DOE/PC/90160--T2

DOE/PC/90160--T3

DE92 004875

ADVANCED ATOMIZATION CONCEPT FOR CWF BURNING IN SMALL COMBUSTORS - PHASE II

Contract No. DE-AC22-90PC90160

Contract Period of Performance:
28 September 1990 - 30 November 1991

Quarterly Technical Progress Report No. 3

Period Covered by Report: 1 April 1991 to 30 June 1991

Prepared by:

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1.0 EXECUTIVE SUMMARY

The present project involves the second phase of research on a new concept in coal-water fuel (CWF) atomization that is applicable to burning in small combustors. It is intended to address the most important problem associated with CWF combustion; i.e., production of small spray droplets in an efficient manner by an atomization device. Phase I of this work was successfully completed with the development of an opposed-jet atomizer that met the goals of the first contract.

Present atomizer designs employ either a stream of fuel that is impacted internally by an air blast to produce a spray; or a jet of fuel that issues from an orifice and externally encounters an annular flow of air, causing atomization by parallel shear. In the present atomizer design, two opposed jets of CWF are directed at each other and encounter a perpendicular blast of air at the collision point to create a spray of very much finer droplets.

In Phase I of this program, performance as a function of operating conditions was measured, and the technical feasibility of the device established in the Atlantic Research Atomization Test Facility employing a Malvern Particle Size Analyzer. Testing then proceeded to a combustion stage in a test furnace at a firing rate of 0.5 to 1.5 MMBtu/H. In the present Phase II, the tasks to be performed are listed below together with a summary of progress on each during the previous quarter. During this quarter, the period of performance was extended at no cost until 30 November 1991.

Task 1: Optimizing the Design. The Malvern Particle Size Atomizer has been calibrated against NIST standard glass beads of 5-30 microns diameter. Atomizer air orifices of slotted instead of circular configuration have been evaluated with both water and CWF fluids. With CWF sprays, there was very little difference measured between the two types of orifices.

Task 2: Fabrication of a Prototype Atomizer. The opposed-jet unit for use in the Pittsburgh Energy Technology Center (PETC) Fuel Evaluation Facility (FEF) has been fabricated and is in hand. Testing will be conducted in the next quarter.

Task 3: Acquisition of Comparative Atomizer and
Task 4: Comparison of Performance. A commercially-available Parker Hannifin (PH) atomizer was received, and testing has been completed. The unit was found to produce very fine sprays with CWF; however, high-atomizing air-to-fuel (A/F) ratios (1.2) were required. A more serious problem was plugging of air passages by CWF during operation. Attempts to correct this were unsuccessful.

Task 5: Study of Scaling Parameters. This task involves the evaluation of the opposed-jet atomization concept for use in smaller- and larger-scale applications. During the period, the smaller-scale testing was completed. It is concluded that the opposed-jet atomizer can be operated down to about 200,000 Btu/H with some sacrifice in spray droplet size.

Task 6: Erosion Study. Work on this task has not yet started.

Task 7: Supply of Coal-Water Fuels. A sample of Kemmerer Western bituminous coal was received from Energy International for slurryability testing. Based on satisfactory results with this sample, four tons of the coal were ordered and received for production of the CWF for use by PETC in the FEF.

2.0 INTRODUCTION

Slotted atomizing air orifices were evaluated for use in the opposed jet atomizer and very little difference was found between these slotted versus circular orifices. The opposed-jet unit for use in the PETC FEF has been fabricated but not yet tested. Also, a commercially-available Parker Hannifin (PH) atomizer has been acquired for comparative testing. This PH unit produced fine sprays but at high A/F ratios. Clogging of the PH unit was found to be a problem.

The opposed-jet concept was evaluated for application on smaller scale. It appears that it can be operated down to about 200,000 Btu/H with some sacrifice in spray droplet size.

A sample of Kemmerer Western bituminous coal was received from Energy International for slurryability testing. Based on satisfactory results with this sample, four tons of the coal were ordered and received for production of the Fuel "B" CWF for use by PETC in the FEF. Indications are that fuel B will have a higher viscosity and lower solids loading than fuel "A". This is typical of CWF's made from lower rank coals.

Modification number A001 of 7 May 1991 was received this quarter. This modification fully funds the contract and extended the period of performance until 30 November 1991.

3.0 PROJECT DESCRIPTION

3.1 Task 1: Optimizing the Design

Atlantic Research Corporation (ARC) will refine the design of the atomizer, which was developed in the prior contract (DE-AC22-87PC79656). Areas to be examined experimentally include the following:

1. The introduction of cross-flow air in a manner causing the least impediment to the collision of the slurry jets.

   NOTE: For example, in the absence of cross-flow air, there is a tendency for the slurry jets on impact to form a thin disc, which breaks up at the periphery. One candidate configuration for the air orifice, therefore, might be a narrow slot aligned with the plane of the disc.

2. Elimination of the spray "blow-back" which causes a deposit on the face of the atomizer during CWF combustion.

   NOTE: During the prior contract, this effect was observed in spray chamber tests with both water and CWF, as well as in combustion testing.

In addition to using spray chamber tests, ARC may perform cold-flow tests in the tunnel furnace, if appropriate.

3.2 Task 2: Fabrication of Prototype Atomizer

ARC will provide to PETC an arrangement drawing of the proposed prototype atomizer for a check of installation requirements in the FEF furnace. After receiving approval from PETC, ARC will fabricate and assemble one atomizer.

3.3 Task 3: Acquisition of Comparative Atomizer

In this task, ARC will acquire an atomizer similar in capacity to the prototype but of different design. All available sources may be considered with the intention of ensuring the best atomization performance available. If appropriate, more than one unit may be obtained and tested in the spray chamber under this task.

ARC will obtain PETC's concurrence in the preferred comparative atomizer before using it in Task 4.

3.4 Task 4: Comparison of Performance

ARC will conduct cold flow tests in the spray chamber using a Malvern particle size analyzer to characterize the performance of the prototype atomizer over a range of CWF flow and air flows. Similar tests will be made with the comparative atomizer. Two CWF's will be used:

- Fuel A will be produced from an Eastern bituminous coal and will be similar to the Upper Elkhorn (2.5% ash) CWF used in the prior contract.
- Fuel B will be produced from a Western subbituminous coal containing less than 4% ash; the particle size distribution of the coal will be similar to Fuel A

A complete survey of performance for each atomizer will be conducted with Fuel A only, at a selected (optimum) viscosity. However, more than one viscosity will be employed for each fuel in less comprehensive testing to permit comparisons of viscosity effects on the performance of the atomizers.

Subsequently, both atomizers will be made available to PETC for testing in the FEF Combustor. Detail drawing of the prototype atomizer will be provided. Both units will be dimensionally within the manufacturing tolerances.

3.5 Task 5: Study of Scaling Parameters

In studying the scaling parameters of the opposed-jet design, ARC will fabricate two units suitable for cold-flow testing. These should correspond approximately to the CWF capacities of a single-family residence and a commercial building. Both of these atomizers will be characterized with Fuel A.

In addition, the larger unit will be tested with Fuel C - a "boiler-grade" CWF (produced from the same coal as Fuel A) in which the coal particle size distribution corresponds to 80% passing 200 mesh.

3.6 Task 6: Erosion Study

Using a relatively large volume of Fuel A in a recirculation loop, ARC will examine wear rates in orifices of the type used in opposed-jet atomizers. The testing will include the shear rates and orifice sizes employed in the prototype unit, the residential-scale unit, and the commercial-scale unit. Materials tested will include hardened steel and at least one ceramic.

3.7 Task 7: Supply of Coal-Water Fuels

ARC will supply PETC with CWF's for the testing of the prototype atomizer and the comparative atomizer in the FEF combustor, which is rated at 0.5 MMBtu/H.

The anticipated requirements are:

- Fuel A - 1200 gallons, with an option for 600 gallons additional within six months.
- Fuel B - 600 gallons, with an option for 300 gallons additional within six months.

ARC will provide rheological information and data relating apparent viscosity of CWF's to atomization performance, over a range encompassing the fuel supplied. (This will facilitate the correlation of PETC's combustion results with ARC's spray chamber data.)

ARC will obtain PETC's concurrence on fuel specifications, shipping mode, and schedule.

4.0 PROJECT STATUS

4.1 Task 1. Optimizing the Design

The testing and calibration of the Malvern Particle Size Analyzer that is to be used for the Phase II effort on the contract has been completed. The calibration against NIST standard beads of 5-30 microns diameter is shown in Figure 1. The points represent five separate tests. Overall, the data reproduce the standard NIST curve on the figure very well; however, the scatter is appreciably greater than the error bands on the S-curve. We attribute the scatter to the fact that the Malvern Particle Size Analyzer is set up to measure spray droplets, and the calibration must be performed with the NIST standard glass beads in a water suspension. Accordingly, the liquid analyzer cell must be hand-held in the path of the laser beam during the calibration testing, giving rise to irreproducibility. For this reason, we did five separate tests and plotted all the data together. We feel confident that the absolute accuracy of the instrument is completely satisfactory, as is the reproducibility of measurements in sprays as shown by the data below.

Two series of "reproducibility" tests were performed with water sprays. The first employed a set of (brass) orifices for the water jet that had previously been used quite extensively, the point that the orifice diameters had increased from 0.024" to slightly greater than 0.025" (about a 10% area increase). The streams of water that issued from the orifices were visually irregular and would change slightly during a test. The data were taken by running a set of five tests at pressures of 40, 70, 100, 70, 40 psig, then shutting the system down for a while, restarting, and repeating, for a total of five sets of five tests each. The results are collected in Table 1, listed as mass median diameter of each spray (Sauter mean diameters would be slightly lower).

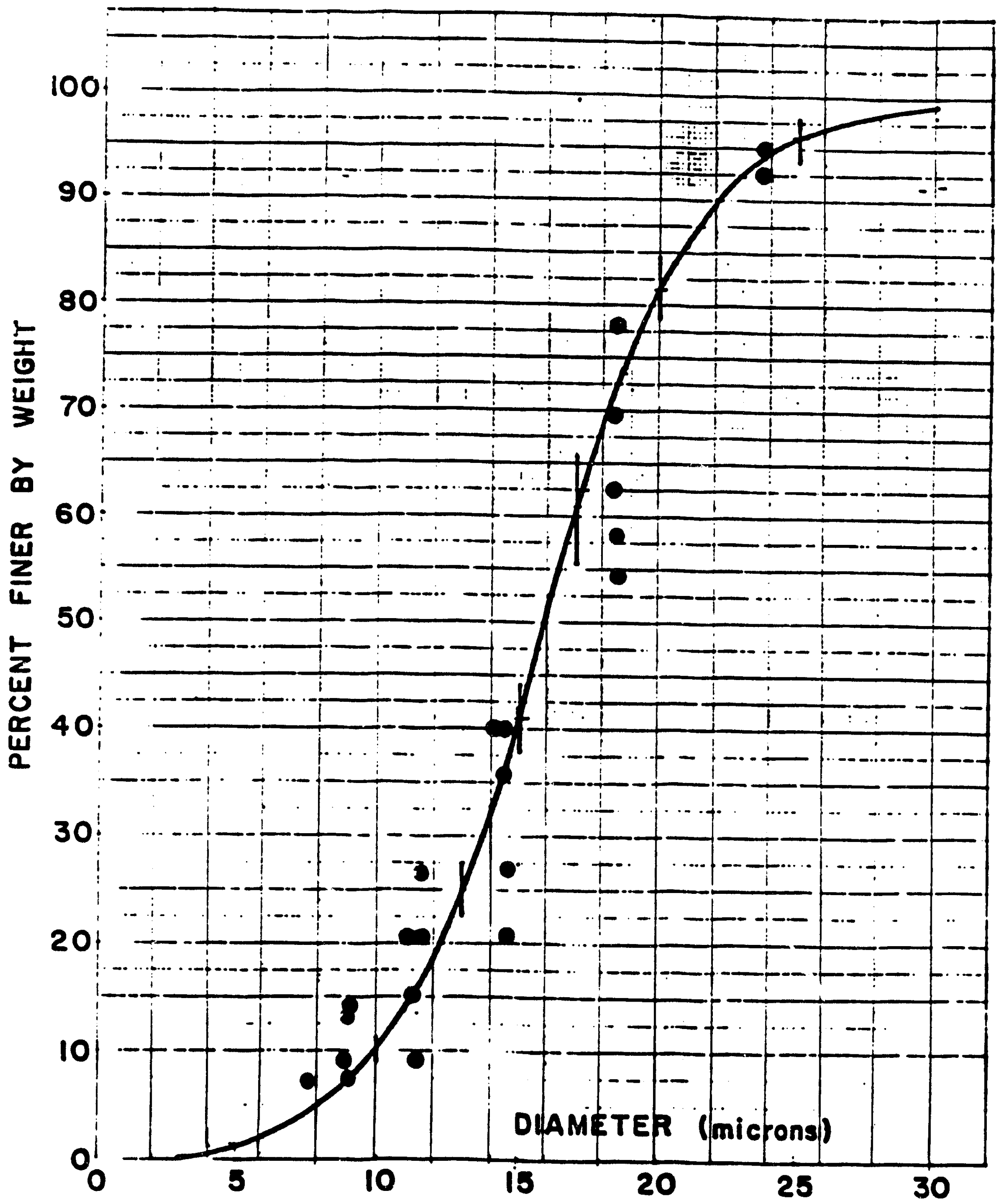

Figure 1. Malvern Calibration Test Results. ARC Data (Points) Versus NIST Standard Glass Beads (S-Curve).

The data are reasonably reproducible with an overall average [(standard deviation/average mass median diameter (MMD) x 100] of 14%. This result can be compared with the comparable value of about 22% reported in Phase I of the program (2nd Quarterly Report, November 1987 - January 1988, Contract No. DE-AC22-87PC79656).

In an effort to try to improve on the reproducibility, the old water nozzles were replaced with new nozzles of 0.020" diameter. The appearance of the water streams was markedly improved, as can be seen from the data listed in Table 2, the reproducibility is much better, with an overall average [(standard deviation/average MMD) x 100] of 6%. It is noted that the MMD's of these sprays are higher (at the higher atomizing pressures) than those of the sprays from the 0.025" orifice of Table 1. This indicates that at lower operating capacity, the spray can be expected to be coarser, as was found to be the case in earlier work. Also, it is noted that as the orifice diameter decreased from 0.025" to 0.020", a 36% decrease in area, the flow rate decreased from 22.1 g/sec to 10.5 g/sec, or 52.5% (at the same driving pressure). This disproportionate drop in flow rate is attributed to a lower discharge coefficient for the smaller orifice.

In the tables, the listed operating conditions are typical of the optimum conditions found in the earlier work. The mass flow rates of air ($\dot{m}$) were calculated from the discharge equation for orifices:

$$\dot{m} = CAP \sqrt{\frac{\gamma M}{RT}} \; (0.58) \text{ g/sec}$$

With $A = 0.0792 \text{ cm}^2$

$$P = \frac{\text{psia}}{14.7} \times 10^6 \text{ dynes/cm}^2$$

Table 2. Reproducibility Test Results Using Water Sprays and Liquid Injector Nozzles.

Water Orifice Diameters	-	0.020"
Water Flow Rate	-	10.5 g/sec
Air Orifice Diameter	-	0.125"
Distance From Spray Collision Zone to Laser Beam	-	4"
Distance From Air Orifice to Collision Zone	-	12 mm
Distance Between Water Nozzle Orifices	-	2"

Pressure (psia)	40.0	50.0	60.0	50.0	40.0
$\dot{m}$ (air) (g/sec)	4.94	6.18	7.42	6.18	4.94
A/F Ratio	0.47	0.59	0.71	0.59	0.47
Mass Median	28.0	21.0	18.0	23.0	32.0
Droplet Diameter (microns)	33.0	23.0	19.0	25.0	31.0
	32.0	24.0	18.0	25.0	34.0
	34.0	26.0	19.0	25.0	35.0
Average MMD's	32.0	24.0	18.5	25.0	33.0
Standard Deviation	2.6	2.2	0.6	1.2	1.8
Standard Deviation/Average x 100 (%)	8.0	9.0	3.0	5.0	5.0

γ = Heat capacity ratio = 1.4

R = Gas constant = 8.3 x 10^7 cgs units

T = 300°K

The discharge coefficient is unknown and is taken as unity, although in reality it is lower, possibly in the range of 0.8-0.9. The factor 0.58 represents the so-called thermodynamic efficiency factor and is given by:

$$(2/\gamma + 1)^{\frac{\gamma + 1}{2(\gamma - 1)}}$$

The $\dot{m}$ (air) values were used to calculate the "A/F" ratios in the tables.

A parameter to be evaluated under Task 1 involves changing the configuration of the air orifice to determine what, if any, effect this has on atomization. A slotted orifice was fabricated and tested against the conventional circular orifice. The plan was to measure water sprays first, and if promising results were obtained, to then measure CWF sprays. The water tests were performed with the slotted orifice oriented perpendicular and parallel to the streams of CWF. Measurements were made with the air orifice at 12 mm and 4 mm from the collision zone of the CWF jets and atomizing air. The data were very close for both distances and were averaged. Tests were performed at a water flow rate equivalent to approximately 1 MMBtu/H of CWF flow. A summary of data is presented in Table 3.

It is apparent that a slotted orifice oriented perpendicular to the water jets produced droplets of significantly lower mass median diameter. This is true at least at the lower pressure and A/F ratios. With the slotted orifice oriented parallel to the water jets, the effect was not as great, but is still evident at the lower pressures. The results are encouraging enough to warrant further testing with CWF sprays. It can also be noted that the reason the A/F ratios are slightly different at the same pressures for the slotted versus circular orifices is that the slotted opening has a slightly larger discharge area.

Table 3. Summary of Results of Water Testing to Evaluate Slotted Versus Circular Atomizing Air Orifices.

Atomizing Air Pressure (psia)	"Air-to-Fuel" Ratio	Orifice Orientation	Droplet MMD (microns)
55	0.39	⬮	5.8
75	0.53	"	5.8
95	0.68	"	5.8
115	0.81	"	5.8
55	0.39	⬬	12.0
75	0.53	"	8.6
95	0.68	"	7.9
115	0.81	"	6.8
55	0.34	○	21.6
75	0.46	"	13.5
95	0.59	"	10.5
115	0.71	"	5.8

Based on these water spray results, testing then proceeded to CWF sprays with the slotted orifices. This testing has been completed during the present quarter, but the data have not been completely reduced and analyzed. However, qualitative observations are possible.

The atomizer was evaluated at approximately 1 MMBtu/H capacity using an approximately 57% CWF of 250 cp. The slotted orifice was oriented both vertically and horizontally. With the slot oriented vertically, performance was poorer than with the circular orifice at low atomizing A/F ratios and about equal at high A/F ratios, the dividing line being an A/F of approximately 0.7. With the slot oriented horizontally, the performance was slightly better than with the circular orifice at low A/F ratios and about the same at high A/F ratios.

These results show that the differences between the slotted and circular air orifices were not nearly as great with CWF atomization as with water. Tabulated results will be presented in future reports.

4.2 Task 2. Fabrication of a Prototype Atomizer

The opposed-jet atomizer for use in the PETC FEF, which had been designed and submitted for approval by PETC, has been fabricated by a local machine shop during the quarter. The unit appears satisfactory, but testing has not yet been performed. This will be conducted in the next quarter.

4.3 Task 3. Acquisition of Comparative Atomizer

The Parker-Hannifin atomizer was received at the end of May from the vendor, and testing has begun (see Task 4).

4.4 Task 4. Comparison of Performance

The evaluation of the Parker-Hannifin atomizer was conducted during the period. In summary, we found that very fine droplet sprays, down to 22 microns MMD, can be achieved; however, an A/F ratio of almost 1.2 was required. An even more serious problem, however, was plugging of the atomizer after a short period of operation during every test series. By the end of each test series, the atomizer was plugged with dried CWF in several air passages and was producing an erratic spray. Several attempts to identify the cause of this problem and correct it were unsuccessful. Our best assessment of the problem is that the high degree of swirl of the atomizing air creates a strong vortex with a low-pressure area near the atomizer face and an accompanying recirculation flow. The overall effect is to draw CWF back into the air channels. While only a relatively small amount of CWF is involved, it nevertheless is enough to cause partial blockage after a while. Reports in the literature hint at this problem with the Parker-Hannifin atomizer. The test data are still being reduced and analyzed and will be presented in the next report.

4.5 Task 5. Study of Scaling Parameters

This task involves the evaluation of the opposed-jet atomization concept for use in smaller- and larger-scale applications. During the period, the smaller-scale testing was completed, although the data have not yet been completely analyzed. Preliminary observations are reported here.

In order to down-scale the system, the CWF orifices must be reduced in area. It is not acceptable to simply reduce the CWF flow rate by reducing the driving pressure, because the CWF jets then do not have sufficient energy to penetrate the atomization air stream and are blown away without being finely atomized. The smallest available orifice for CWF is 0.012" in diameter. This compares with the 0.023" diameter orifice that is used at 1 MMBtu/H, and represents a factor of four decrease in area; however, the discharge coefficient also decreases enormously, so a high CWF driving pressure is still required, and the jet energy is retained because the slurry velocity is high.

The objective was to attempt to operate at a capacity of 0.1 MMBtu/H; but as mentioned below, testing could only be done down to 0.24 MMBtu/H. An air orifice of 1/16 inch diameter (0.020 cm^2 area, one-quarter the area employed at 1 MMBtu/H) was used. Initial testing with the CWF orifices of 0.012 inch diameter showed that these became plugged very soon after each test was started even with CWF diluted to 53% solids. Accordingly, testing had to be conducted with larger orifices, and the next available size was 0.018 inch diameter. This size performed satisfactorily with no plugging problems even with 57% CWF which was used in the testing. At a CWF flow rate of 3.5 g/sec, equivalent to 0.24 MMBtu/H, the best MMD attained for the sprays was 60 microns at an A/F ratio of 0.40. At higher and lower A/F, the MMDs were larger. At a CWF flow rate of 5.8 g/sec, equivalent to 0.40 MMBtu/H, the MMDs minimized at 45 microns at an A/F of approximately 0.5. These results are consistent with droplet MMDs of 20-30 microns that are achieved at 1 MMBtu/H at A/F ratios of 0.7 using this CWF. A fuller explanation of the mechanism of the small-scale atomization process will be reported later, but the conclusion to be drawn from the testing is that the opposed-jet atomizer can be operated probably at about 200,000 Btu/H with some sacrifice of spray droplet size.

4.6 Task 6. Erosion Study

Work on this task has not yet started.

4.7 Task 7. Supply of Coal-Water Fuels

A sample of the Kemmerer Western bituminous coal was received from Energy International for slurryability testing. A number of laboratory-scale slurries were prepared using varying recipes and processing conditions. We eventually settled on a formulation of 50% coal (dry basis) and 1.5% dispersant (total dry solids 51.5%) with 1.3% base. This yielded a fluid slurry which appeared to have satisfactory properties, although the quality of the CWF was not as good as the fuel "A" CWF. Accordingly, we placed a purchase order with Energy International for four tons of the Kemmerer to process the 900 gallons of CWF for PETC use. Upon receipt of the coal in late June, production of CWF began. Initially, several test batches were prepared to verify the earlier recipe based on the sample of coal and to determine larger-scale operating conditions. Coal analysis sheets received from Energy International are appended to this report.

5.0 PLANNED ACTIVITIES

Activities planned for the next quarter (1 July 1991 to 30 September 1991) will include the following:

- Task 1 - An atomizing air orifice with an expanding outlet will be tested.
- Task 2 - The atomizer for the PETC FEF will be tested and shipped.
- Task 3,4 - Completed. Parker-Hannifin atomizer will be shipped to PETC.
- Task 5 - The opposed-jet atomizer will be modified and tested at larger scale.
- Task 6 - Orifices made of various materials will be tested for erosion rates.
- Task 7 - Production of CWF with the Kemmerer coal will be completed and sent to PETC.

6.0 SUMMARY

Progress was made on Tasks 1 and 2, involving testing of alternative atomizer designs and fabricating a unit for PETC use. Tasks 3 and 4 covering acquisition and testing of a Parker-Hannifin atomizer were completed. Task 5 was partially completed with the evaluation of the small-scale atomizer. Work on Task 6 to study atomizer nozzle erosion will begin next period. The production of CWF from Kemmerer coal under Task 7 was started, and product will be shipped next quarter. The period of performance of the contract was extended at no cost to 30 November 1991.

ENERGY INTERNATIONAL CORPORATION
135 William Pitt Way
Pittsburgn, Pennsylvania 15238

July 1, 1991

Mr. Harley L. Heaton
Atlantic Research Corporation
5390 Cherokee Avenue
Alexandria, VA 22313

Reference: Purchase Order No. 1M85109

Subject: Analysis of KEM-362-WRM-A

Dear Harley:

A representative sample of your Kemmerer coal was analyzed by Commercial Testing & Engineering Company, Denver Laboratory. Their analytical data are enclosed.

On June 5, 1991 approximately 7,100 tons of newly-mined Kemmerer coal was loaded into twenty-three 55-gallon steel drums with 5.5 mil poly-liners to protect against contamination. During packaging and analysis, appropriate quality assurance practices were used and were confirmed by our observer. Our shipper confirms that delivery was made on June 12 to Atlantic Research.

We sincerely hope this coal satisfies the needs of your project, as we are interested in advancing the technologies associated with increased and improved coal utilization. Please consider Energy International for your future special coal needs.

Sincerely,

Russell C. Maxwell, Jr.
Project Manager, Coal-Based Fuels

Enclosure

Telephone 412-826-5350 Telex 5106019265 (U-PARC UQ) Fax 412-826-5378

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 • (708) 953-9300

SINCE 1908

Member of the SGS Group (Societe Generale de Surveillance)

PLEASE ADDRESS ALL CORRESPONDENCE TO:
10775 E. 51ST AVE., DENVER, CO 80239
TELEPHONE: (303) 373-4772
FAX: (303) 373-4791
TELEX: 255976

June 21, 1991

ENERGY INTERNATIONAL CORP.
135 WILLIAM PITT WAY
PITTSBURGH PA 15238

Sample identification by
ENERGY INTERNATIONAL CORP.

SAMPLE ID: KEMMERER COAL
PO# EI-185-2023
KEM - 362 - WRM- A

Kind of sample reported to us COAL

Sample taken at KEMMERER COAL MINE

Sample taken by ENERGY INTERNATIONAL CORP.

Date sampled ------

Date received June 11, 1991

Analysis Report No. 72-219641

PROXIMATE ANALYSIS

	As Received	Dry Basis
% Moisture	23.06	xxxxx
% Ash	4.13	5.37
% Volatile	35.25	45.81
% Fixed Carbon	37.56	48.82
	100.00	100.00
Btu/lb	9724	12639
% Sulfur	0.53	0.69
MAF Btu		13356
SO_2 lb/mill Btu @ 100%	1.09	
Alk. as Sodium Oxide	0.03	0.04

ULTIMATE ANALYSIS

	As Received	Dry Basis
% Moisture	23.06	xxxxx
% Carbon	55.80	72.53
% Hydrogen	3.93	5.11
% Nitrogen	1.06	1.38
% Sulfur	0.53	0.69
% Ash	4.13	5.37
% Oxygen(diff)	11.49	14.92
	100.00	100.00

FORMS OF SULFUR

	As Received	Dry Basis
% Pyritic	0.07	0.09
% Sulfate	0.02	0.03
% Organic(diff)	0.44	0.57

WATER SOLUBLE ALK.

	As Received	Dry Basis
% Sodium oxide	xxxxxx	xxxxxx
% Potassium oxide	xxxxxx	xxxxxx

FUSION TEMPERATURE OF ASH, (°F)

	Reducing	Oxidizing
Initial Deformation (IT)	2215	2293
Softening (ST)	2242	2308
Hemispherical (HT)	2255	2395
Fluid (FT)	2490	2560

RECEIVED
JUN 28 1991

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.

Manager, Denver Laboratory

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 • (708) 953-9300

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TELEX: 25597[illegible]

June 21, 1991

ENERGY INTERNATIONAL CORP.
135 WILLIAM PITT WAY
PITTSBURGH PA 15238

Sample identification by
ENERGY INTERNATIONAL CORP.

SAMPLE ID: KEMMERER COAL
PO# EI-185-2023
KEM - 362 - WRM- A

Kind of sample reported to us	COAL
Sample taken at	KEMMERER COAL MINE
Sample taken by	ENERGY INTERNATIONAL CORP.
Date sampled	------
Date received	June 11, 1991

Analysis Report No. 72-219641

ANALYSIS OF ASH	WEIGHT %, IGNITED BASIS
Silicon dioxide	45.59
Aluminum oxide	19.58
Titanium dioxide	0.62
Iron oxide	4.97
Calcium oxide	9.36
Magnesium oxide	3.61
Potassium oxide	0.30
Sodium oxide	0.62
Sulfur trioxide	14.43
Phosphorus pentoxide	0.29
Strontium oxide	0.18
Barium oxide	0.26
Manganese oxide	0.19
Undetermined	0.00
	100.00

Silica Value = 71.76
Base:Acid Ratio = 0.29
T_{250} Temperature = 2571 °F

Type of Ash = LIGNITIC
Fouling Index = 0.62
Slagging Index = 2251.00

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.

Manager, Denver Laboratory

END

DATE FILMED

2 / 11 / 92