

DOE/PC/92521--T273

TECHNICAL REPORT

September 1, 1995, through November 30, 1995

Project Title: **INNOVATIVE PROCESS FOR CONCENTRATION OF FINE PARTICLE COAL SLURRIES**

DOE Cooperative Agreement Number: DE-FC22-92PC92521 (year 4)
ICCI Project Number: 95-1/5.2A-3P
Principal Investigator: Marcus Rajchel, Williams Technologies, Inc.
Clarke Rajchel Engineering Joint Venture
(WTI/CRE-JV)
Other Investigators: Henry P. Ehrlinger, Consultant; Dan Harnett
(WTI); A. Fonseca, Consol; R. Maurer,
Destec Energy
Project Manager: Dr. K. Ho, ICCI

ABSTRACT

Williams Technologies, Inc. and Clarke Rajchel Engineering are developing a technology (patent pending) to produce high quality coal water slurries from preparation plant fine coal streams. The WTI/CRE technology uses the novel implementation of high-shear cross-flow separation which replaces and enhances conventional thickening processes by surpassing normally achievable solids loadings. Dilute ultra-fine (minus 100 mesh) solids slurries can be concentrated to greater than 60 weight percent and re-mixed, as required, with de-watered coarser fractions to produce pumpable, heavily loaded coal slurries. The permeate (filtrate) resulting from this process has been demonstrated to be crystal clear and totally free of suspended solids.

The primary objective of this project is to demonstrate the WTI/CRE coal slurry production process technology at the pilot scale. The technology will enable Illinois coal producers and users to realize significant cost and environmental benefits both by eliminating fine coal waste disposal problems and producing an IGCC fuel to produce power which meets all foreseeable clean air standards. In addition, testing is also directed at concentrating mine tailings material to produce a tailings paste which can be mine-back-filled and thus eliminate the need for tailings ponds.

This reporting period, September 1, 1995 through November 30, 1995, marked the inception of this project. During this period Task #1, Procurement and Set-Up, was completed. The pilot plant apparatus was constructed at the SIU Coal Research Center in Carterville, Illinois. All equipment and feedstock were received at the site.

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

EXECUTIVE SUMMARY

It has been estimated that the Illinois coal industry discards over 4,000,000 tons of coal fines into tailings impoundments each year. Much of this coal is of fairly high quality due to a high degree of inherent natural mineral liberation. As such, this coal might be considered "pre-prepared" for a number of various fine coal beneficiation processes. Also, it does not require milling for feed to such processes as IGCC or co-firing with pulverized coal in utility boilers. Coal fines most often go under-utilized because of inadequate means of de-watering and because of associated filter-cake handling problems. Williams Technologies, Inc. and Clarke Rajchel Engineering are developing a technology (patent pending) to produce high quality coal water slurries from preparation plant fine coal streams.

In this engineering study, recovered fine coal from Consol Inc.'s Rend Lake Preparation Plant will be concentrated with the WTI/CRE process and prepared as a 60-70 weight percent solids slurry fuel. Fines from the Rend Lake fine coal cleaning circuit which have been cleaned (via flotation) to less than 6.5% ash and 1.3% sulfur and with a nominal concentration of 15 weight percent, and of a size suitable for feed to Destec's slurry fed coal gasification plant will be utilized in the demonstration.

The primary objective of this project is to demonstrate the WTI/CRE coal slurry production process technology at a pilot plant scale. The technology will enable Illinois coal producers and users to realize significant cost and environmental benefits both by eliminating fine coal waste disposal problems while producing an IGCC fuel which will meet all foreseeable clean air standards. By-products (ammonia and elemental sulfur) of the gasification process both are important to the economy of the State of Illinois. In addition, testing is also directed at concentrating mine tailings material to produce a tailings paste which can be mine-back-filled and thus eliminate the need for tailings ponds.

Central to the WTI/CRE process technology is the novel implementation of high-shear cross-flow separation which replaces and enhances the thickening process by surpassing normally achievable solids loadings. Dilute ultra-fine (minus 100 mesh) solids slurries can be concentrated to greater than 60 weight percent and re-mixed, as required, with de-watered coarser fractions to produce pumpable, heavily loaded coal slurries. The permeate (filtrate) resulting from this process has been demonstrated to be crystal clear and totally free of suspended solids.

The State of Illinois holds all of the energy resources required to meet its energy needs into the next century and beyond and can do so with economical and environmentally acceptable technologies currently available. It is recognized that coal gasification represents the best means for utilizing high-sulfur Illinois coals in an environmentally friendly manner. IGCC plants are inherently more efficient than conventional combustion technologies. With pollution controls, conventional power plants achieve only 32-35% efficiencies while IGCC plants can demonstrate 42% and higher fuel-to-electricity efficiencies.

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Conventional flue-gas-desulfurization (FGD) technologies generate large amounts of calcium sulfate wastes which present an additional disposal liability. With gasification, the SO_x and NO_x precursors are converted to byproducts which are or can be made salable. Sulfur species in gasification are reduced to hydrogen sulfide which can be oxidized to elemental sulfur by any of number of sour gas treatment technologies. The high sulfur content of Illinois coal, in this case, becomes an asset rather than a liability. Nitrogen species are also reduced in the gasification environment. In this case, ammonia is the by-product. In the highly agricultural state of Illinois, market conditions could make it favorable to alter processing conditions such that additional ammonia is generated

Coupled with the improvement in combustion efficiency of IGCC, all barriers to the usage of Illinois coals are eliminated. The need to import low-rank coals from western states, with the concomitant storage and handling problems can be reduced or eliminated. Gasification of Illinois coal remains the only certain path to maintaining all of the economic and environmental benefits of a healthy Illinois coal mining industry over time.

The project team has been assembled to present a "total technology approach to provide a package which addresses the interests of the Illinois power generation industry. The project team includes the proposers, Williams Technologies, Inc/Clarke Rajchel Engineering Joint Venture; Consol, Inc coal company of Illinois; Destec Energy, Inc., and Southern Illinois University. An example of the target interest is represented by the planned Franklin County Industrial Park which has shown interest in providing an environmentally friendly supply of power to their users while maintaining the support of the Illinois Coal industry.

The specific goals of the effort are:

- o To improve the overall plant efficiency of Illinois coal preparation facilities and thus reduce overall costs by reducing wastes and lowering plant capital and operating costs.
- o To provide the slurry production technology to produce a fuel suitable for the Destec slurry fed gasification process using recovered preparation plant fines.
- o To demonstrate a process which will reduce or eliminate the need for large tailings impoundments.
- o To gather data which will provide the engineering information required to design a demonstration-scale process facility for the production of coal-water slurry fuels from preparation plant fines which is suitable for the Destec slurry fed IGCC process.
- o To produce a cleaner fuel by taking advantage of the natural mineral liberation associated with preparation plant coal fines.

- o To demonstrate the utility of the technology in producing a tailings paste which is suitable for mine back-filling.

Additionally, during the project, efforts will be made to generate interest within the Illinois conventional coal-fired power generation industry to utilize coal slurry produced by the WTI/CRE technology as a re-burn fuel for NO_x abatement.

The specific tasks involved in achieving these goals include:

- a. Ambient Temperature Tests
This testing will have the goals both equipment shake-down and base-line testing. Slurries will be concentrated to 60 weight percent solids or better and performance data measured.
- b. Elevated Temperature Tests
Advantage of reduction in slurry carrier fluid viscosity will be tested to demonstrate substantial improvements in water removal rates. Slurries will be concentrated and performance data taken.
- c. Optimum Vibrational Frequency Tests and Feed Pulse
Optimum shearing frequency will be investigated for the pilot scale separator. Also, the effects of disturbing the fines bed have not been quantified and will be tested here by implementing periodic feed pressure pulsation.
- d. Process Control Strategy Tests
Optimal operations in a commercial plant will most likely include some level of instrumentation which will aid in start-up, shut-down, normal run-mode operation, and product quality control.
- e. Long Duration Testing
In these tests, Rend Lake Flotation Concentrate feed slurry will be placed in an agitated feed tank and continuously concentrated in a closed loop for a period of one to two weeks.
- f. Tailings Paste Production
Tailings material will be concentrated to determine whether a paste suitable for mine back-fill can be produced or if the material can be concentrated such that a better feed for belt filtration and subsequent tailings pile stacking can be achieved.
- g. Destec Slurry Fuel Evaluation
Preparation of fuel samples will be performed in consultation with Destec Energy, Inc. Destec will perform a heat-rate analysis and gasifier acceptability of various samples taken from each test in Tasks #2, #3 and #6.

This quarter, September 1, 1995 through November 30, 1995, marked the inception of the project. During this period Task #1, Procurement and Set-Up, was completed. The pilot plant apparatus was constructed at the SIU Coal Research Center in Carterville, Illinois. All equipment and feedstock were received at the site.

During plant shake down, it was verified that:

1. Slurry can be circulated through the system and water can be separated and equilibrium flow and system pressure conditions can be satisfactorily maintained.
2. Feed slurry heating and heat recovery system are functional and target feed slurry temperature can be controlled.

During plant shake-down several engineering issues arose and were addressed. The impact of these solutions will be determined during testing which will take place in December, 1995 and January, 1996 and will be reported in the 1st Quarter 1996 Report.

OBJECTIVES

The overall objective of this program is to demonstrate the fine particle slurry dewatering process being developed by the Williams Technologies, Inc.-Clarke Rajchel Engineering Joint Venture (WTI/CRE) through construction and operation of a nominal 5 gallon per minute pilot plant.

The specific objectives of this research include:

1. Demonstration of an inexpensive high shear cross-flow membrane separation process for cost effective production of multiple use coal-water slurry (CWS) fuels/IGCC feeds. The key to the success of this program is the proof that increased loading, improved rheology, and best stability is possible by incorporating the essential elements of the CRE process into slurry production practice.

The focus of this project will be the application of the technology for the conversion of low value fine-coal/coal-waste streams to high value fuel using fine coal from existing Illinois coal preparation facilities.

2. Information gained from this program will provide the engineering data to design a fully automated Coal-Water Slurry production plant which would be demonstrated in future industry-led programs. One near-term application is to provide power for a planned industrial park in Franklin County, Illinois. The "total technology" package, including locally supplied coal from Consol, fuel preparation technology by WTI/CRE, and gasification technology supplied by Destec Energy.
3. Prepare fuels for analysis by an IGCC manufacturer (Destec Energy) and determine both the suitability of the fuel for gasification feed and computation of unit power production costs.
4. The technology may be applied to help reduce costs associated with coal-waste/mine-tailings disposal. In this program, typical tailings material will be processed to determine if a suitable tailings paste can be prepared which can be mine-back-filled. The advantages include smaller tailings disposal area footprint by obviating the need for tailings ponds. Proof that costs for all fine-coal/fine-coal-waste can be reduced significantly such that Illinois Coal becomes more cost competitive. All means of coal preparation cost reduction will improve the marketability of Illinois coal.
5. Based upon data obtained during this test program, process economic calculations will be performed and contrasted to the costs of other fuels including coals imported from western states, slurry fuels prepared from run-of-mine Illinois coals, and power supplied by existing Illinois power utilities.

INTRODUCTION AND BACKGROUND

Coal fines are unavoidably generated as a result of the mining and handling of coal. Most often, the coal preparation plant fines report to a slurry which is disposed of in a variety of different ways. Depending upon the value contained in and tonnage of the fine coal stream, it is usually either processed and filtered to produce a cake suitable for blending with the coarse product, or it is impounded in settling ponds as waste or for future recovery.

The technological approach used to remove water from fine coal slurries in this program utilizes cross-flow membrane separation, heat, and feed pulsation to effect a separation of water from the fine particle slurries. The separation of water from CWS is effected by pumping the slurry across a fine pore membrane surface. The membrane is vibrated radially at high frequency (50-60 Hz) which prevents the pores from being blinded by the finest slurry particles. The product is a thickened slurry. In previous laboratory work, fine particle slurries approaching 60 weight percent coal have been produced. Major advantages of the technology include:

- a) Eliminates flocculants which are required by both filtration and thickening processes.
- b) Achieves higher solids concentrations than achievable in conventional thickeners.
- c) Slurry concentration equipment is compact in comparison to other fine particle de-watering/thickening equipment. The footprint of the commercial machinery is approximately eight feet by eight feet, including pumps.
- d) Equipment is simple requiring maintenance similar to that of a pump.
- e) Provides a suitable, pumpable fuel for coal gasification and combustion technologies.
- f) High potential for use as a NO_x reducing re-burn fuel

The approach also will find utility in the de-watering of tailings muds from coal wash plants. Tailings impoundments often require large acreages of settling ponds. Thickening tailings to a paste consistency will allow the waste material to be disposed of in a much smaller area, perhaps obviating tailings impoundments entirely by enabling simple mine back-fill.

EXPERIMENTAL PROCEDURES

Previous work with the WTI/CRE technology established that it was both technically and economically interesting. The previous work included separation of water from CWS with a laboratory-scale separator which uses a single membrane surface with approximately one-half square foot of membrane separation area. The apparatus used in this program is considered to be pilot scale; the feed flow rate is up to five gallons-per-minute which is about 1.35 tph (slurry basis). The cross-flow separator in the pilot plant utilizes multiple membrane plates stacked vertically to increase the filtration area. The configuration is similar to (but not identical) that of the commercial-scale equipment. The total pilot cross-

flow separator membrane area can be configured with up to 19.5 square feet of separation area.

In previous work, water removal performance has been shown to be enhanced by the addition of heat to the feed. A package boiler provides heat to the feed by injection of process steam. To reduce the process requirements, heat is recovered by exchanging heat from both the product slurry and separated water (permeate) with the feed in double-pipe heat exchangers. These heat exchangers, have been designed to recover 80 percent of the heat in the feed slurry, but would be designed for higher efficiency in a commercial scale facility. The process flow sheet is depicted in the flow basic flow diagram shown in Figure 1.

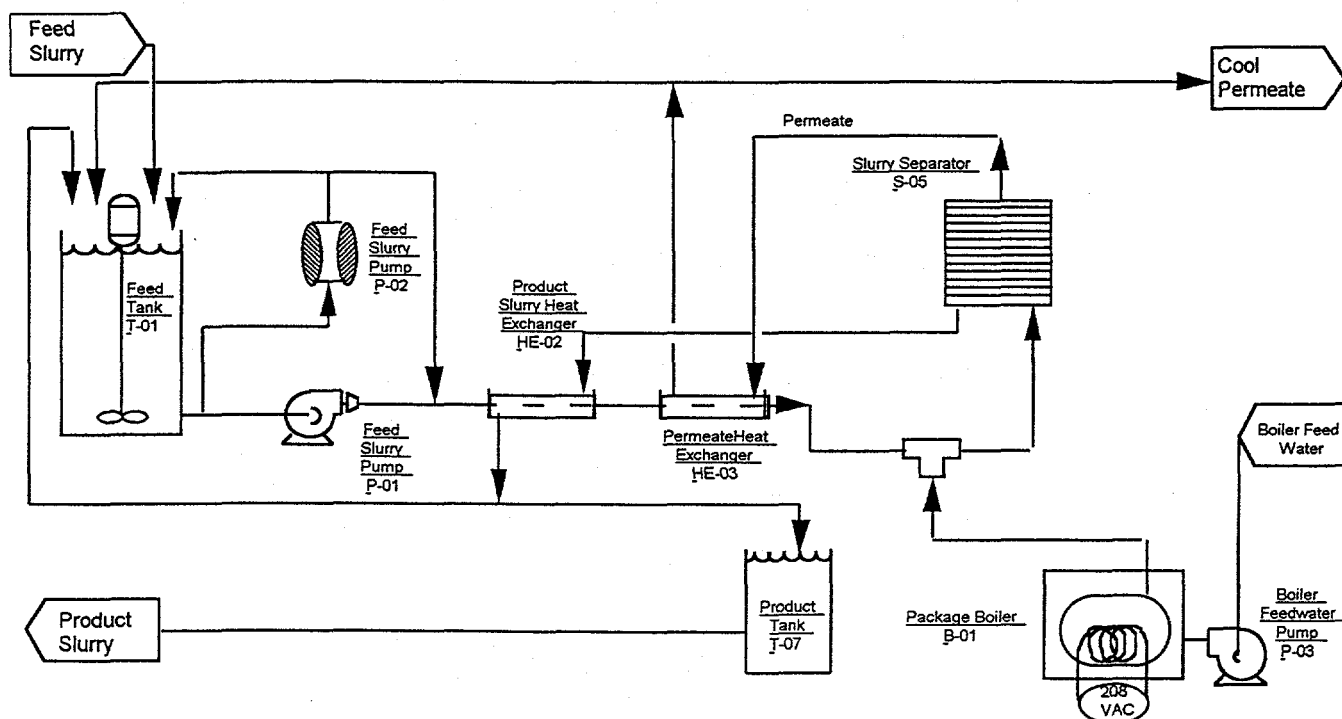


Figure 1 -- Pilot Plant Process Flowsheet

The pilot plant program has been divided into separate tasks described below:

Task #1 Procurement and Set-Up

The pilot plant apparatus is to be constructed at the SIU Coal Research Center in Carterville, Illinois. All equipment, supplies, and slurry feedstocks are to be delivered to this site

One New Logic International, Inc. V-SEP "Series P" high-shear membrane separator will be delivered to the test facility at the Coal Research Center at SIU will be arranged. The unit will be connected to SIU electric power by SIU personnel.

A 6.93 boiler horsepower Chromalox process steam generator will be delivered and electrically and mechanically connected by SIU personnel and inspected by WTI/CRE personnel.

All piping and instrumentation will be completed by WTI/CRE personnel.

Samples of both froth flotation concentrate and fine coal wastes will be taken at Consol's Rend Lake Preparation Plant under the supervision of Mr. Henry Ehrlinger. Mr. Ehrlinger will assure that the samples are properly taken and that they are delivered in a timely manner to the test facility.

Upon mechanical and electrical completion of the pilot plant apparatus, the plant will be commissioned and tested first with water and then with feed slurry. When commissioning and testing is deemed complete and satisfactory, the experimental program will commence.

Task #2 Ambient Temperature Tests

This testing will have the goals both equipment shake-down and base-line testing. The first work performed on fine coal slurry concentration included tests only at ambient temperatures. At temperatures of only 65 degrees Fahrenheit, the process performed well enough to indicate both technical and economic success.

This test will duplicate earlier work except that it will have been performed using pilot scale equipment rather than laboratory scale equipment.

The test will consist of placing 200 gallons of Rend Lake flotation concentrate in the unit's feed tank. A reasonable oscillation frequency will be applied and the material will be concentrated to a target loading of 60 weight percent.

Task #3 Elevated Temperature Tests

Two hundred gallons of Rend Lake Flotation Concentrate will be concentrated to a solids loading of 60 weight percent. The means of heating the feed will be via direct steam injection into the V-SEP machine's slurry feed pump discharge. The manufacturer indicates that the standard V-SEP machine can be reliably operated at temperatures up to 300 degrees Fahrenheit and 200 psig. It is recommended that because of some of the materials of construction in the pilot scale unit, temperatures should not exceed 200 deg. F.

Flux rate (water removal rate) will be measured versus slurry feed temperature at: ambient temperature, 100 degrees Fahrenheit, 120 deg. F, 160 deg. F, and 200 deg. F.

Task #4 Optimum Vibrational Frequency Tests and Feed Pulse

Previous test work by the principal investigator suggested that improvement in water removal rates of between 10% and 25% can be achieved if the feed pressure is periodically pulsed between the normal operating pressure and some lower pressure. It has been postulated that the disturbance in the traveling fines bed which forms along the surface of the membrane decreases the cake resistance of the fines bed until the bed re-establishes itself.

The effects of disturbing the fines bed have not been quantified, but are known to degrade with time. To maintain high flux rates, a periodic flow or pressure pulse will be included in normal operation of these experiments.

Task #5 Process Control Strategy Tests

Optimal operations in a commercial plant will most likely include some level of instrumentation which will aid in start-up, shut-down, normal run-mode operation, and product quality control. These tests will consider the effects of start-up and shut-down procedures as well as the anticipated instrumentation required to produce a product of consistent quality.

Questions to be answered include: Can the machine be started and stopped under full load without flushing? What means, if any, will be required to control the amount of water removal?

Task #6 Long Duration Testing (Two weeks of continuous testing)

In these tests, approximately 200 gallons of Rend Lake Flotation Concentrate feed slurry will be placed in an agitated feed tank and continuously concentrated to a target loading of 60 weight percent. All products will be returned to the feed tank and continuously re-mixed.

The experiments will test the performance of the filter media over time. It is expected that the filter media will survive with insignificant media wear. (This is predicted by manufacturer experience in industrial usage).

The test matrix will include:

- a. One week of testing at ambient slurry feed temperature.
- b. One week of testing at elevated temperature.

At a feed rate of 5 gallons per minute, the entire contents of the feed tank will be concentrated in a matter of less than two hours. Since this will be a two week test, all product slurry and clear permeate will be recycled back to the feed tank such that the process operates in a closed loop.

Feed slurry, product slurry, and clear permeate will be sampled (100 milliliters each) twice per shift and at operator discretion to monitor the performance of the process operation.

Task #7 Tailings Paste Production (Two days of testing)

Tailings material will be concentrated to determine whether a paste suitable for mine back-fill can be produced or if the material can be concentrated such that a better feed for belt filtration and subsequent tailings pile stacking can be achieved.

This work will be performed in close consultation with Consol research service engineers (Dr. Anthony Fonseca).

Task #8 Destec Slurry Fuel Evaluation

Preparation of fuel samples will be performed in consultation with Destec Energy, Inc. Destec will perform a heat-rate analysis and gasifier acceptability of various samples taken from each test in Tasks #1, #2, and #6. Physical data from each sample will serve as input for Destec's software gasification model.

RESULTS AND DISCUSSION

As of this report, the construction and commissioning (Task #1) has been completed. No engineering experiments (Tasks #2 through #8) have been completed.

During plant shake-down, it was verified that:

- a. Slurry can be circulated through the system and water can be separated and equilibrium flow and system pressure conditions can be satisfactorily maintained.
- b. Feed slurry heating and heat recovery systems are functional and target feed slurry temperature can be controlled.

During plant shake-down several engineering issues arose and were addressed. The impact of these solutions will be determined during testing which will take place in December, 1995 and will be reported in the 1st Quarter 1996 Report.

CONCLUSIONS AND RECOMMENDATIONS

Pilot plant commissioning and shake-down are now complete and there is nothing further significant to report

DISCLAIMER

This report was prepared by Marcus Rajchel representing Williams Technologies, Incorporated of Tulsa, Oklahoma with support in part by grants made possible by the U.S. Department of Energy Cooperative Agreement Number DE-FC22-92PC92521 (Year 4) and the Illinois Department of Commerce and Community Affairs through the Illinois Coal Development Board and the Illinois Clean Coal Institute. Neither Marcus Rajchel nor Williams Technologies nor any of its subcontractors nor the U.S. Department of Energy, the Illinois Department of Commerce and Community Affairs, Illinois Coal Development Board, Illinois Clean Coal Institute, nor any person acting on behalf of either:

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PROJECT MANAGEMENT REPORT
September 1, 1995, through November 30, 1995

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Project Manager: Dr. K. Ho, ICCI

COMMENTS

Project Schedule

Laboratory testing has been delayed by 4 to 6 weeks due to delays in start-up of test equipment. Tests scheduled for November have not been started; testing has been rescheduled for early December, pending the arrival of replacement filter membranes for the separation unit. Due to the delay in the start of testing, expenditures to date are below projected values. The delay is not expected to increase total expenditures, but some expenditures projected for the first Quarter have been deferred to the second Quarter.

Projected Expenditures

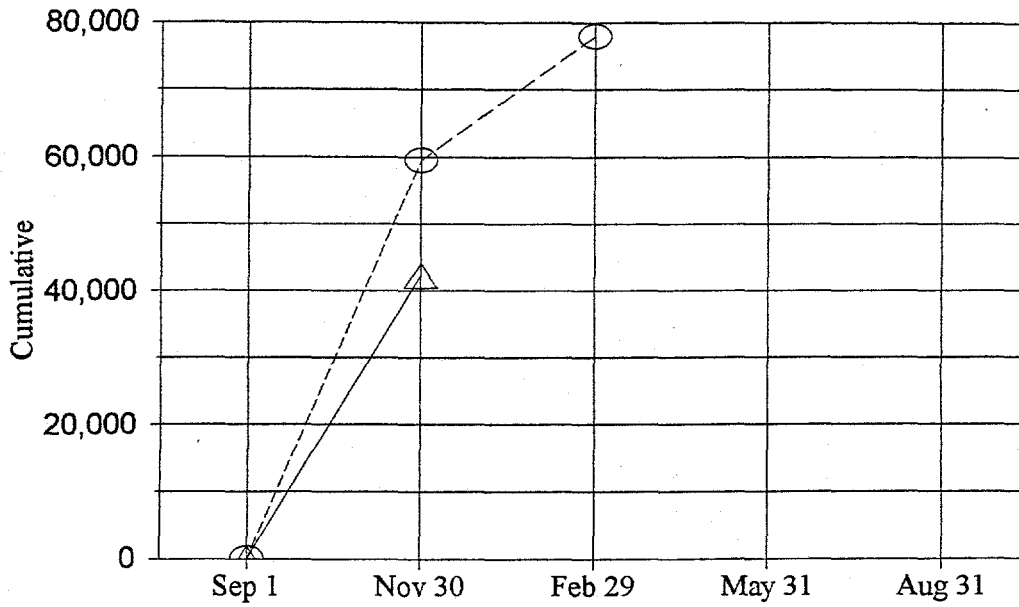
1. Direct Expenses of \$10,000 have been deferred to the second Quarter due to monthly payment arrangements with suppliers, namely SIUC and New Logic International. The remaining payments to these two parties are projected to occur in December, 1995, and January, 1996.
2. WTI/CRE JV purchased an electric steam boiler for use in the test program. This boiler appears as the \$2,000 under Major Equipment. The original proposal stated that WTI/CRE would rent this equipment for \$800. The purchase price will be covered by reductions in other direct expenses. WTI/CRE JV will request a budget change in detail in a separate letter to ICCI.

Projected and Estimated Expenditures

Quarter*	Types of Cost	Direct Labor	Fringe Benefits	Materials & Supplies	Travel	Major Equipment	Other Direct Costs	Indirect Cost	Total
Sept. 1, 1995 to Nov. 30, 1995	Projected	19,900	4,960	1,500	6,000	--	22,550	4,610	59,520
	Estimated	18,771	4,689	1,500	3,608	2,000	9,450	3,602	43,620
Sept. 1, 1995 to Feb. 29, 1996	Projected	32,500	8,119	2,000	6,000	--	23,050	6,287	77,956
	Estimated								
Sept. 1, 1995 to May 31, 1996	Projected								
	Estimated								
Sept. 1, 1995 to Aug. 31, 1996	Projected								
	Estimated								

* Cumulative by Quarter

COSTS BY QUARTER
Innovative Process for Concentration
of Fine Particle Coal Slurries



⊖ Projected △ Estimated Actual

Total ICCI Award \$ 77,956.

SCHEDULE OF PROJECT MILESTONES

TASK	1995				1996		
	SEP	OCT	NOV	DEC	JAN	FEB	MAR
A	█						
B		X		█			
C		X		O			
D		X		O			
E		X		O			
F		X		O			
G		X		O			
H		X		O			
I					X		
J			X	O			
K			X			X	
L			X			X	

RESEARCH TASKS

- A. Project Kick-Off & Planning
- B. Procurement & Set-Up
- C. Ambient Temperature Tests
- D. Elevated Temperature Tests
- E. Optimum Frequency & Pulse Tests
- F. Process Control Strategy Tests
- G. Long Duration Testing
- H. Tailing Paste Production
- I. Destec Slurry Fuel Evaluation
- J. Analytical Testing
- K. Technical Reporting
- L. Project Management Reporting

COMMENTS

The start of laboratory testing has been delayed by 4-6 weeks due to delays in equipment start-up. To date, no scheduled tests have been started. Testing will resume in December, 1995, pending the procurement of replacement parts for the separation unit.