"MULLED COAL - A BENEFICIATED COAL FORM FOR USE AS A FUEL OR FUEL INTERMEDIATE"

Contract No. DE-AC22-90PC90167

Technical Progress Report No. 7
For the Period October 1, 1991 through December 31, 1991

Prepared By:

ENERGY INTERNATIONAL CORPORATION
135 William Pitt Way
Pittsburgh, PA 15238
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FINAL

Prepared For:

PETC Project Manager: Anthony E. Mayne
Pittsburgh Energy Technology Center
U.S. Department of Energy
P. O. Box 10940
Pittsburgh, PA 15236

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</tbody>
</table>
I. EXECUTIVE SUMMARY

Energy International Corporation was awarded a contract by DOE-PETC (DE-AC22-90PC90167) to evaluate a new concept for utilization of the fine coal wet cake produced by many of the physical beneficiation processes now under development. The project started with the selection of coal feedstocks on May 15, 1990. This report covers activities from October 1, 1991 through December 31, 1991.

II. INTRODUCTION

Under the auspices of the Department of Energy and private industry, considerable progress has been made in:

- preparation of coal-water fuels
- combustion of low-ash coal-based fuel forms
- processes to provide deeply-cleaned coal

These technology advances are compatible with the national objective to increase the environmentally responsive use of readily available and abundant coal resources, and to reduce oil and gas fuel consumption.

As these technical developments move toward commercial application, the need for coordinated efforts and integrated requirements has become increasingly apparent. Systems are vitally needed to integrate energy delivery systems from the raw resource through processing to application and end use. Problems have been encountered in the preparation of conventional coal-water fuels that mutually satisfy the requirements for storage stability, handling, preparation, atomization, combustion, and economics. Experience has been slow in evolving generic technologies or products and coal-specific requirements and specifications continue to dominate the development. Thus, prospects for commercialization remain highly specific to the coal, the processor, and the end use.

Developments in advanced beneficiation of coal to meet stringent requirements for low ash and low sulfur can be anticipated to further complicate the problem areas. This is attributable to the beneficiated coal being procured in very fine particles with high surface areas, modified surface characteristics, reduced particle size distribution range, and high inherent moisture. Experience in the storage, handling, and transport of highly beneficiated coal has been limited. This is understandable, as quantities of such product are only now becoming available in meaningful quantities.

Since inception of the project, we have:

- Developed formulations for stabilizing wet filter cake into a granular free flowing material (Mulled Coal).
- Applied the formulation to wet cake from a variety of coal sources ranging from anthracite to subbituminous coal.
- Evaluated effects of moisture loss on mull properties.
- Developed design concepts for equipment for preparing the Mulled Coal and converting it into Coal Water Fuel.
This report covers activities from October 1, 1991 to December 31, 1991. During this period we have:

- Obtained storage and handling system design data for the granular coal.
- Completed the 74-day aging study on various mull formulations to determine the effects of time and exposure on mull properties.
- Demonstrated the continuous production of mulled coal from wet filter cake.
- Demonstrated the continuous production of CWF from mull.
- Performed atomization studies on Mulled Coal and CWF prepared from Mulled Coal.

III. PROJECT DESCRIPTION

The Mulled Coal project was divided into a series of tasks designed to produce formulations and system designs suitable to convert fine coal "wet cakes" into materials that can be stored, handled, and transported to a site where it can be utilized as a fuel in existing and developing combustion devices.

The work was divided into two phases:

Phase I provided the technology base and established the technical feasibility of the concept of stabilizing the fine coal "wet cake" in a form that can be readily stored and moved to the location where it is either combusted "as is" or converted into a desired fuel form. The information-developed during Phase I provides a basis for design and implementation of a demonstration program (Phase II).

Phase II will demonstrate the ability to utilize the Mulled Coal to improve the ability to store and move fine coal products as a stable "wet cake". Tasks in this phase will first test components of the fine coals and subsequently demonstrate operations of an integrated system for storing, handling, and combustion of the highly beneficiated fine coal products.

Phase I - Once the feed coals were selected, basic technical information for formulations of Mulled Coal were developed through bench studies. Some base assumptions for the process concept were:

1. Chemical formulations will have to consider end use as well as the chemistry involved with the beneficiated processes.
2. If any changes in particle sizes are required for the combustor, they should be made before formulation of the Mulled Coal.
3. Conversion from Mulled Coal to the final fuel form should require minimal equipment and relatively moderate conditions such as dilution, addition of small quantities of reagents, mild agitation, and little heating. Grinding, high temperatures, corrosive or hazardous materials, etc. should be minimized.
Phase II - Phase II comprises the design, acquisition, and testing of the system components required to simulate the storage, transportation and combustion of the "mulled coal" formulation(s). The "mulled coal" was prepared in sufficient quantities to perform a full system test of the preferred formulations.

IV. PROJECT STATUS

1.0 Phase I - Technology Development

1.1 Feedstock Procurement

Sufficient raw coal has been procured to satisfy project requirements.

1.2 Feasibility Study

Evaluation of reagents and various mull formulations have been completed.

1.3 Laboratory Scale Tests

Lab scale testing of the mull and slurry components is complete.

2.0 Phase II - System Demonstration

2.1 Component Development

2.1.1 MC Preparation

Four tons of deep-cleaned Upper Elkhorn #3 coal were sent to Virginia Tech to be ground to approximately 20 micron average particle size and centrifuged to approximately 40-45 wt. % moisture content. Twenty-four drums of wet cake were sent back to EI to be made into mulled coal product for the full system test at UND ERC at Grand Forks, North Dakota. The drums of wet cake were found to contain one to two inches of water at the top, and the moisture content varied from 55 wt. % moisture near the top to 45% moisture near the bottom. This cake was very difficult to feed using the Accurate feeder because it had a consistency of wet sand.

This wet cake was fed at various flow rates with a Mull Agent into the 2-inch continuous processor to make mulled coal product. Because of the high moisture content, the Mull Agent concentration had to be increased to 6 wt. % of dry solids and the wet cake feed rate had to be reduced to 30 lb/hr to make a satisfactory mull. This was mainly due to the short residence time in the 2-inch processor. In order to speed up the mull production rate, the following changes were made:

1. A 6 cu. ft. batch mortar mixer was rented to make the mull product in 2 stages.

2. For stage 1, approximately 70 to 80 lbs. of wet cake was charged to the cement mixer with 4.0 wt. % Mull Agent. After 15 minutes mixing, the pre-mull was dumped into an intermediate storage bin.
3. For stage 2, the pre-mull was fed into the 2-inch continuous processor at 75 lb/hr with an additional 2.0 wt. % mull agent to make the final mull product.

A total of 12 drums of mulled coal product were made using this procedure of which 7 drums (1900 lb) were shipped to Grand Forks, North Dakota (UNDEERC) for the full system test.

2.1.2 ESTL Testing

Five samples from the storage and handling studies were resubmitted to Henk Colijn and Associates for flowability studies (see Table I). These samples all had a 20 micron average particle size and an initial 30% moisture content. They were stored for 74 days in their respective containers (Table I). Open storage dried out the mulled coal products. The greater the exposed area, as shown in the shallow exposed tray, the greater the evaporation. The compressive strength for a specific final moisture level is about the same whether the material was previously stored or not (see Figures 1 and 2 and Tables II and III). The final moisture content is the determining factor. The samples did not show any appreciable oxidation effect.

The design analyses of the 30% wet cake, 20 um particle size (005-114-1), the 30% H2O-2% Mull Agent 12 um particle size (005-114-A), and the 30% H2O-2% Mull Agent 70 um particle size (005-114-B) samples that were submitted previously are given in Table IV. The critical arching dimension and stable rathole diameter for the wet cake (sample 005-114-1) are much larger than for any of the samples with Mull Agent added. Also, the flowability of the mull at a given moisture content and Mull Agent concentration increases significantly as the particle size is increased. Basically, the finer the grind, the stronger the cohesive strength of the mull, and the poorer the flowability.

The following conclusions can be made from the flowability test data:

1. The flowability of the solids can be improved by decreasing the moisture content for a given particle size coal.

2. Increasing the particle size increases the flowability.

3. Open storage of the mulls does not appear to affect the flowability for a specific moisture level.

Henk Colijn stated that material handling systems can be designed to handle and store the mulled product in the 20 to 30% moisture content range, but the high moisture mulls (>30 wt. %) could be handled easily only in larger volume systems (>200 tons).
Table I

Samples of Aging Studies Mulled Coal Samples
Submitted to Hank Colijn for Flowability Testing

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Storage Container</th>
<th>Moisture, Wt.%</th>
<th>Mull Agent Wt. % of Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-1</td>
<td>Open bin</td>
<td>14.0</td>
<td>1</td>
</tr>
<tr>
<td>B-4</td>
<td>Open bin</td>
<td>20.6</td>
<td>2</td>
</tr>
<tr>
<td>B-5</td>
<td>Closed bin</td>
<td>28.5</td>
<td>2</td>
</tr>
<tr>
<td>B-6</td>
<td>Nitrogen inerted bin</td>
<td>26.8</td>
<td>2</td>
</tr>
<tr>
<td>B-7</td>
<td>Shallow exposed tray</td>
<td>2.5</td>
<td>2</td>
</tr>
</tbody>
</table>

Note: All samples were prepared from Upper Elkhorn #3 feedstock coal that was ground to 20 micron average particle size and blended with water to 30 wt. % moisture content.

(1) Moisture content after 74 days storage time.
(2) Mull Agent content of initial sample (time = 0).
Table II

H. Colijn and Assoc.
Basic Hopper Design Criteria

<table>
<thead>
<tr>
<th>Company:</th>
<th>ENERGY INTERNATIONAL CORP.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material:</td>
<td>Mullled Coal After 74 days of storage</td>
</tr>
<tr>
<td>Moisture</td>
<td>14.0%  20.6%  28.5%</td>
</tr>
<tr>
<td>Mull Agent</td>
<td>1.0%  2.0%  2.0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>B 1</th>
<th>B 4</th>
<th>B 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical Arching Dimension for mass-flow:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steady flow:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>round outlet diameter</td>
<td>0.7'</td>
<td>0.8'</td>
<td>1.6'</td>
</tr>
<tr>
<td>slot outlet dimension</td>
<td>0.35'x1.0'</td>
<td>0.4'x1.2'</td>
<td>0.8'x2.4'</td>
</tr>
<tr>
<td>Time Consolidation:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>round outlet diameter</td>
<td>2.1'</td>
<td>2.0'</td>
<td>2.8'</td>
</tr>
<tr>
<td>slot outlet dimension</td>
<td>1'x3'</td>
<td>1'x3'</td>
<td>1.3'x3.9'</td>
</tr>
<tr>
<td>Stable Rathole diameters:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steady flow</td>
<td>1.5'</td>
<td>1.4'</td>
<td>2.5'</td>
</tr>
<tr>
<td>Time Consolidation</td>
<td>3.1'</td>
<td>3.0'</td>
<td>5.5'</td>
</tr>
<tr>
<td>Minimum Hopper slope angles (with horizontal) for mass flow (deg):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cone:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UHMP</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>304-2B stainless steel</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Wedge:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UHMP</td>
<td>90</td>
<td>90</td>
<td>89</td>
</tr>
<tr>
<td>304-2B stainless steel</td>
<td>90</td>
<td>90</td>
<td>83</td>
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<tr>
<td>Self-cleaning hopper and chute angle (with horizontal) (deg):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UHMP</td>
<td>77</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>304-2B stainless steel</td>
<td>78</td>
<td>78</td>
<td>70</td>
</tr>
<tr>
<td>Rusted carbon steel</td>
<td>75</td>
<td>75</td>
<td>80</td>
</tr>
</tbody>
</table>
### Table III

**H. Colijn and Assoc.**

**Basic Hopper Design Criteria**

<table>
<thead>
<tr>
<th>Company:</th>
<th>ENERGY INTERNATIONAL CORP.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material:</td>
<td>Mulled Coal After 74 days of storage</td>
</tr>
<tr>
<td>Moisture</td>
<td>26.8% 2.5%</td>
</tr>
<tr>
<td>Mull Agent</td>
<td>2.0% 2.0%</td>
</tr>
<tr>
<td>Sample No.</td>
<td>B 6  B 7</td>
</tr>
</tbody>
</table>

#### Critical Arching Dimension

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>B 6</th>
<th>B 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>26.8% 2.5%</td>
<td>26.8% 2.5%</td>
</tr>
<tr>
<td>Mull Agent</td>
<td>2.0% 2.0%</td>
<td>2.0% 2.0%</td>
</tr>
<tr>
<td>Critical Arching Dimension for mass-flow:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steady flow:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>round outlet diameter</td>
<td>1.5'</td>
<td>0.7'</td>
</tr>
<tr>
<td>slot outlet dimension</td>
<td>0.7'x2.1'</td>
<td>0.35'x1.0'</td>
</tr>
<tr>
<td>Time Consolidation:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>round outlet diameter</td>
<td>2.5'</td>
<td>1.1'</td>
</tr>
<tr>
<td>slot outlet dimension</td>
<td>1.2'x3.6'</td>
<td>0.5'x1.5'</td>
</tr>
</tbody>
</table>

#### Stable Rathole Diameters:

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>B 6</th>
<th>B 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steady flow</td>
<td>2.2'</td>
<td>1.25'</td>
</tr>
<tr>
<td>Time Consolidation</td>
<td>4.8'</td>
<td>2.2'</td>
</tr>
</tbody>
</table>

#### Minimum Hopper Slope Angles

<table>
<thead>
<tr>
<th>Cone:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>UHMP</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>304-2B stainless steel</td>
<td>85</td>
<td>90</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wedge:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>UHMP</td>
<td>80</td>
<td>79</td>
</tr>
<tr>
<td>304-2B stainless steel</td>
<td>76</td>
<td>79</td>
</tr>
</tbody>
</table>

#### Self-Cleaning Hopper and Chute Angle (with horizontal) (deg):

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>UHMP</td>
<td>65</td>
<td>60</td>
</tr>
<tr>
<td>304-2B stainless steel</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Rusted carbon steel</td>
<td>77</td>
<td>70</td>
</tr>
</tbody>
</table>
Critical Arching Diameter vs Moisture Content

For various Agent Additions

Aged Samples - 74 Days
- 1% agent, open bin
- 2% agent, open bin
- 2% agent, closed bin
- 2% agent, inerted bin
- 2% agent, exposed tray

Moisture Content %
Figure 2

Stable Rathole Diameter vs Moisture Content for Various Agent Additions

Aged Samples - 74 Days
- 1\% agent, open bin
- 2\% agent, open bin
- 2\% agent, closed bin
- 2\% agent, inerted bin
- 2\% agent, exposed tray

Subject: Coal Agent Mixture
Table IV

H. Colijn and Assoc.
Basic Hopper Design Criteria

| Company: | ENERGY INTERNATIONAL CORP. |
| Material: | Wet Coal Fines and Coal-Mull Mix |

| Moisture | 30.3% | 28.0% | 29.6% | 29.6% |
| Mull Agent | 0.0% | 2.0% | 2.0% | 2.0% |

| Sample No. | 005-114-1 | 005-114-A | 005-114-B | 005-90A |
| Critical Arching Dimension for mass-flow: | | | | |
| Steady flow: | | | | |
| round outlet diameter | 5.1' | 2.0' | 0.9' | 1.3' |
| slot outlet dimension | 2.5'x7.5' | 1'x3' | 0.5'x1.5' | 0.6'x1.2' |
| Time Consolidation: | | | | |
| round outlet diameter | 18' | 3.8' | 2.6' | 3.4' |
| slot outlet dimension | 8'x24' | 1.8'x5.4' | 1.2'x3.6' | 1.6'x4.8' |

| Stable rathole diameters: | | | | |
| Steady flow | 25' | 3.9' | 1.8' | 2.8' |
| Time Consolidation | * | 8.0' | 4.8' | 7.0' |

| Minimum hopper slope angles (with horizontal) for mass flow (deg): | | | | |
| Cone: | | | | |
| UHMP | 90 | 90 | 90 | 85 |
| 304-2B stainless steel | 90 | 90 | 90 | 83 |
| Wedge: | | | | |
| UHMP | 80 | 80 | 80 | 75 |
| 304-2B stainless steel | 90 | 90 | 86 | 73 |

| Self-cleaning hopper and chute angle (with horizontal) (deg): | | | | |
| UHMP | 70 | 65 | 65 | 72 |
| 304-2B stainless steel | 83 | 73 | 68 | 68 |
| Rusted carbon steel | 80 | 70 | 70 | 84 |

Average Particle Size - Microns | 20 | 12 | 70 | 20 |

* Too large to compute
2.2 Full System Test

2.2.1 Design Assembly

Six tests were made by EI using the Continuous Processing System (see Figure 3) to evaluate the effect of dispersant concentration for making Coal-Water-Fuel (CWF) from the mulled coal product. The concentration of the dispersant was varied from 0.5 to 2.0 wt. % of dry coal. The C-W-F products were analyzed for viscosity and percent solids (see Table V).

For test 006-TCP-1, the slurry had a higher viscosity at 1 wt. % dispersant due to the higher solids content. The actual coal solids would be approximately 55% after the Mull Agent and dispersant are omitted.

For tests 006-TCP-2 through 6, the water feed was increased as the dispersant was decreased. This was done by keeping the total additive solution amount constant while reducing the additive concentration. The slurry viscosities were very good over the dispersant concentration range of 2.0 to 0.67 wt. % of coal (see tests 006-TCP-2, 3, 4, and 6 on Table V and Figures 4 through 8). The mulled coal feed was not converted to slurry at the 0.5% dispersant level (see test 006-TCP-5).

It was concluded that CWF could be made in the Continuous Processing System at dispersant concentrations of 0.67 to 2.0 wt. % of coal.

2.2.2 Full System Test

Approximately 1.5 tons of mulled coal product were shipped to UNDEERC for atomization testing. The mulled product was tested in a dry, "as is" format and as a CWF with dispersant additive. Preliminary results indicate that for the as-received mulled (+/- 40 wt. %) the residence time seemed to have a significant effect on the atomized particle size up to a particle residence time of +/- .4 seconds but did not change significantly after that time. The particle size of the air-dried mulled (+/- 30 wt. %) was not affected by particle residence time, presumably because there is much less loosely bound moisture which can evaporate during short resident times.

Three CWF’s were created by feeding the mulled coal product through a 2" continuous processor where a dispersant was injected. As the mulled coal was converted to a CWF it was fed directly to a Moyno pump intake and delivered to UNDEERC’s atomization chamber in a continuous process. The atomization characteristics of the three CWF formulations were analyzed at varying dispersant concentrations, air-to-fuel ratios and temperatures. The atomization performance of the three CWF’s were comparable with no significant difference observed between dispersant concentrations of 8.3%, 12.5% and 25%. At high atomizing air-to-fuel ratios, droplet mean diameters were approximately 20-30 um bigger than similar atomization tests using water, with this difference becoming larger at lower atomizing air-to-fuel ratios. The CWF rheology, as determined by both low and high shear viscometers, indicated that the CWF’s peak apparent viscosity did increase with increasing additive loading. All three formulations showed slightly dilatant behavior at low shear rates up to approximately 400 to 800 sec^-1. However, at high shear rates all three fuels exhibited pseudoplastic behavior with very similar apparent viscosities. All three formulations performed well as potential CWF’s for boiler or heat engine applications.
Figure 3
CONTINUOUS PROCESSING SYSTEM FOR
MAKING NULLED COAL AND/OR COAL-WATER-SLURRY

- Hull Agent Feed Burette
- Water Feed Burette
  (used only for making coal-water-slurry)
- Dispersing Agent Feed Burette
- Peristaltic Tubing Pumps
- Accurate Volumetric Feeder
- 2-Inch Continuous Processor
- Product Container
Table V

CONVERSION OF MULLED COAL PRODUCT TO COAL-WATER-SLURRY IN THE
2-INCH CONTINUOUS PROCESSOR AT VARIOUS DISPERSANT CONCENTRATIONS

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Mull Rate</th>
<th>Dispersant Rate</th>
<th>Viscosity</th>
<th>Slurry Product</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1b/hr</td>
<td>cc/min.</td>
<td>conc. %</td>
<td>% of coal</td>
</tr>
<tr>
<td>006-TCP-1</td>
<td>52</td>
<td>7.6</td>
<td>25</td>
<td>1.0</td>
</tr>
<tr>
<td>006-TCP-2</td>
<td>52</td>
<td>15.2</td>
<td>25</td>
<td>2.0</td>
</tr>
<tr>
<td>006-TCP-3</td>
<td>52</td>
<td>15.2</td>
<td>18.75</td>
<td>1.5</td>
</tr>
<tr>
<td>006-TCP-4</td>
<td>52</td>
<td>15.2</td>
<td>12.5</td>
<td>1.0</td>
</tr>
<tr>
<td>006-TCP-5(3)</td>
<td>52</td>
<td>15.2</td>
<td>6.25</td>
<td>0.5</td>
</tr>
<tr>
<td>006-TCP-6</td>
<td>52</td>
<td>15.2</td>
<td>8.33</td>
<td>0.67</td>
</tr>
</tbody>
</table>

---

(1) 25 wt. % in water solution

(2) Includes agent added to coal (6 wt. % of dry coal) plus dispersant

(3) Did not make slurry
Figure 5

SHEAR STRESS VS SHEAR RATE CURVES
FOR TEST 006-TCP-2

\[ \tau = A \cdot \% \cdot \eta [\text{Pa}] \]
\[ D = M \cdot \% \cdot S_0 [\text{s}^1] \]
\[ \eta = \tau / D [\text{Pa} \cdot \text{s}] \]

Date: 10.15.91
No.: 1
Substance:
Temperature: 21
ROTOVISCO RV: 100
System: M-500
Sensor system:
A: 5
M: 2.29
Program time:
\[ l_1 = 0 \]
\[ l_2 = 2 \]
\[ l_3 = 0 \]
Signature: [Signature]

[Diagram of ROTOVISCO flow curve with data points and equation labels]
Figure 7
SHEAR STRESS VS SHEAR RATE CURVES
FOR TEST 006-TCP-4

ROTOVISCO Flow curve

\[ \tau = A \cdot \% \tau \cdot S_t \ [\text{Pa}] \]
\[ D = M \cdot \% D \cdot S_p \ [\text{s}^{-1}] \]
\[ \eta = \tau / D \ [\text{Pa} \cdot \text{s}] \]

Date
No.
Substance
Temperature
ROTOVISCO RV
System
Sensor system
A
M
Program time
1
2
3
Signature

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Figure 8
SHEAR STRESS VS SHEAR RATE CURVES
FOR TEST 006-TCP-6

\[ \tau = A \cdot S_t \cdot S_d [Pa] \]
\[ D = M \cdot \%S \cdot S_d [s^{-1}] \]
\[ \eta = \tau / D [Pa \cdot s] \]

Date: 10.15.87
No.: 1
Substance: 60412-260
Temperature: 21
ROTOSCO RV: 10.0
System: N50.0
Sensor system: M5.14
A: 2.29

Program time:
\[ t_1 = 0 \]
\[ t_2 = 2 \]
\[ t_3 = 0 \]

Signature: 2EM
V. PLANNED ACTIVITIES

Complete results of the atomization studies will be included in the Phase II Report.

VI. SUMMARY

Storage and handling characteristics of the aged mull product continued. The flowability of the mulled product can be improved by decreasing moisture content, and/or increasing the mean particle size. Open air storage of the mulled product does not affect its flowability. Although moisture content is reduced, the product retains the Mulling Agent bonding and attractive free-flowing characteristics.

The atomization characteristics of three CWF formulations were analyzed at varying dispersant concentrations, air-to-fuel ratios and temperatures. All three formulations performed well as potential CWF's for boiler or heat engine applications.
Mr. Anthony E. Mayne, Project Manager
U.S. Department of Energy
Pittsburgh Energy Technology Center
P. O. Box 10940 (MS 922-H)
Pittsburgh, PA 15236

Subject: Contract No. DE-AC22-90PC90167
Quarterly Technical Progress Report

Dear Mr. Mayne:

Enclosed are two Final copies of the Technical Progress Report for the period of October 1, 1991 through December 31, 1991 as required by the subject contract.

Very truly yours,

Burl E. Davis
Project Manager

Enclosures (2)

cc: John R. Columbia (MS 921-165)
END

DATE FILMED

10/20/92