6 feed coal in standard pulverized form.

TASK 1 - FUEL PREPARATION

Beneficiated coals (BCs) and feed coals are acquired from other DOE projects and shipped to CE. These fuels are then processed into either a dry pulverized coal form by CE or a coal-water fuel (CWF) form using OXCE Fuel Company technology. The feed coals are fired as standard grind (70% minus 200 mesh) pulverized coal (PC), while the dry beneficiated fuels are generally dry ultra fine coal (DUC).

Six twenty-ton batches of test fuels had been stored at PETC in sealed, inerted drums since the last quarter of 1987. These fuels included:

1. Illinois No. 6 feed coal
2. Pittsburgh No. 8 feed coal
3. Upper Freeport feed coal
4. Illinois No. 6 microbubble flotation product (MFP)
5. Pittsburgh No. 8 microbubble flotation product (MFP)
6. Upper Freeport microbubble flotation product (MFP)

Samples from each batch were analyzed to determine if the effects of aging during storage made them unrepresentative of the intended test fuels. Results of the new analyses were compared to data taken in 1987 and 1988. As can be seen in Table 1, the only significant change is the shift in sulfur forms from pyrite to sulfate. While this change can affect furnace slagging, load capability in most boilers would not be significantly affected, as shown in Reference 1, page 17.

Since oxidation of coal particles can affect their formulation into CWF, preliminary formulation tests were run to determine if the three microbubble flotation products can be used in representative "standard" CWFs, as well as "heatable" CWFs. Results showed that the Upper Freeport and Pittsburgh products were suitable for CWF with 62 to 67 percent solids, while the Illinois product made CWFs with approximately 55% solids. All these results are similar to making typical CWFs from fresh microfine coal.

Based on the above analyses, the stored fuels were judged to be representative test fuels. The drums were shipped to CE for preparation of the fuels for testing, and a test schedule was recommended to DOE. The Illinois No. 6 and Upper Freeport feed coals were then prepared for pilot-scale testing (Task 3).

TABLE 1

SUMMARY OF COAL ANALYSES OF THE MFP AND FEED COAL
ILLINOIS NO. 6 (DRY BASIS)

	BY BECHTEL (10/87)		BY PETC (3/88)		BY CE (6/89)	
	Feed Coal	Product	Feed Coal	Product	Feed Coal	Product
PROXIMATE, WT %						
Volatile Matter	41.14	41.05	39.35	40.63	38.60	40.94
Fixed Carbon (diff)	50.47	55.15	51.03	55.17	52.38	55.66
Ash	8.39	3.80	9.62	4.20	9.02	3.40
ULTIMATE, WT %						
Hydrogen	5.03	5.19	5.04	5.24	5.02	5.09
Carbon	73.61	71.67	71.08	75.15	69.30	74.91
Sulfur	3.17	2.71	2.75	2.47	2.87	2.45
Nitrogen	1.35	1.40	1.41	1.43	1.34	1.51
Oxygen (diff)	8.45	9.23	10.10	11.50	12.45	12.64
Ash	8.39	3.80	9.62	4.20	9.02	3.40
HHV (Btu/lb coal)	12985	13730	12790	13447	12675	13009
FORMS OF SULFUR, WT %						
Pyritic	1.43	1.03	0.70	0.30	0.53	0.01
Sulfate	0.04	0.02	0.11	0.20	0.35	0.39
Organic	1.70	1.66	1.94	1.98	2.12	2.00
ASH COMPOSITION, WT %						
SiO ₂	51.29	41.99	54.44	43.54	51.70	42.80
Al ₂ O ₃	20.82	19.24	21.48	21.09	20.70	19.50
Fe ₂ O ₃	17.90	20.05	14.33	18.98	16.90	21.70
CaO	2.63	3.64	2.86	4.14	2.20	3.40
MgO	0.91	1.41	0.78	1.39	0.90	1.50
Na ₂ O	0.67	2.63	0.32	2.75	0.50	2.40
K ₂ O	2.19	2.30	2.86	3.24	2.00	2.50
TiO ₂	1.09	2.40	1.16	2.06	0.80	2.70
P ₂ O ₅	0.16	0.17	0.17	0.22	0.10	0.10
SO ₃	1.23	4.44	1.99	2.47	2.10	2.20
ASH FUSION TEMPERATURES, °F (RED)						
IDT	2240	2028	2020	1950	1980	1910
ST	2357	2126	2170	2090	2210	2040
HT	2418	2249	2220	2140	2350	2100
FT	2543	2277	2280	2200	2420	2160

TABLE 1 (continued)

SUMMARY OF COAL ANALYSES OF THE MFP AND FEED COAL
PITTSBURGH NO. 8 (DRY BASIS)

	BY BECHTEL (10/87)		BY PETC (3/88)		BY CE (6/89)	
	Feed Coal	Product	Feed Coal	Product	Feed Coal	Product
PROXIMATE, WT %						
Volatile Matter	41.54	44.27	42.55	42.39	40.68	43.20
Fixed Carbon (diff)	46.76	52.34	48.23	53.74	49.91	54.10
Ash	11.70	3.39	9.22	3.87	9.41	2.70
ULTIMATE, WT %						
Hydrogen	4.90	5.34	5.21	5.44	5.40	5.70
Carbon	70.63	78.59	72.47	78.41	72.36	78.20
Sulfur	4.64	3.51	4.06	3.05	3.78	2.80
Nitrogen	1.19	1.33	1.28	1.37	1.20	1.40
Oxygen (diff)	6.94	7.84	7.77	7.86	7.85	9.20
Ash	11.70	3.39	9.21	3.87	9.41	2.70
HHV (Btu/lb coal)	12193	14207	13215	14150	12365	14150
FORMS OF SULFUR, WT %						
Pyritic	2.45	1.28	1.13	0.37	1.35	0.02
Sulfate	0.07	0.04	0.53	0.33	0.49	0.51
Organic	2.12	2.09	2.16	2.36	1.70	2.27
ASH COMPOSITION, WT %						
SiO ₂	42.68	34.54	39.03	30.86	40.40	32.50
Al ₂ O ₃	18.34	21.63	20.22	19.04	20.60	23.20
Fe ₂ O ₃	28.34	27.32	28.41	31.42	29.50	24.40
CaO	2.86	4.12	4.31	4.42	2.60	4.90
MgO	0.73	1.17	0.22	1.29	0.70	1.30
Na ₂ O	0.71	2.38	1.36	4.63	0.70	2.40
K ₂ O	1.43	1.56	2.00	2.02	1.70	1.60
TiO ₂	1.32	2.08	1.29	2.01	1.00	1.90
P ₂ O ₅	0.27	0.40	0.26	0.29	0.20	0.20
SO ₃	3.16	4.40	2.47	3.37	2.20	3.80
ASH FUSION TEMPERATURES, °F (RED)						
IDT	NM	2153	1900	1910	1980	1940
ST	NM	2261	2020	2040	2090	2060
HT	NM	2333	2075	2080	2200	2110
FT	NM	2458	2130	2140	2380	2370

TABLE 1 (continued)

SUMMARY OF COAL ANALYSES OF THE MFP AND FEED COAL
UPPER FREEPORT (DRY BASIS)

	BY BECHTEL (10/87)		BY PETC (3/88)		BY CE (6/89)	
	Feed	Coal	Product	Feed	Coal	Product
PROXIMATE, WT %						
Volatile Matter	29.09	29.65	28.07	28.40	28.04	28.25
Fixed Carbon (diff)	60.47	65.71	61.48	66.22	61.26	66.67
Ash	10.44	4.64	10.45	5.38	11.38	5.09
ULTIMATE, WT %						
Hydrogen	4.62	4.89	4.94	5.10	4.70	5.09
Carbon	78.28	83.12	78.01	82.80	76.94	83.33
Sulfur	1.72	1.20	1.74	1.23	1.76	1.23
Nitrogen	1.50	1.61	1.43	0.65	1.30	1.58
Oxygen (diff)	3.44	4.54	3.44	4.84	4.60	3.68
Ash	10.44	4.64	10.45	5.38	10.70	5.09
HHV (Btu/lb coal)	13889	14644	14769	14770	13516	14385
FORMS OF SULFUR, WT %						
Pyritic	1.08	0.67	1.17	0.49	0.44	0.02
Sulfate	0.02	0.01	0.01	0.02	0.60	0.51
Organic	0.62	0.52	0.06	0.72	0.38	0.67
ASH COMPOSITION, WT %						
SiO ₂	45.53	40.67	43.60	41.97	45.90	42.00
Al ₂ O ₃	25.06	25.59	23.33	24.63	25.70	25.70
Fe ₂ O ₃	17.16	17.30	20.59	16.70	15.90	16.60
CaO	3.23	3.59	4.14	3.78	2.50	2.70
MgO	0.85	1.18	0.86	1.20	0.90	1.10
Na ₂ O	0.45	1.74	0.39	2.11	0.50	1.30
K ₂ O	2.52	2.55	3.01	3.46	2.60	2.80
TiO ₂	1.25	2.21	1.29	1.94	1.20	2.20
P ₂ O ₅	0.31	0.41	0.19	0.32	0.20	0.30
SO ₃	3.33	4.30	2.50	3.14	2.30	2.50
ASH FUSION TEMPERATURES, °F (RED)						
IDT	2408	2219	2000	1970	1980	1950
ST	2533	2336	2130	2100	2240	2170
HT	2583	2391	2185	2145	2400	2380
FT	2658	2512	2240	2210	2420	2440

TASK 2 - BENCH-SCALE TESTS

All test fuels are fully characterized using various standard and advanced analytical techniques. These tests evaluate the impacts of parent coal properties and beneficiation processes on the resulting BCF's qualities.

A few selected fuels are tested in a laminar flow drop tube furnace to determine fly ash particle size and chemical composition. Results include mineral matter measurements and modeling of fly ash history.

A swirl-stabilized, entrained flow reactor is used to characterize the surface compositions and the states of ash particles formed during combustion. Deposition rates on a target are determined, and the size and compositions of the deposits from different fuels are compared.

The bench-scale testing during the past quarter was done in support of the fuel preparation (Task 1) activities. Results are shown in Table 1.

TASK 3 - PILOT-SCALE TESTING

Combustion experiments are conducted with selected fuels in MIT's Combustion Research Facility (CRF) to characterize the effects of fuel type, beneficiation process, and firing mode upon flame stability, carbon conversion, and gaseous emissions. Combustion tests are also run in CE's Fireside Performance Test Facility (FPTF) with most of the base project fuels, to evaluate combustion performance, furnace wall slagging, convection pass fouling, fly ash erosion, electrostatic precipitator performance, and emissions.

Three combustion tests were run in the FPTF (Figure 1) firing the Illinois No. 6 feed coal. Test conditions are summarized in Table 2. Analysis of the test data was started and preparations were made to fire the next feed coal - Upper Freeport.

TABLE 2
ILLINOIS NO. 6 PARENT COAL TEST MATRIX

<u>Test Number</u>	<u>Fuel Heat Input (10⁶Btu/hr)</u>	<u>Test Duration (hrs)</u>	<u>Avg. Flame Temp (°F)</u>	<u>Gas Temp Ent Convective Pass (°F)</u>
1	3.75	12	2750	2250
2	4.00	23	2850	2375
3	4.00	23	2975	2325

FIGURE 1
FIRESIDE PERFORMANCE TEST FACILITY

TASK 4 - SCALE-UP TESTS

The purpose of the scale-up tests is to verify that the results obtained from tests done at bench and pilot scales in Tasks 2 and 3 can be used to provide reasonable estimates of the performance effects when firing BCFs in commercial-scale furnaces. Two beneficiated fuels will be fired in either a small utility boiler or a full-scale test furnace.

The only activities in this task were discussions on fuel procurement, test facility selection, and scheduling.

TASK 5 - TECHNICAL-ECONOMIC EVALUATIONS

The results of bench-scale, pilot-scale, and scale-up tests (Tasks 2, 3, and 4) are used to predict the performance of three commercial boilers. The boilers include the following: a 560MW coal-designed utility unit, a 600MW oil designed utility unit (from Reference 1); and an 80,000 lb/hr oil-designed, shop-assembled industrial unit. Eight of the base project BCFs are used in models of each unit to calculate performance.

This task has not started, since the results of the preceding tasks are needed to do the predictions.

WORK PLANNED FOR NEXT QUARTER

- Prepare Upper Freeport and Pittsburgh No. 8 feed coals for testing.
- Set up a drying system for filter cake BCs.
- Process microbubble filter cakes into CWFs.
- Continue standard bench-scale tests.
- Start drop tube furnace tests at CE and MIT.
- Test Upper Freeport feed coal in MIT's CRF and CE's FPTF.
- Write report describing the Task 5 boilers.
- Test Upper Freeport and Pittsburgh No. 8 feed coals in CE's FPTF.

REFERENCE

1. Galton, G. W., Beal, H. R., Hargrove, M. J., and Levasseur, A. A., "Retrofit Evaluations of Standard Grind and Fine Grind Coal-Water Fuels," Eighth International Symposium on Coal Slurry Fuels Preparation and Utilization, May, 1986, Orlando, Florida.

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