TECHNICAL REPORT

March 1, 1992 through May 31, 1992

Project Titled: **GASIFIER FEED - TAILOR-MADE FROM ILLINOIS COALS****DE-FG 22-91PC91334**

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Project Monitor:

Franklin I. Honea, CRSC

Project Duration:

September 1, 1991 to August 31, 1992

ABSTRACT

The main purpose of this project is to produce a feedstock 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 30-35% 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 Technology 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.

As reported earlier, a variety of possible samples of coal have been analyzed and the gasification performance evaluation reported. Additionally, commercial sized samples of -28 mesh x 100 mesh coal -100 x 0 coal were subjected to pumpability testing. Neither the coarse product nor the fine product by themselves proved to be good candidates for trouble free pumping, but the mix of the two proved to be a very acceptable product which would be pumpable over long distances at high density without the use of additives.

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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/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 will have a reactivity which is desirable as a gasifier feed.

The gasification of coal slurry is a technology which has been proven to be scientifically sound 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 \$100.00 per ton. Illinois coal slurries meet all of the desirable characteristics needed for gasification: 1) it can be concentrated to a grade of greater than 13,000 Btu/pound as compared to about 8500 Btu/pound for western coal, 2) it can be densified to over 70% solids and remain pumpable as compared to about 55% for western coal, and 3) 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 either an agglomeration problem or a soot formation problem in a commercial gasifier. The results were very satisfactory; neither concern proved to be a problem.

The methods to provide the slurry were to conduct flotation tests from which Btu recovery, sulfur recovery, and ash rejection were 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 were to be conducted to determine the optimum and maximum densities of which coal slurry from Illinois coals may be pumped.

The work plan was to work with the Illinois Coal Association, DESTEC Energy, and Williams Technology, to identify an ideal gasifier feed based

upon chemical analyses, particle size analysis, pulp density, sulfur content, and reactivity. DESTEC has provided guidelines for this requirement. Given these requirements, Williams Technology provided targets with regard to pumpability and offer suggestions for reaching the rheological goals. The Illinois Coal Association served as liaison in reaching coal companies who have waste streams from their coal washing plants from which to conduct test work. The ISGS has obtained samples from the selected companies, and has generated quantities of concentrate to achieve the guidelines for combustibility and pumpability testing.

A meeting was held in Plaquemine, LA, 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 Illinois coal products, and 4) ISGS prepares specific products for evaluation of performance analyses, TGA analyses, and pumpability.

Plant flotation tests have been conducted in which both the fine waste streams from Springfield and Herrin seam coals have been concentrated from about 9000-6000 Btu/pound to over 13,000 Btu/pound with recoveries of energy units of over 90% accompanied by a reduction in ash forming minerals to 8-10%. This product, along with gravity concentrates, have been tested for pumpability.

Exploration tests on reactivity have been conducted on several samples. A relationship has been established to do additional work in this area during the next reporting period.

A project review meeting was held on February 28, 1992, at Williams Technology's offices and pumping facility in Arizona, to review present work, give guidelines on future work, and to visit the Black Mesa pipeline installation. Testing of typical samples of flotation concentrate and gravity concentrates, and a weighted composite of the two products was conducted following the proven Black Mesa Pipeline Company's practice. Neither the flotation concentrate by itself, nor the -28 mesh x 100 gravity coal concentrate by itself met acceptable pumping standards; however, when the two products were blended 50-50 which is about the weight ratio they would be produced in a typical waste recovery plant, they proved to be nearly ideal, having no settling problems in pumping, could be pumped at about 63% solids, required no costly additives while the slurry viscosity was near 190 centipoise. These conditions are very similar to those normally encountered in the Black Mesa system.

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This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

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 will have a reactivity which is desirable as a gasifier 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.

Introductions and Background

The gasification of coal slurry is a technology which has been proven to be scientifically sound 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 \$100.00 per ton. A pulverized coal plant generates steam slag in some form and either SO_x + NO_x gases or scrubber sludge, neither of which is desirable. The CO_2 generation is a function of plant efficiency thus IGCC would produce significantly less CO_2 for the same amount of power generation.

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, LA, and Texaco's Cool Water, CA, 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 10,000,000 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. Examples of recent flotation tests are found in Tables 3 and 4.

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 and soot formation. During 1990, 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, LA, 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 than 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, gasifier 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.

Because of the 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, and 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.

Experimental Procedures

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; and 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 feedstock. (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.

RESULTS AND DISCUSSION

During the first quarter, the goals of the project were discussed and assigned to the several investigators. ISGS provided DESTEC with a suite of possible feedstocks for appraisal by performance analyses screening which was completed and reported. (Tables 1, 2a, and 2b are attached.)

The heat rate (Btu/KWH) of the coal concentrate generated during the program is lower than that derived from either local steam coal or western coal. This brings power plant efficiency from 33-35% to over 40%.

During the second quarter, ISGS produced plant size quantities of concentrates to be used for pumpability testing while conducting test work on a companion project. These have been submitted to Williams Technology for a determination of the pumpability of the fine (-100 mesh) product, the coarse (-14 mesh x 100 mesh) product, and a blend of the two. The test report indicates that the blend of the coarse and fine products is very pumpable (Table 3).

A meeting was held at Williams Technology's test facility and plant on February 28, 1992. Representatives of DESTEC, Williams Technology, ISGS, and CRSC were present. The meeting was to review present work, give guidelines on future work, and to visit the Black Mesa pipeline installation.

CONCLUSIONS AND RECOMMENDATIONS

Using the flotation concentrate made from the waste streams of conventional coal washing plants, a natural feed for slurry fed, slagging,

entrained flow gasification is produced. A product in excess of 13,000 Btu/pound, less than 9% ash and containing over 90% of the energy content of the waste stream, is routinely reported.

This material has a lower heat rate (Btu/KWH) than regular steam coal, or western coal. Heat rate is inversely proportional to plant efficiency. Instead of having 33-35% thermal efficiency normal to many power plants, flotation concentrate fed to an IGCC unit will provide near 42-43% efficiency, and provide a clean and efficient use for Illinois coal.

The coal flotation concentrate is a slurry, and the IGCC technology uses a slurry as feed. This saves the cost of more complete dewatering. The gas stream is treated for sulfur removal as elemental sulfur which is a revenue commodity rather than a waste product requiring disposal cost. Thus, the presence of sulfur in the coal is an economic advantage. IGCC is the cleanest and most efficient way to use coal and Illinois coal with its high sulfur content is an ideal feedstock. Thus, Illinois should push the development of IGCC as quickly as possible to preserve Illinois coal markets.

Table 1.

CHEMICAL ANALYSES OF
SELECTED GASIFIER FEED SLURRIES

	A	B	C	D	E	F	G
Ash	8.30	6.80	15.70	11.60	11.50	11.60	11.40
T/S	2.19	2.58	2.77	2.42	5.08	3.79	7.43
Py/S	0.83	0.83	1.23	0.81	3.57	2.23	6.00
O/S	1.36	1.75	1.54	1.61	1.51	1.56	1.43
Btu	13420	13598	12250	13150	12384	12755	11706
VM	30.40	30.80	27.70	29.80	28.10	28.90	26.50
FC	61.30	62.10	56.00	60.10	56.60	58.30	53.50
H	4.41	4.47	4.03	4.32	4.07	4.19	3.85
C	77.61	78.64	70.84	76.05	71.61	73.76	67.70
N	1.11	1.12	1.01	1.09	1.02	1.05	0.97
O*	6.40	6.39	5.65	4.52	6.72	5.61	8.65

- * 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. Samples "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:

	Ash	T/S	Py/S	O/S	BTU	VM %	FC %	H %	C %	N %	O %
"A" Wash Plant Waste	8.3	2.19	0.83	1.36	13,420	30.4	61.3	4.41	77.61	1.11	6.40
Capt. Mine	12.54	3.59	---	---	12,441	39.32	48.14	4.86	69.76	1.47	7.79

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 prediction for these two Illinois No. 6 coals are compared in the following table (2b). Slurry concentration for both samples was taken as 65%. A GE 7F gas turbine was used in the evaluation.

Table 2b.

COAL	CAPTAIN MINE	"WASTE" CONC. "A"
Dry, TPD	2,296.3	2,044.6
As Received, TPD	2,870.3	2,555.7
Oxygen Required (95%), TPD	2,206.8	2,033.1
Slag Product, TPD	339.8	203.6
SYNGAS PROPERTIES		
Moisture Content, Vol. %	24.97	24.30
Dry Composition, Vol. %		
H ₂	33.19	31.14
CO	50.09	53.25
CO ₂	11.53	10.12
CH ₄	2.21	2.73
N ₂	1.72	1.55
Ar+ Other	1.25	1.20
HHV: (Btu/Scf)		
Wet	218.0	226.5
Dry	290.5	299.3
NET POWER (MW)	270.2	269.3
HEAT RATE, BTU/KWHR (HHV)	8,811.5	8,490.2

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.

The gasification performance evaluation is a process developed by Destec for comparing fuels at their operating facility at Plaquemine, Louisiana. The formula for this analysis is both proprietary and site specific.

PROJECT MANAGEMENT REPORT

March 1, 1992 through May 31, 1992

Project Title: GASIFIER FEED - TAILOR-MADE FROM ILLINOIS COAL

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SCHEDULE OF PROJECT MILESTONES

Milestones:

- A. Planning Discussions (Task 1)
- B. Sample Acquisition and Product Preparation (Task 2 and 3)
- C. Gasification Reactivity Testing (Task 4)
- D. Rheological Testing (Task 5)
- E. Summary Discussions (Task 6)
- F. Quality Analyses/Quality Control (Task 7)
- G. Quarterly and final reports

END

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