TECHNICAL REPORT
September 1 through November 30, 1994

Project Title: PRODUCTION OF A PELLET FUEL FROM ILLINOIS COAL FINES

DOE Cooperative Agreement Number: DE-FC22-92PC92521 (Year 3)
ICCI Project Number: 94-1/1A-3P
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ABSTRACT

The primary goal of this research is to produce a pellet fuel from low-sulfur Illinois coal fines which could burn with emissions of less than 1.8 lbs SO$_2$/10$^6$ Btu in stoker-fired boilers. The significance of 1.8 lbs SO$_2$/10$^6$ Btu is that in the Chicago (9 counties) and St. Louis (2 counties) metropolitan areas, industrial users of coal currently must comply with this level of emissions. Stokers are an attractive market for pellets because pellets are well-suited for this application and because western coal is not a competitor in the stoker market. Compliance stoker fuels come from locations such as Kentucky and West Virginia and the price for fuels from these locations is high relative to the current price of Illinois coal. This market offers the most attractive near-term economic environment for commercialization of pelletization technology.

For this effort, we will be investigating the use of fines from two Illinois mines which currently mine relatively low-sulfur reserves and that discard their fines fraction (minus 100 mesh). The research will involve investigation of multiple unit operations including column flotation, filtration and pellet production. The end result of the effort will allow for an evaluation of the commercial viability of the approach. This quarter pellet production work commenced and planning for collection and processing of a preparation plant fines fraction is underway.

"U.S. DOE Patent Clearance is NOT required prior to the publication of this document."
EXECUTIVE SUMMARY

Each year in Illinois, approximately 5% of the state's annual production of coal, which represents about 2 million tons of coal fines, is discarded (1). To recover currently discarded coal fines, column flotation is a technology that is developing and beginning to be applied on an industrial scale. Although column flotation has considerable promise as a method of recovering coal fines, the product from the process even after filtering still contains an appreciable amount of moisture.

Wet fines are undesirable from the utility's perspective because in the winter they can freeze causing problems in coal handling; in the summer the fines can dry and be carried off by the wind. Because of these properties, many utilities refuse to accept a significant fraction of wet coal fines with the product they buy. Thus at many mines, practical size enlargement processes are essential for the successful marketing of coal fines. However, no size enlargement process will be applied unless the resulting product can be profitably marketed.

The primary goal of this research is to produce a pellet fuel from low-sulfur Illinois coal fines which could burn with emissions of less than 1.8 lbs SO\textsubscript{2}/10\textsuperscript{6} Btu in stoker-fired boilers. The significance of 1.8 lbs SO\textsubscript{2}/10\textsuperscript{6} Btu is that in the Chicago (9 counties) and St. Louis (2 counties) metropolitan areas, industrial users of coal currently must comply with this level of emissions. Industrial stoker-fired boilers are an attractive market for pellets because pellets are well-suited for this application and because western coal is not a competitor in the stoker market. Compliance stoker fuels come from locations such as Kentucky and West Virginia and the price for fuels from these locations is high relative to the current price of Illinois coal. This market offers the most attractive near-term economic environment for commercialization of pelletization technology.

For this effort, we will be investigating the use of fines from two Illinois mines which currently mine relatively low-sulfur reserves and that discard their fines fractions (minus 100 mesh). The sulfur content of the utility coal from these mines is in the range of 1.2 to 1.6%. Sulfur dioxide levels would range from 2.0 to 2.6 lbs SO\textsubscript{2}/10\textsuperscript{6} Btu. Although the utility coal does not meet the 1.8 lbs SO\textsubscript{2}/10\textsuperscript{6} Btu standard, the fines fractions have the potential to meet or approach this level of emissions because increased amounts of inorganic sulfur (pyrite) can be removed by column flotation.

This research will involve investigation of multiple unit operations including column flotation, filtration and pellet production. The end result of the effort will allow for an evaluation of the commercial viability of the approach. This quarter pellet production work commenced and planning for collection and processing of a preparation plant fines fraction is underway.

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OBJECTIVES

This research will utilize a systems approach to determine the lowest cost method of producing a pellet fuel for stoker-fired boilers which can burn at 1.8 lbs SO_2/10^6 Btu. For this work, fines from AMAX Coal's Wabash mine and Monterey Coal's Hornsby mine will be evaluated. These are relatively low sulfur mines. The effort will involve flotation, filtration and pelletization to generate a process flowsheet for producing the pellet fuels.

To accomplish the project objectives, the following will be studied:

A. Column Flotation- this work will be performed at SIU under the direction of Dr. Rick Honaker. The Wabash fines will be obtained this year as part of an ongoing ICCI funded project. The Monterey sample will be collected during the proposed research.

B. Filtration Testing- filtration testing will be conducted in apparatus simulating belt filtration using sample from column flotation.

C. Pelletization Testing- pellets will be produced by a laboratory roller-and-die pellet mill.

D. Pellet Characterization- pellets will be characterized for physical characteristics such as strength, impact resistance and weatherability. Pellets will also be characterized for chemical characteristics such as the ash fusion temperature, free swelling index and ash composition (to determine the base to acid ratio). The objective is to develop a pellet formulation which results in the optimum physical and chemical properties at the lowest overall pellet cost.

Based on the above information, flowsheets involving flotation, filtration and pelletization will be prepared.

INTRODUCTION AND BACKGROUND

This research represents a continued progression from research to development for the pellet production and combustion research program at the ISGS (2,3,4,5). The proposed research also represents a continuation of four previous ICCI-funded research projects with total ICCI funding of over $348,000 related to the production and combustion of pellet fuels produced from Illinois coal fines. The Army Construction Engineering Research Lab (CERL) has also contributed $40,000 to the research. Two of the previous projects have been funded in the coal cleaning research category, two in combustion. Each has had both pellet production and pellet combustion tasks.

The ISGS program has, from the outset, been multi-process oriented, considering all operations required to recover and successfully market pellets derived from Illinois
coal fines. Operations considered have been: flotation, dewatering, size enlargement and combustion. The recently completed ICCI funded research project also had a market analysis task. The market analysis was for pellets produced from low-sulfur coal fines and was a precursor to this work.

EXPERIMENTAL

Materials

The coal fines used in the pellet production work reported this quarter were from Cyprus-AMAX’s Wabash mine near Keenesburg, Illinois. This mine currently does not have a minus 100 mesh coal recovery circuit. It is estimated that with the use of a developing technology such as column flotation, approximately 150,000 tons/year of cleaned coal could be obtained from this stream.

Recovery of fines from the refuse stream at the Wabash plant could not be facilitated for this research. Rather, the fines were from work performed by Southern Company Services investigating selective agglomeration as a method of cleaning fine coal. This was a DOE funded effort of which Amax R&D was a partner. Amax R&D had ten barrels of sample from the testing of Wabash mine coal which they gave to the ISGS. The coal was in filter cake form and had been ground to approximately 75% passing 150 mesh (106 microns) for the selective agglomeration tests. It is projected that these fines approximate the quality of fines obtainable from the refuse stream in sulfur content and particle size.

The total sulfur content of the fines was 1.4%; the heating value was 12980 Btu/lb. The ash content was 4.7% (all values dry basis).

Calcium hydroxide with a surface area of 20.7 m²/gram was obtained from the Mississippi Lime Company. The corn starch used was obtained from a commercial vendor.

Procedures

Pellet Production: Pellets for this research were prepared at the ISGS Applied Research Laboratory using a laboratory version of a California Pellet Mill (CPM), a roller-and-die extrusion pelleting machine (6).

Physical Characterization of Pellets

Crushing Strength - A Geotest model S2013 was used for strength testing. For each test, a pellet was positioned on its side, a force applied at 0.25 cm/minute and load at failure in lb-f (pounds-force) recorded. For each result reported, six pellets were tested. The high and low values were discarded and the result reported is the average of four tests.
Pellet strength is reported in terms of diametral compression. For pellets to be characterized in this manner, conversion from lb-f to psi is accomplished by use of the following formula.

$$\text{Strength (psi)} = \frac{2 \times \text{Load}}{3.14 \times \text{Diameter} \times \text{Length}}$$

The diameter of each pellet corresponds to the die opening of the CPM. The length of each pellet was measured by use of a digital micrometer. Because a CPM produces pellets with irregular ends, the ends of each pellet were sanded to produce planar surfaces.

The pellets were tested for green strength (strength after formation), cured strength (1 week after production, room temperature conditions) and immersed strength (after water immersion for two hours).

**Ro-Tap Test** - One-half pound of cured pellets was placed on a 4 mesh Tyler screen and mechanically sieved for ten minutes. The weight remaining on the screen was then measured. The Ro-Tap Durability Index (RDI) is:

$$\text{RDI} = \left( \frac{\text{wt. of + 4-mesh fraction}}{\text{wt. of sample}} \right) \times 100$$

**Drop Resistance** - This test determines the pellet’s ability to survive an impact such as would occur if a pellet was dropped off a belt conveyor. The test is conducted by dropping 10 green pellets from 1 and 5 feet onto a concrete floor. Pellets that remain intact are characterized as "pass", pellets that split into a few large pieces are characterized as "pass/fail", and those that break into many small pieces as "fail". The average result is reported for each of the two drop distances.

**Cured Pellet Final Moisture** - Representative cured pellets were selected and placed on a hot plate at 105 °C until weight loss due to evaporation ceased. The percent moisture was then calculated.

**RESULTS AND DISCUSSION**

As mentioned, this research represents a continuation of the ISGS program targeted at fine coal recovery and utilization via pelletization. For recovery and utilization of fines via pelletization, multiple unit operations are involved. Involved in this research are column flotation, filtration and pelletization. To accomplish this in an efficient manner and build on research progress made by the ICCI program, the column flotation research will be performed in cooperation with Dr. Rick Honaker of SIU. Dr. Honaker recently completed a ICCI funded column flotation research project which compared the performance of several commercially available flotation columns on treating Illinois coal fines. This work will utilize the results from that work in determining which column to be used in treating the waste fines fraction in this work.
We are scheduled to obtain a fine refuse sample from Monterey Coal Company's Hornsby mine. Preparations are being made for the collection and processing of that sample. This quarter the principal investigator visited Dr. Honaker at SIU quarter to discuss and plan for this effort.

Originally, it was planned to obtain column flotation filter cake from Dr. Honaker from work he was going to perform on fines from Cyprus AMAX's Wabash mine. This was from work that was to be performed in the recently concluded contract year. It was not possible for Dr. Honaker to obtain this sample. Because of this we will utilize sample we previously obtained from the Wabash mine.

Some testing using these fines was commenced. Pellets were prepared containing 0, 5, 7.5 and 10% calcium hydroxide and 2% corn starch. The results of these tests are reported in Table 1. Pellets containing 7.5 and 10% calcium hydroxide and 2% corn starch were of good quality. The pellets containing 5% calcium hydroxide and no binder were of poorer quality. The numbers reported in Table 1 verify this but are not fully informative. The pellets exiting the machine from these formulations were much shorter than the pellets from the pellets containing 7.5 and 10% calcium hydroxide and 2% corn starch and by observation more fines were produced.

Visual observation of the 7.5 and 10% calcium hydroxide and 2% corn starch pellets was that high quality pellets were produced. For corn starch, the least amount of fines were produced but fines production for the other conditions was not inordinately large. A advantage of using calcium hydroxide was that the green strength was higher than when corn starch was used as a binder.

A disappointing aspect of the test results was the poor response of the pellets to immersion in water (wet strength). Corn starch does not generally provide good weatherability characteristics but previous test using calcium hydroxide as a binder has shown good response to submersion in water(3). This has been attributed to atmospheric carbonation of the calcium hydroxide which formed an exterior cementitious matrix of calcium carbonate. In the results reported this quarter, the calcium hydroxide bound pellets fared the best but still deteriorated significantly. The exact reason for the poorer performance is believed to the high compaction pressure used to form the pellets. The strength of the pellets in this work was significantly higher than in previous work. Too high of compaction pressure can result in horizontal flaws in the pellets that fracture when the pellets are placed under water. Also, at high compaction pressure, the porosity of the pellet may have decreased which could inhibit the carbon dioxide from carbonating any portion of the pellet save the exterior. Pellet weatherability will be a factor further explored this year. Except for this aspect, the corn starch and calcium hydroxide were demonstrated to be effective binders.

Economics and the end use would indicate which is the "best" choice. If no sulfur capture is needed to meet an emissions goal, corn starch is preferable because the heating value of the pellet would be higher and the ash content lower. For the
Wabash fines, sulfur capture of about 20% is required to meet 1.8 lbs SO₂/10⁶ Btu. Thus for these fines, calcium hydroxide would be required for sulfur capture. The results reported this quarter indicate that at least 7.5% calcium hydroxide is required to make a decent quality pellet. Other factors such as the ash fusion temperature of the pellet would influence the amount of calcium hydroxide used to make an acceptable pellet stoker fuel.

For fines from Monterey’s Hornsby mine, the indication is that column flotation can clean the fines to 1.8 lbs SO₂/10⁶ Btu and in this case, corn starch or a similar binder has advantages. How clean these fines can be cleaned will be determined later in this research year.

CONCLUSIONS

The research is progressing well. Information obtained toward the end of last year’s research indicate that pelletization has the greatest chance for commercial application by focusing on the fines from the Monterey Hornsby mine and producing a stoker fuel. The emphasis of the current research will reflect this finding.

Table 1. Results from pellet characterization tests.

<table>
<thead>
<tr>
<th>Pellet Formulation</th>
<th>Green¹ Strength</th>
<th>Cured¹ Strength</th>
<th>Wet² Strength</th>
<th>Ro-Tap³ Durability</th>
<th>Drop⁴ Resistance</th>
<th>Final⁵ Moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Binder</td>
<td>25</td>
<td>23</td>
<td>-</td>
<td>65.8</td>
<td>6P,4P/F</td>
<td>6.0</td>
</tr>
<tr>
<td>5% Ca(OH)₂</td>
<td>30</td>
<td>44</td>
<td>-</td>
<td>85.8</td>
<td>8P,2P/F</td>
<td>9.2</td>
</tr>
<tr>
<td>7.5% Ca(OH)₂</td>
<td>58</td>
<td>121</td>
<td>-</td>
<td>96.4</td>
<td>All pass</td>
<td>6.6</td>
</tr>
<tr>
<td>10% Ca(OH)₂</td>
<td>72</td>
<td>172</td>
<td>-</td>
<td>97.3</td>
<td>All pass</td>
<td>8.9</td>
</tr>
<tr>
<td>2% Corn Starch</td>
<td>30</td>
<td>147</td>
<td>-</td>
<td>98.7</td>
<td>All pass</td>
<td>6.0</td>
</tr>
</tbody>
</table>

¹ Measured strength measured along radial axis, value is for diametral compression and is in lb/in².
² Measured as in ¹ but all pellet conditions failed to hold integrity under water to varying extents, the pellets containing 7.5 and 10% calcium hydroxide held up the best.
³ Percent remaining on a 4 mesh screen after 10 minutes on a Ro-tap.
⁴ All pellets passed a 1 foot drop test, the results reported are for dropping ten pellets on a concrete floor from 5 feet, P represents pass, P/F is pass/fail which represent a pellet which fractures into large pieces on impact.
⁵ Moisture after air curing for one week.
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REFERENCES


PROJECT MANAGEMENT REPORT
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COMMENTS

COSTS BY QUARTER