TECHNICAL REPORT
September 1, 1991 through November 30, 1991

Project Titled: GASIFIER FEED - TAILOR-MADE FROM ILLINOIS COALS

Principal Investigators: Henry P. Ehrlinger, Ill
Illinois State Geological Survey
615 E. Peabody Drive
Champaign, IL 61820
(217) 244-4989

Co-Investigators: John Lytle, David Rapp, Larry Kohlenberger, Kristi K. Brewer, ISGS,
Destec Energy, Williams Technology, and Illinois Coal Association

Project Monitor: Dr. Franklin I. Honea, CRSC

Project Duration: September 1, 1991 to August 31, 1992

ABSTRACT

The main purpose of this project is to produce a feed stock from preparation
plant fines from an Illinois coal that is ideal for a slurry fed, slagging,
entrained-flow coal gasifier. The high sulfur content and high Btu value of
Illinois coals are particularly advantageous in such a gasifier; preliminary
calculations indicate that the increased cost of removing sulfur from the gas
from a high sulfur coal is more than offset by the increased revenue from the
sale of the elemental sulfur; additionally the high Btu Illinois coal
concentrates more energy into the slurry of a given coal to water ratio. The
Btu is higher not only because of the higher Btu value of the coal but also
because Illinois coal requires less water to produce a pumpable slurry than
western coal, i.e., as little as 30 to 35% water may be used for Illinois coal
as compared to approximately 45% for most western coals.

This project will bring the expertise of four organizations together to
perform the various tasks. The Illinois Coal Association will help direct the
project to be the most beneficial to the Illinois coal industry. Destec
Energy, a wholly-owned subsidiary of Dow Chemical Company, will provide
guidelines and test compatibility of the slurries developed for gasification
feedstock. Williams Technologies, Inc. will provide their expertise in long
distance slurry pumping and test selected products for viscosity, pumpability,
and handlability. The Illinois State Geological Survey will study methods for
producing clean coal/water slurries from preparation plant wastes including
the concentration of pyritic sulfur into the coal slurry to increase the
revenue from elemental sulfur produced during gasification operations, and
decrease the pyritic sulfur content of the waste streams. ISGS will also test
the gasification reactivity of the coals.

A meeting was held in Plaquemine, Louisiana on September 19,1991 in which
ISGS, Destec, and Williams Technology defined their individual roles.
Sequentially these are 1) ISGS provides a suite of theoretical products based
upon blends of real plant products, 2) Destec conducts performance analyses on
examples, 3) DOW & ISGS perform TGA analyses on real products from Powder
River (Wy) basin, 4) ISGS prepares specific products for evaluation of
performance analyses, TGA analyses and pumpability. Items 1 & 2 are included
in this report.

This project is funded by the U. S. Department of Energy (METC) and by the
Illinois Department of Energy and Natural Resources as part of their cost-
shared program.

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EXECUTIVE SUMMARY

With the beginnings of coal slurry gasification it was apparent that Illinois coals were natural feedstock candidates. Concentrates of Illinois coal from either a run-of-mine source or coal washing plant waste can be made to exceed 13,000 Btu per pound, have relatively low ash content, and densify to at least 70% solids while remaining pumpable. The sulfur content is an advantage in that elemental sulfur is a commodity by-product with a sales value rather than being an item which must be removed by expensive scrubbing technology which produces a low cost commodity under the best of circumstances, or a voluminous waste under ordinary circumstances.

The purpose of this project is to demonstrate that an ideal coal slurry for coal gasification can be generated from waste streams from coal washing plants within the state of Illinois. This ideal coal slurry will contain over 13,000 Btu/pound, will contain sulfides which can be recovered and sold as elemental sulfur, a low ash content which becomes saleable granulated slag, will be transportable at a high density and have a reactivity which is desirable as a gasifier feed.

The gasification of coal slurry is a technology which has been proven to be sound scientifically and environmentally effective. The integrated gasification-combined cycle power plants have the capability to achieve heat rates as low as 8200 Btu/KWH (42% efficient). Additionally, the IGCC plant is largely waste-free. The products are medium Btu clean gas, steam, inert granulated slag and elemental sulfur. The slag and sulfur are marketable; the sulfur has sold for about $115.00 per ton. Illinois coal slurry meet all of the desirable characteristics needed for gasification: first, it can be concentrated to a grade of greater than 13,000 Btu/pound as compared to about 8500 Btu/pound for western coal, second, it can be densified to over 70% solids and remain pumpable as compared to about 55% for western coal, and third the sulfur is a marketable product in a gasifier rather than a penalty as when Illinois coal is utilized in conventional combustion.

During 1990, Arch of Illinois provided a 400 ton lot of washed No. 6 coal for a test at Destec's Plaquemine, LA, 162 net MW gasifier. The purpose was to determine if Illinois coal presented an agglomeration problem in a commercial gasifier. The results were very satisfactory.

The methods to provide the slurry will be to conduct flotation tests from which Btu recovery, sulfur recovery and ash rejection are the primary goals. Particle size analyses will be designed to meet the most desirable product for combustion in a slurry-fed gasifier, and rheological studies will be conducted to determine the optimum and maximum densities of which coal slurry from Illinois coals may be pumped.

The work plan is to work with the Illinois Coal Association, Destec Energy, and Williams Technology, Inc., to identify an ideal gasifier feed based upon chemical analyses, particle size analysis, pulp density, sulfur content and reactivity. Destec will provide guidelines for this requirement. Given these requirements, Williams Technology will provide targets with regard to pumpability and offer suggestions for reaching the rheological goals. The Illinois Coal Association will serve as liaison in reaching coal companies who
have waste streams from their coal washing plants from which to conduct test work. The ISGS will obtain samples from the selected companies, generate quantities of concentrate to achieve the guidelines for combustibility and pumpability testing.

A meeting was held in Plaquemine, Louisiana on September 19, 1991 in which ISGS, Destec, and Williams Technology defined their individual roles. Sequentially these are 1) ISGS provides a suite of theoretical products based upon blends of real plant products, 2) Destec conducts performance analyses on examples, 3) DOW & ISGS perform TGA analyses on real products from Powder River (Wy) basin, and 4) ISGS prepares specific products for evaluation of performance analyses, TGA analyses and pumpability. Items 1 & 2 are included in this report.

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PROJECT DESCRIPTION

Goals and Objectives

The purpose of this project is to demonstrate that an ideal coal slurry for coal gasification can be generated from waste streams from coal washing plants within the State of Illinois. This ideal coal slurry will contain over 13,000 Btu/pound, will contain sulfides which can be recovered and sold as elemental sulfur, a low ash content which becomes a saleable granulated slag, will be transportable at a high density and have a reactivity which is desirable as a gasifier feed.

Relevance and Significance

The gasification of coal slurry is a technology which has been proven to be sound scientifically and environmentally effective. The integrated gasification-combined cycle power plants have the capability to achieve heat rates as low as 8200 Btu/KWH (42% efficiency) as compared to a good pulverized coal plant with pollution controls to limit both sulfur and nitrogen oxide emissions which might have a fuel-to-electricity heat rate as low as 9300 Btu/KWH (37% efficiency) using hot gas cleaning. Additionally, the IGCC plants are waste free: the products are medium Btu clean gas, steam, inert granulated slag and elemental sulfur. The slag and sulfur are marketable; the sulfur at about $115.00 per ton; a pulverized coal plant generates steam, slag in some form and either SO₂ + NOₓ gases or scrubber sludge neither of which is desirable.

Gasification of coal for the generation of combustible gases which are low in acid rain precursors has been shown to be a very viable. DESTEC Energy at Plaquemine, Louisiana and Texaco's Cool Water, California plants have used several coals to prove their technologies, both having utilized Illinois coals on controlled runs.

The coal industry of Illinois wastes a significant amount of coal as fines from washing plants. A small amount is recovered in three flotation plants and several fine size gravity separation plants treating wash plant waste. An estimate is much more than 4,000,000 tons of recoverable coal is being impounded as waste per year in Illinois. This coal, when concentrated by gravity or flotation approaches the size and chemical requirements for gasification.

The goal of this research is to determine what the optimum chemical analyses, size analyses, and solids consistency of the slurry for gasification should be, then to tailor-make the raw materials available from Illinois coal plants into that product.

One consideration which must be explored when selecting a new or different coal for the design coal is the tendency for agglomeration. During the past year, Arch of Illinois gave DESTEC Energy, Inc. a 400 ton lot of coal which was ground and fired in the second stage of the Plaquemine, Louisiana plant. No adverse effect was noted during that test run.
An additional feature of using Illinois coal is that it densifies and remains pumpable at over 70% solids while the western coal will normalize at about at 54% solids. This means that with Illinois coal concentrate at 13,000 Btu/pound, 33 pounds of water per million Btu must be vaporized while with Western coal at 8500 Btu/pound, 100 pounds of water per million Btu must be vaporized.

Also, while the concentrate from Illinois coal may have to be ground, the cost of a finishing grind is substantially less that grinding a run-of-mine coal as is the case with the material provided by Western coal.

The coal slurry which is considered in the research is capable of being pumped at high solids using existing pipeline technology. For larger tonnages the use of mine to user pipeline is suggested, for smaller users (less than 2,000,000 tons per year) tanker railway cars or tanker barges are suggested. In either case the rheology of selected samples will be studied.

The short term goal of this project is to provide coal companies - gasifiers users - and transportation specialists with a document which defines the problems of manufacture, utilization, and transport of an idealized tailor-made gasification fuel.

The long term goal of course is that this work will lead to a stable market for Illinois coal with a natural or even augmented sulfur content while complying with clean air standards in a more competitive manner.

Potential Importance

Because of recent enactment of the Clean Air Act, much of Illinois' high Btu-high sulfur coal market is in jeopardy. Three alternatives are available to the user of coal. First, substitute western low Btu coal for Illinois coal which will meet the mandated sulfur to energy ratios. This can be done either by total substitution, or by blending to a desired endpoint. Second, the installation of scrubbers in their several forms. Lastly, adapting power plant practice to take advantage of the high-Btu, high-sulfur coal feedstock available with Illinois coal. Illinois coal has ideal properties for integrated gasification combined cycle which produces power at 42% efficiency and produces no appreciable pollutants.

The advantages of Illinois coal over western coal are as follows: Illinois' coal has high sulfur which increases the recovery of elemental sulfur; Illinois' coal has high Btu and requires less water to slurry which increases the efficiency of IGCC; Illinois' coal is near high population centers and requires less cost and fuel to transport.

The concept of this project is to provide an idealized slurry feed for gasifier utilization which achieves the following results: 1) is made from a beneficiated wash plant waste product which can be made from existing mined coal, reducing mining cost on a per ton basis to the mining company, 2) the pyritic sulfur content for the coal can be concentrated into the gasifier feed reducing the amount impounded which ultimately will oxidize in the tailings ponds to acidify the area, and which is profitable as a sulfur producer, 3) the quality of the gasifier feed will be optimized with respect to volatile matter, Btu, sulfur content and ash content to the highest combustible content
compatible with the gasifier, and 4) the preferred concentrate will be
densified by thickening or centrifuge to provide the highest density,
pumpable, rheologically correct slurry to maximize the fixed conditions of the
gasifier both technically and cost wise.

Western coals with their 8500 Btu content will densify to 53-56% solids
whereas the 13,000 plus Btu concentrate which can be made from waste streams
from Illinois coal can be densified to over 70% while remaining very pumpable.
The fuel therefore would be used to generate gas and steam rather than to
vaporize unnecessary liquid.

Specific Goals

The purpose of this research is to develop a coal slurry from waste streams
using Illinois coal that is ideally suited for a gasification feed. The
principle items to be studied are 1) methods of concentrating pyrite and
decreasing other ash forming minerals into a high grade gasification feed
using froth flotation and gravity separation techniques; 2) chemical and
particle size analyses of coal slurries; 3) determination of how that slurry
can be densified and to what degree of densification is optimum from the
pumpability and combustibility analyses; and 4) reactivity studies.
TECHNICAL PROSPECTUS

Research Approach

Task 1. Planning Discussions

Discussion with co-investigators to determine optimum conditions with regard to: 1) physical and chemical properties of the coal; 2) ideal density to satisfy both combustion and rheological factors; 3) desired sulfur content to operate the sulfur recovery unit under its most efficient conditions; 4) a review of conditions which will determine transportation methods, i.e., tank truck, rail tank car, or pipeline for coal slurry or truck vs. rail car for coal filter or centrifuge cake. (All investigators)

Task 2. Sample Acquisition

Sampling of waste stream products from selected plants within the state to appraise their candidacy for test work. Sampling existing flotation and gravity concentration operations within the state of Illinois as a reference toward manufacture of ideal or tailor-made gasifier feed stock. (Illinois Coal Association and ISGS)

Task 3. Sample Preparation

Generation of test size lots required for combustion and/or rheological or filter testing. (ISGS)

Task 4. Gasification Reactivity Testing

Gasification reactivity testing in ambient and high pressure TGA apparatus to obtain gasification data under a limited variety of conditions from which samples have been produced in Task 3. (ISGS and DESTEC)

Task 5. Rheological Testing

Selected samples from Task 3 will be densified, stabilized and measured by appropriate means to determine pumpability. (Williams Technology)

Task 6. Summary Discussions

A final meeting to recommend a product for commercial testing. While not in the scope of this proposal, the long term goal is to provide the definition of a product which can be commercially manufactured by one or more coal operations for continuous testing or as a plant feed for a commercial sized slurry fed gasifier. (All investigators)

Task 7. QA/QC Guidelines on Analytical Procedures and Results

QA/QC guideline and procedures will be established during the first quarter and a plan will be filed at the ISGS.
Task 8. Project Management and Technical Reports

The ISGS will prepare the reports to the CRSC from the input from all of the participants.

SUMMARY AND CONCLUSIONS

During this reporting period three major activities occurred. 1) A meeting was held at Plaquemine, Louisiana, the site of Destec Energy's LGTI Unit. In attendance were representatives of Destec, LGTI, Williams Technology, ISGS and the project monitor from CRSC. The Goals of the project were defined and the impact and opportunities for gasification, Illinois coal production, and pipeline transport of coal slurry were discussed. 2) ISGS provided to Destec a suite of possible feedstocks for Destec appraisal by a performance analyses screening procedure (Table 1), and 3) Destec completed this analyses and suggested recommended targets for ISGS Production of test quantities of idealized gasifier fuels (Tables 2a and b).

Additionally, Dr. Albert Tsang of DOW/LGTI visited ISGS to discuss analyses by pressurized TGA so that all concerned would have the same understanding of procedure and interpretation of results of this analytical procedure. Additionally he visited an operating coal production plant with the P.I. in southern Illinois.

Attached are Table 1, "Chemical Analyses of Selected Gasifier Slurries", Table 2a "Results of Destec Gasification Performance Predictions of Washing Plant Tailings" parts a and b which show the concentrate from a typical coal washing plant waste is a viable gasification feed stock when slurried at 63% solids.
Table 1.
CHEMICAL ANALYSES OF SELECTED GASIFIER FEED SLURRYS

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash</td>
<td>8.3</td>
<td>6.8</td>
<td>15.7</td>
<td>11.6</td>
<td>11.5</td>
<td>11.6</td>
<td>11.4</td>
</tr>
<tr>
<td>T/S</td>
<td>2.19</td>
<td>2.58</td>
<td>2.77</td>
<td>2.42</td>
<td>5.08</td>
<td>3.79</td>
<td>7.43</td>
</tr>
<tr>
<td>Py/S</td>
<td>0.83</td>
<td>0.83</td>
<td>1.23</td>
<td>0.81</td>
<td>3.57</td>
<td>2.23</td>
<td>6.00</td>
</tr>
<tr>
<td>O/S</td>
<td>1.36</td>
<td>1.75</td>
<td>1.54</td>
<td>1.61</td>
<td>1.51</td>
<td>1.56</td>
<td>1.43</td>
</tr>
<tr>
<td>BTU</td>
<td>13420</td>
<td>13598</td>
<td>12250</td>
<td>13150</td>
<td>12384</td>
<td>12755</td>
<td>11706</td>
</tr>
<tr>
<td>VM</td>
<td>30.4</td>
<td>30.8</td>
<td>27.7</td>
<td>29.8</td>
<td>28.1</td>
<td>28.9</td>
<td>26.5</td>
</tr>
<tr>
<td>FC</td>
<td>61.3</td>
<td>62.1</td>
<td>56.0</td>
<td>60.1</td>
<td>56.6</td>
<td>58.3</td>
<td>53.5</td>
</tr>
<tr>
<td>H</td>
<td>4.41</td>
<td>4.47</td>
<td>4.03</td>
<td>4.32</td>
<td>4.07</td>
<td>4.19</td>
<td>3.85</td>
</tr>
<tr>
<td>C</td>
<td>77.61</td>
<td>78.64</td>
<td>70.84</td>
<td>76.05</td>
<td>71.61</td>
<td>73.76</td>
<td>67.70</td>
</tr>
<tr>
<td>N</td>
<td>1.11</td>
<td>1.12</td>
<td>1.01</td>
<td>1.09</td>
<td>1.02</td>
<td>1.05</td>
<td>0.97</td>
</tr>
<tr>
<td>O*</td>
<td>6.40</td>
<td>6.39</td>
<td>5.55</td>
<td>4.52</td>
<td>6.72</td>
<td>5.61</td>
<td>8.65</td>
</tr>
</tbody>
</table>

* Oxygen by difference. Since FE is not taken into account, the oxygen contents in samples "E" & "G" are artificially high. Sample "A" is a true analysis of a sample, "B" through "G" are calculated values but probably realistic of what can be produced.

- Products A & B are flotation concentrates made from -100 mesh washing plant waste.
- Products C & D are flotation concentrates combined with the coal fraction from the spiral separation of -28 mesh x 100 mesh waste from coal washing.
- Products E, F & G are combinations of "D" above, enriched with varying quantities of high-grade pyrite concentrate from the spirals.
Table 2a.

**RESULTS OF DESTEC GASIFICATION PERFORMANCE PREDICTIONS OF WASHING PLANT "TAILINGS"**

The predicted gasification performance of the baseline ("A") wash plant "tailings" are complete. The ultimate analysis on a dry basis, provided by the Illinois State Geological Survey (ISGS) for a typical flotation concentrate, produced from -100 mesh washing plant waste is tabulated below:

<table>
<thead>
<tr>
<th></th>
<th>Ash</th>
<th>T/S</th>
<th>Py/S</th>
<th>O/S</th>
<th>BTU</th>
<th>VM</th>
<th>FC</th>
<th>N</th>
<th>C</th>
<th>N</th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;A&quot; Wash</td>
<td>8.3</td>
<td>2.19</td>
<td>0.83</td>
<td>1.36</td>
<td>13,420</td>
<td>30.4</td>
<td>61.3</td>
<td>4.41</td>
<td>77.61</td>
<td>1.11</td>
<td>6.40</td>
</tr>
<tr>
<td>Plant Waste</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capt. Mine</td>
<td>12.54</td>
<td>3.59</td>
<td></td>
<td></td>
<td>17,441</td>
<td>39.32</td>
<td>48.14</td>
<td>4.86</td>
<td>69.76</td>
<td>1.47</td>
<td>7.79</td>
</tr>
</tbody>
</table>

Also included in the tabulation is the ultimate analysis used for the Illinois No. 6 coal tested at LGTI (2nd stage) from the Captain Mine.

Results of the gasification performance predictions for these two Illinois No. 6 coals are compared in the following table on page 2. Slurry concentration for both samples was taken as 65%. A GE 7F gas turbine was used in the evaluation.
### Table 2b.

<table>
<thead>
<tr>
<th></th>
<th>COAL-</th>
<th>CAPTAIN MINE</th>
<th>WASTE CONC. &quot;A&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry, TPD</td>
<td>2,296.3</td>
<td>2,044.6</td>
<td></td>
</tr>
<tr>
<td>As Received, TPD</td>
<td>2,870.3</td>
<td>2,555.7</td>
<td></td>
</tr>
<tr>
<td>Oxygen Required (95%), TPD</td>
<td>2,206.8</td>
<td>2,033.1</td>
<td></td>
</tr>
<tr>
<td>Slag Product, TPD</td>
<td>339.8</td>
<td>203.6</td>
<td></td>
</tr>
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</table>

**SYNGAS PROPERTIES**

<table>
<thead>
<tr>
<th></th>
<th>Moisture Content, Vol. %</th>
<th>24.97</th>
<th>24.30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Composition, Vol. %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>H₂</strong></td>
<td>33.19</td>
<td>31.14</td>
<td></td>
</tr>
<tr>
<td><strong>CO</strong></td>
<td>50.09</td>
<td>53.25</td>
<td></td>
</tr>
<tr>
<td><strong>CO₂</strong></td>
<td>11.53</td>
<td>10.12</td>
<td></td>
</tr>
<tr>
<td><strong>CH₄</strong></td>
<td>2.21</td>
<td>2.73</td>
<td></td>
</tr>
<tr>
<td><strong>N₂</strong></td>
<td>1.72</td>
<td>1.55</td>
<td></td>
</tr>
<tr>
<td>Ar + Other</td>
<td>1.25</td>
<td>1.20</td>
<td></td>
</tr>
</tbody>
</table>

**HHV: (Btu/Scf)**

<table>
<thead>
<tr>
<th></th>
<th>Wet</th>
<th>218.0</th>
<th>226.5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry</td>
<td>290.5</td>
<td>299.3</td>
</tr>
</tbody>
</table>

**NET POWER (kW)**

|                | 270.2 | 263.3 |

**HEAT RATE, BTU/KWHR (HHV)**

|                | 8811.5 | 8490.2 |

### SUMMARY

The gasification performance evaluation of the "A" flotation concentrates, from -100 mesh washing plant waste are shown to compare very favorably with the predicted gasification performance of the Illinois No. 6 "Captain Mine" coal. Therefore, it is concluded that the "A" baseline material presently being "wasted" from wash plant operations in southwestern Illinois is a viable gasification feedstock when slurried at 63% solids.
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Illinois State Geological Survey
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(217) 244-4989

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