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FINAL

IMPROVEMENT OF STORAGE, HANDLING, AND TRANSPORTABILITY OF FINE COAL

Contract No. DE-AC22-93PC93157

QUARTERLY TECHNICAL PROGRESS REPORT NO. 8

Covering the Period October 1, 1995 to December 31, 1995

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1.0 PROJECT SUMMARY

1.1 Background and Objectives

Fine coal production is on the rise in the U.S., and it will continue to increase as underground mining companies invest in more productive equipment. Fine coal cleaning technologies have been developed which can efficiently and economically separate coal from clay and other mineral matter in the fine size fractions, but they have not gained universal acceptance in the coal industry because the product is considered too wet by most coal users.

Historically, coal producers take one of two approaches in dealing with fine coal production. On the one hand, they may wash it and recover it as a wet cake which must be thermally dried prior to shipment. On the other hand, many operators make to attempt to recover fine coal, and dispose of it as a wet cake or slurry in refuse piles, slurry impoundments and abandoned deep mines. There are environmental problems related to both of these practices.

The Mulled Coal process was developed as a means of overcoming the adverse handling characteristics of wet fine coal without thermal drying. The process involves the addition of a low cost, harmless reagent to wet fine coal using off-the-shelf mixing equipment. Based on laboratory- and bench-scale testing, Mulled Coal can be stored, shipped, and burned without causing any of the plugging, pasting, carryback and freezing problems normally associated with wet coal. On the other hand, Mulled Coal does not cause the fugitive and airborne dust problems normally associated with thermally dried coal.

The objectives of this project are to demonstrate that:

- The Mulled Coal process, which has been proven to work on a wide range of wet fine coals at bench scale, will work equally well on a continuous basis, producing consistent quality, and at a convincing rate of production in a commercial coal preparation plant.
- The wet product from a fine coal cleaning circuit can be converted to a solid fuel form for ease of handling and cost savings in storage and rail car transportation.
- A wet fine coal product thus converted to a solid fuel form, can be stored, shipped, and burned with conventional fuel handling, transportation, and combustion systems.

1.2 Project Overview

It is useful to describe the project in groups of activities in order to fully understand the interactions between activities and to better understand the information flow and decisions of the project. The project is organized around two major demonstrations: (1) the production of Mulled Coal in a commercial operating setting, and (2) the delivery of the Mulled Coal product through existing commercial storage, transport, and handling systems.

The initial project activities were performed largely at the EI facilities and were conducted to produce the formulations, test procedures, and design packages required to procure and install the Mulled Coal circuit at the Drummond Company, Inc., Chetopa Preparation Plant in Graysville, Alabama. The installed circuit will be used for the demonstration of Mulled Coal production. The second set of demonstrations will be the shipment and handling of Mulled Coal in existing coal transportation systems. Data collected from all phases of production and delivery will then be analyzed, evaluated, and reported.

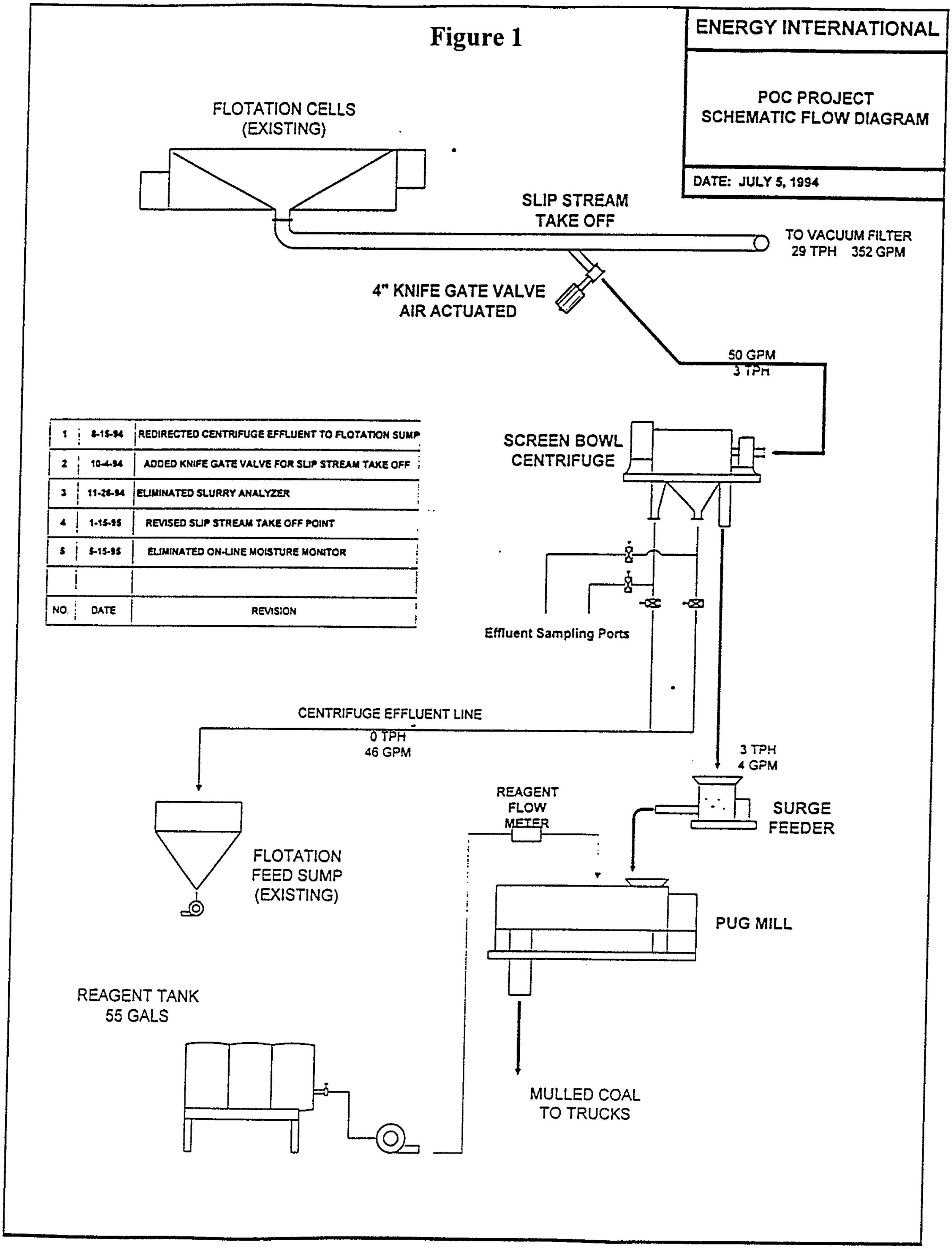
The Mulled Coal circuit was installed in the operating preparation plant located at the Chetopa Mine site. The Chetopa Plant processes 360 to 450 tonnes/hr (400 to 500 tons/hr) of raw coal to produce 250 to 320 tonnes/hr (275 to 350 tons/hr) of clean coal for shipment to the steam coal market. Approximately 45 to 55 tonnes/hr (50 to 60 tons/hr) of fine coal is cleaned in froth cells to produce 40 to 45 tonnes/hr (45 to 50 tons/hr) of a fine clean coal that is 10-14 percent ash. Froth concentrate reports to a vacuum filter where a 24-27 percent moisture filter cake is discharged to a collecting belt. In current operations, the wet filter cake is combined with the coarser size fractions of clean coal for storage and delivery to market. The wet filter cake comprises about 15 to 18 percent of the total clean coal product from the plant.

The proof-of-concept (or POC) circuit was designed to process a 2.7 tonnes/hr (3 tons/hr) slipstream of froth concentrate from the existing froth cells in the Chetopa Plant as feed to the Mulled Coal circuit. The froth concentrate was dewatered in a centrifuge to prepare a wet fine coal feed material for conversion into a free-flowing granular material. The Mulled Coal product was directed to an open storage pile. The POC unit is of a design that can be scaled up to 135 tonnes/hr (150 tons/hr). Figure 1 shows the key components of the Chetopa Plant cleaning circuit and the Mulled Coal circuit that has been installed.

The Mulled Coal circuit was installed in an empty bay at the Chetopa Plant. This area is convenient to the discharge location from the froth cells and at a lower elevation. The use of gravity feeds minimized field fabrication. Equipment has been installed to divert a 2.7 tonnes/hr (3 tons/hr) slipstream of the froth concentrate to a dewatering centrifuge. The concentrated wet coal fines from the centrifuge dropped through a chute directly into a surge hopper and feed system for the Mulled Coal circuit. The Mulled Coal product was gravity discharged from the circuit to a truck or product discharge area from which it was hauled to a stockpile located at the edge of the active clean coal stockpile area.

During the 3-month operating period, the facility produced 870 tonnes (966 tons) of the Mulled Coal for evaluation in various storage, handling, and transportation equipment and operations. Immediately following the production demonstration, the circuit was disassembled and the facility was decommissioned. Since the completion of the production demonstration, the activities have included the shipment of product Mulled Coal to the Gorgas Power Station of Alabama Power and the evaluation of the data and results of the activities to date.

Figure 1


ENERGY INTERNATIONAL
POC PROJECT
SCHEMATIC FLOW DIAGRAM
DATE: JULY 5, 1994
FLOTATION CELLS
(EXISTING)
SLIP STREAM
TAKE OFF
TO VACUUM FILTER
29 TPH 352 GPM
4" KNIFE GATE VALVE
AIR ACTUATED
50 GPM
3 TPH
1 8-15-94 REDIRECTED CENTRIFUGE EFFLUENT TO FLOTATION SUMP
2 10-4-94 ADDED KNIFE GATE VALVE FOR SLIP STREAM TAKE OFF
3 11-28-94 ELIMINATED SLURRY ANALYZER
4 1-15-95 REVISED SLIP STREAM TAKE OFF POINT
5 5-15-95 ELIMINATED ON-LINE MOISTURE MONITOR
NO. DATE REVISION
SCREEN BOWL
CENTRIFUGE
Effluent Sampling Ports
CENTRIFUGE EFFLUENT LINE
0 TPH
46 GPM
3 TPH
4 GPM
REAGENT
FLOW
METER
SURGE
FEEDER
FLOTATION
FEED SUMP
(EXISTING)
PUG MILL
REAGENT TANK
55 GALS
MULLED COAL
TO TRUCKS

2.0 PROJECT TECHNICAL WORK PLANS

This project focuses on achieving two demonstrations of the Mulled Coal technology: (1) Production in a commercial operating environment, and (2) Delivery of product in existing storage, transportation, and handling systems. To successfully complete these demonstrations, the project has been organized into a series of task activities which lead to the demonstrations, support the engineering and management needs of the project, and assess and report the activities and results. The development of the design basis and assessment of Mulled Coal technology application are direct parallels to activities that would be needed in any specific individual commercial application.

The technical approach is comprised of the following:

1. Prepare work plans at the beginning of the project with mechanisms for adding detail and updating the plans as new information is generated.

2. Collect and evaluate information specific to the coal and plant operations at the host site that is needed to complete the circuit design, equipment selections, installation plans, and production scheduling and plans.

3. Use the evaluation results to complete the design, equipment selection, and production planning.

4. Procure, install, and start-up the Mulled Coal circuit at the host site.

5. Conduct the demonstration of production operations.

6. Select delivery destinations and develop specific plans for monitoring dumping, fuel handling, etc. at each unique destination. Final decisions and detailed plans will be made when coal deliveries are ready to be scheduled, which in commercial practice is several months from the expected availability of product for shipment.

7. Conduct the demonstration of Mulled Coal technology in existing storage, transportation, and handling operations.

8. Prepare technical and economic assessment of the technology based on the data generated in the demonstration operations.

3.0 TECHNICAL PROGRESS

3.1 Overview

The production operations of the demonstration circuit were completed during the sixth quarterly period of the contract. The circuit was then disassembled and the facility was decommissioned. During the immediately previous reporting period (the seventh), the major technical activities were the technical and economic evaluations and the shipment of product. The technical and economic evaluations and the preparation of information for the final report continued throughout this period.

During this period, the major areas of analysis completed for reporting were commercial considerations and the estimation of costs of a commercial application.

3.2 Commercial Considerations

The Mulled Coal process was developed as a means of converting ultra clean Coal Water Fuel into a granular, free flowing intermediate fuel form so that it could be stabilized inexpensively for storage and shipment. The process works extremely well in this application, but the use of Coal Water Fuel has not gained widespread acceptance, and it does not appear that there will be many near- term commercial opportunities to apply the process in this manner.

The purpose of this project was to evaluate the application of the Mulled Coal technology to the types of every day wet fine coal problems which have plagued the coal industry ever since the introduction of wet processes for cleaning fine coal. We achieved all of the major project objectives. Starting with a 28Mx 0 clean coal product with ash up to 13% and moisture up to 27%, we proved the concepts that:

> Excellent quality Mulled Coal could be produced consistently and continuously; at a convincing rate of production; and in the environment of a typical commercial coal preparation plant.
>
> Mulled Coal can be stored, handled, and shipped without causing any of the problems normally associated with wet fine coal.
>
> Equipment designs and circuit controls, which were based on laboratory and pilot scale test work, were appropriate for full scale commercial operations.

From experience gained in the proof of concept project, we can identify a number of areas where the Mulled Coal technology can be used on a commercial basis to economically alleviate handling problems or broaden markets. We established major equipment specifications for various levels of production, and we can accurately project key capital and operating costs.

3.2.1 Commercial Applications

3.2.1.1 Slurry Pond Recovery Projects

There is in excess of 100 million tons of fine size, higher rank bituminous coal (28M x 0 or 150M x 0, low vol, mid vol and high vol A) stored in accessible slurry impoundments throughout the U.S. coal fields. This represents a very significant source of low cost fuel, and the inventory figure is growing every day. There are currently over 100 preparation plants with completely wet circuits which have not been provided with fine coal preparation or recovery circuits. Collectively, these plants have an installed capacity of about 50,000 tons per hour. They process about 190 million tons per year of raw coal, and they probably bleed off between 10 and 20 million tons of fine coal each year. Not all of this coal is ending up in accessible slurry impoundments, and not all of the coal which ends up in a pond is worth recovering. However, it is safe to assume that we are putting recoverable coal into accessible slurry impoundments at least twice as fast as we are removing it.

The reason that fine coal was directed to slurry impoundments in the first place, and the reason that it is not being recovered at a faster rate (in spite of the relatively low cost), is market resistance to wet fine coal. And that market resistance is related to the plugging, fouling, bridging, storage and transportation problems which are historically associated with fine wet coal. The Mulled Coal process represents a low cost solution to all of those problems.

Commercial slurry pond recovery projects fall into three general categories:

1. Ponds where the material is low enough in ash that it can be recovered without any further separation process.

2. High ash ponds which are located adjacent to or near refuse-fired cogeneration plants. In these cases the slurry pond material is a desirable boiler feed source because even though it is high ash, it is generally higher in heat value than the coarse refuse which is the primary fuel source for the plant.

3. High ash ponds where a low ash product can be recovered by washing or rewashing in a flotation or combination spiral/flotation circuit.

The common thread running through all of these projects is that they end up with a very low cost wet and sticky product which is difficult to market. Previous solutions have included blending small percentages of the recovered product with a dry coarser coal, blending larger portions with coarser coal and thermally drying the blend, or drying the recovered material by itself with a combination thermal drying/pelletizing process. These solutions are all expensive and they partially offset the built-in cost advantage of removing material from a pond versus conventional mining methods.

In each case, instead of blending, or thermal drying, or pelletizing, the Mulled Coal process could have been used as a low cost final conditioning step to prepare a boiler grade fuel with vastly improved handling characteristics.

3.2.1.2 Integration into Multi-Circuit Preparation Plants

As previously discussed, there are over 100 completely wet preparation plants which are not equipped with fine coal separation or recovery equipment. These plants simply bleed off fine coal in a slurry form.

There are plants which wash to 0, but the handling characteristics of the 1-1/4" x 0 clean coal product are so heavily influenced by the wet, sticky fine coal that markets for the overall product are limited. This is especially true with higher-grind, deep-mine coals where larger percentages of the total product consist of the finer size fractions. Some customers may accept the full 1-1/4" x 0 product, but others, who are more sensitive to wet coal handling problems, will insist that the finest size fractions be excluded from shipments, or they will impose moisture restrictions which will prohibit the inclusion of the finest size fraction.

Many of these plants will install a separate fine coal belt which will divert the finest size fraction away from the regular clean coal collecting belt when shipping to certain customers. The fine coal ends up in a separate stockpile. From there it is either blended with a much drier coal (perhaps raw strip coal), or it is metered in very small quantities back into the regular clean coal product for shipment on less restrictive orders. In either case the fine coal ends up on a lower price market, and the additional handling cost to divert it to ground storage and back into a blend is significant.

In these cases the Mulled Coal process is simply inserted at the tail end of the fine coal preparation circuit. The mechanically dried fine coal product discharges to a surge feeder, which in turn feeds the pug mill where reagent is added and mixed with the wet coal. The Mulled Coal is discharged from the pug mill to the regular clean coal collecting belt, and the process eliminates the adverse handling characteristics which were caused by the untreated wet coal.

3.2.1.3 Alternative to Thermal Drying

There is no substitute for thermal drying when the primary objective is to avoid the cost of shipping water to a distant market, or where a customer has an inflexible requirement for fuel with a very high as-received heat value.

On the other hand there are situations where coal buyers set maximum moisture limits which are based on previous handling problems with coal which exceed the arbitrary limits. When maximum limits are set in the 6% to 8% moisture range, many deep mine producers, who wash to 0, cannot produce a 1-1/4" x 0" clean coal product which meets the low moisture specification.

The options for placing the clean coal product in the low moisture market are thermal drying or diverting or discarding enough fine wet coal until the coarser product meets the designed moisture specification. The Mulled Coal process can be used to make high moisture coal handle like 6% moisture coal. It will usually be less expensive than thermal drying, and there will be none of the environmental and safety hazards normally associated with drying fine coal.

Table I shows a hypothetical comparison of preparing a 10% moisture clean coal product for a 7% maximum moisture market by either thermal drying or using the Mulled Coal process. This illustration could be indicative of a deep mine operator in a high grind seam, who is washing to 0, and preparing coal for the compliance or near-compliance market. Figures used for size distribution, heat value, price and cost may not be entirely appropriate. They are used here only to illustrate the type of analysis needed to compare mulling to thermal drying.

Table I

MULLING VERSUS THERMAL DRYING

	Mulled	Thermally Dried
Size Distribution (% of total)		
1-1/4" x 28M	75	75
28M x 0	25	25
Ash (Dry)	8.0	8.0
Moisture	9.0	6.0
Btu (A/R)	12,699	13,158
Btu (MAF)	15,300	15,300
FOB Mine Price (@ 1.15/MM Btu)	29.21	30.26
Less:		
Cost of Thermal Drying	-	-
Cost of Mulling(1)	.38	2.50
Net Realization	28.83	27.76

(1) Mulling cost is included at $1.50/ton for the 28M x 0 size fraction. The 28M x 0 size fraction was considered to have been at 18% moisture.

The reagent delivery system for commercial installations retains the essential design elements of the project system. Commercial systems will not be supplied with compressed air (it was found to be unnecessary), and the manual valves used to control the system will not be located in a control room.

- The reagent pump will be a magnetically coupled gear pump with a DC drive.
- The flow meter will be a high grade, positive displacement gear type meter.
- Spray nozzles will deliver wide angle, fan patterns.

- Individual spray nozzles can be shut down remotely to maintain ideal system pressure over a wide range of flow rates.

- Reagent flow will be automatically adjusted by a control loop which includes one or more on-line instruments which will monitor key process variables such as coal feed rate and surface moisture. The process control loop may be simplified or even eliminated in applications where flow rate and moisture are consistent, or where Mulled Coal quality is not critical.

Table II below shows reagent system capacities for project equipment and commercial installations.

Table II

Reagent System Capabilities

	Project Equipment	Commercial Installations		
Processing Capacity (TPH)	5	25	50	75
Reagent Flow				
Minimun (GPM)	0.09	0.37	0.75	1.12
Maximum (GPM)	0.38	1.88	3.76	5.64
Nominal Rating (GPM)	0.22	1.13	2.36	3.38
Spray Nozzles				
Number Required	3	4	6	8
Spray Pattern	Fan	Fan	Fan	Fan
Included Angle (Degrees)	120	120	120	120
Flow Rate (GPH)	5	28	39	42
Operating Pressure (PSI)	20	50	50	50
Reagent Tank Capacity				
Day Tank (Gal.)	N/A	500	1,000	1,500
Main Storage Tank (Gal.)	N/A	6,000	10,000	15,000

3.2.1.4 Freeze-Proofing

When washed coal freezes and hangs-up in rail cars, the freezing problem can always be traced to the 28M x 0 size fraction. In cold producing regions, and when coal is shipped into cold regions, it is sometimes necessary to apply freeze-proofing chemicals to the entire shipment in order to insure that cars will dump properly. Depending on the moisture and size consistency of the coal, freeze-proofing can cost as much as $1.00 per ton.

The Mulled Coal process is not a freeze-proofing process. The water enveloped in and attached to individual agglomerates can freeze, but the reagent coating prevents individual agglomerates from freezing to each other, to other pieces of coal or to the steel sides and hoppers of rail cars. When the Mulled Coal process is used to prevent cold weather handling and car dumping problems, only the 28M x 0 size fraction is treated. Cost can run as high as $1.50 per ton for the 28M x 0 coal treated, but costs per overall clean ton (1-1/4" x 0") will only be in the $0.30 to $0.40 per ton range depending on the size distribution of the clean coal product.

3.2.2 Major Equipment

The major pieces of equipment used in a Mulled Coal circuit are a pug mill (double paddle mixer) and a surge feeder. The design considerations for these two pieces of equipment (and all other component parts of the circuit) are described in other sections of earlier reports.

The double paddle mixer will be used in every commercial installation. There may be instances where the use of a surge feeder is not required. Mechanical fine coal dewatering equipment often discharges dry coal with periodic short duration surges. This is especially true in the case of vacuum filters. The surge feeder levels out momentary surges and delivers an even and consistent flow of wet cake to the pug mill. The surge feeder can also be used (as it was in this project) as a means of presenting wet cake to on-line monitors in an ideal configuration and density for accurate measurement. If the flow of wet cake from the dewatering equipment is even, and if on-line monitoring is not required, then the use of a surge feeder is not absolutely necessary. The guiding principle in deciding whether or not to use a surge feeder is that there must be an even flow of material to the pug mill for a precise and efficient application of reagent. Reagent cost accounts for over 80% of the total cost of operating a Mulled Coal circuit; while the cost of using a surge feeder is less than 5%.

In the project we used scale models of commercial size equipment. Throughout the shakedown and production operations, we ran numerous controlled tests to establish capacities and load factors for the scale model equipment. Nominal capacity for the project equipment was established at 5 TPH; with a maximum capacity of 7 TPH or 40% over nominal capacity. Information gathered in the project was used to project dimensions and load factors for commercial size equipment at nominal capacities of 25, 50 and 75 TPH.

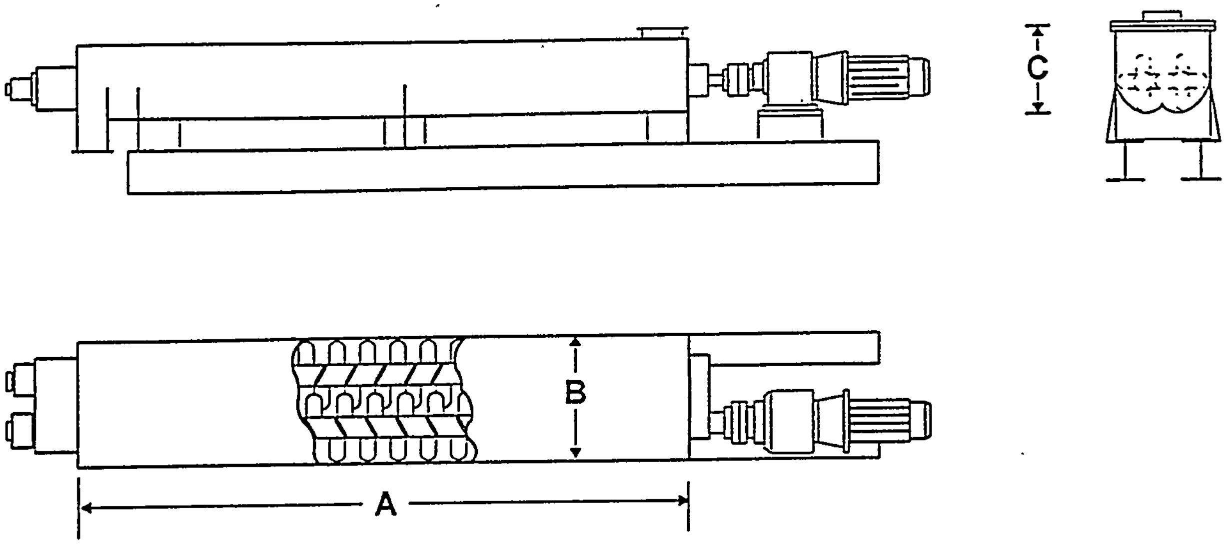
75 TPH is considered to be the maximum nominal capacity rating for a single Mulled Coal circuit. Pug mill mixing shafts are about 12 ft long, and they cannot be supported at any place other than the ends. Horsepower requirements at capacities in excess of 75 TPH could cause shaft flexing problems. Capacities in excess of 75 TPH would require dual circuits, but generally, the capacity of individual Mulled Coal circuits can be set to match the capacity of the centrifuges or filters which provide the wet cake feed to the circuit.

Figures 2 and 3 show the scale up dimensions for the pug mill and surge feeder.

Pug mills in the 25 to 75 ton capacity range are used extensively in commercial minerals processing applications. The 50 TPH and 75 TPH surge feeders are not in common use. They would

Figure 2

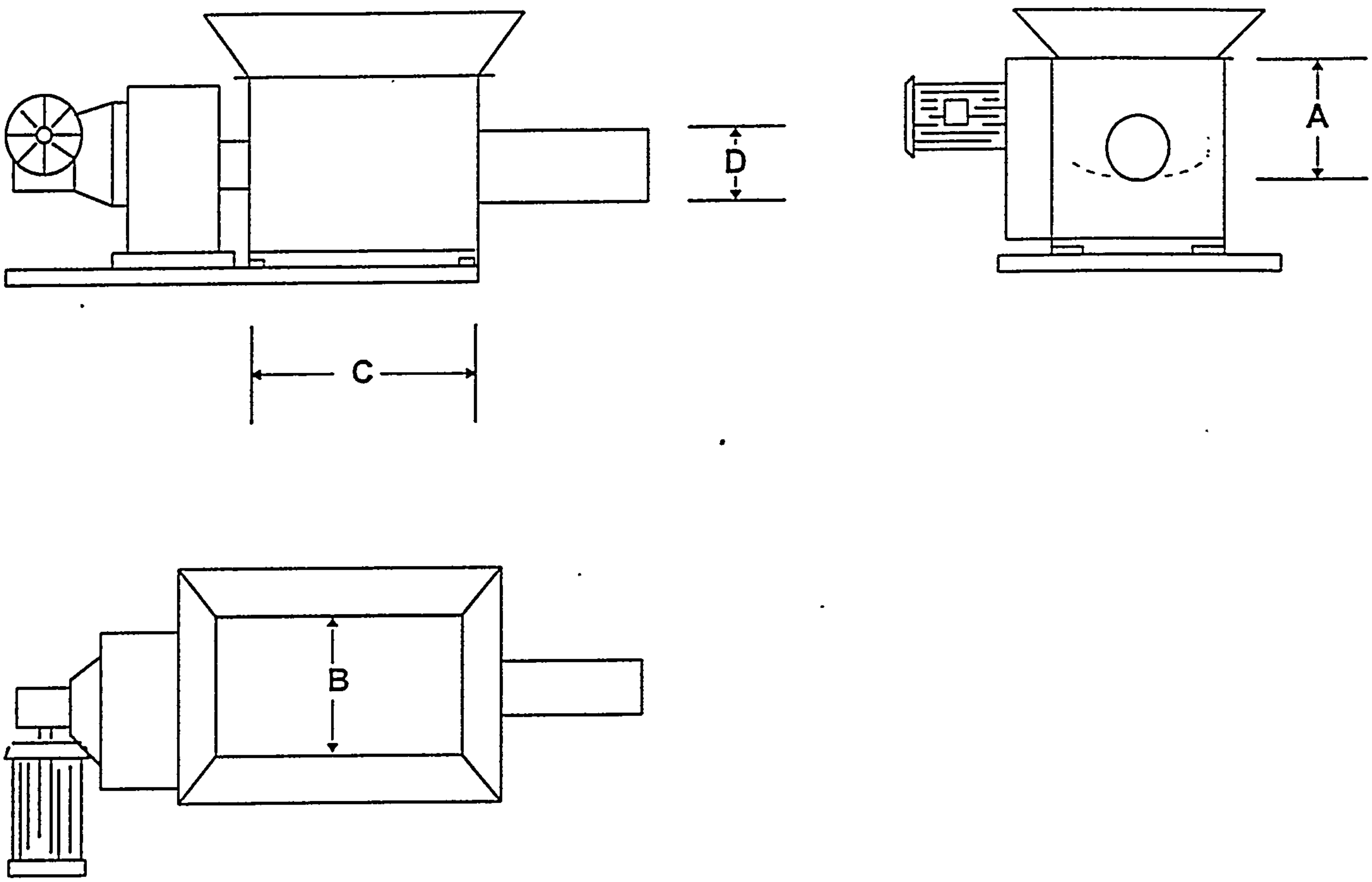
PUG MILL



	PROJECT MACHINE 5 TPH	25 TPH	50 TPH	75 TPH
"A" MIXING CHAMBER LENGTH	120"	120"	120"	120"
"B" MIXING CHAMBER WIDTH	18"	39"	56"	66"
"C" MIXING CHAMBER DEPTH	15"	28"	38"	42"
WORKING CAPACITY (Cu. Ft.)	10	50	100	150
RETENTION TIME (Minutes)	2.28	2.28	2.28	2.28
HORSEPOWER	10	17 1/2	30	50

Figure 3

SURGE FEEDER



	PROJECT MACHINE 5 TPH	25 TPH	50 TPH	75 TPH
"A" HOPPER DEPTH	16"	27"	35"	40"
"B" HOPPER WIDTH	16"	27"	35"	40"
"C" HOPPER LENGTH	29"	50"	63"	73"
"D" DISCHARGE TUBE DIA.	8"	17"	24"	29"
LIVE HOPPER CAPACITY (Cu. Ft.)	3.9	19.6	39.1	58.7
RETENTION TIME (Seconds)	54	54	54	54
HORSEPOWER	3	10	15	20

be special order machines, but that should not present a problem. This type of equipment is not mass produced. Each new machine is manufactured to specifications set out in individual orders. There is absolutely no doubt that this type of surge feeder would perform successfully at 75 TPH.

3.2.3 Capital Cost

Capital and operating costs for a commercial Mulled Coal circuit depend on the type of application, the quality of the wet cake, and the target handling characteristics for the Mulled Coal product.

For instance, if the Mulled Coal circuit is simply being added onto the tail end of a fine coal circuit in an existing plant, then capital costs will be limited to the cost of equipment components, the cost of integrating the electrical and process control circuits into the existing plant control circuits, and the cost of minor structural changes required to fit-in the new equipment. However, if the Mulled Coal circuit is to stand alone to process slurry pond material at a greenfield project, then capital costs must include the cost of a complete plant structure, plus the cost of conveyors to move the material into and out of the new plant. Capital costs will never be significant as compared to reagent costs, but the capital cost for each particular application will differ, and it will be dependent upon a host of local factors.

Wet cake surface moisture, ash, and particle size distribution have a significant impact on required reagent dose, and each project will involve a wet cake with entirely different characteristics. There are predictable relationships between reagent cost and wet cake characteristics. In general, when all other characteristics remain equal:

* Increases in surface moisture will result in increased reagent cost.

* Increases in ash will result in increased reagent cost.

* Increases in mean particle size will result in decreased reagent cost.

The desired handling characteristics of the Mulled Coal product will also affect reagent cost. In an application where the Mulled Coal circuit is used to condition 28M x 0 clean coal in an integrated preparation plant, and the 28M x 0 Mulled Coal is to be blended back in with coarser clean coal products, and the objective is simply to eliminate rail car dumping or freezing problems, then reagent consumption will be relatively low. On the other hand, in a stand alone circuit where the Mulled Coal will be shipped by itself, and the objective is to prepare a fine coal product which will gravity discharge from a bin with mass flow characteristics, then reagent consumption will be relatively high.

In order to make a precise estimate of capital and operating costs for a particular project, it is necessary to know the type of application, the quality of wet cake to be treated, and the desired handling characteristics for the end product. However, there are equipment components and capital costs which will be common to all projects, and we can make general predictions of reagent costs which will cover a range of wet cake and end product quality. The following sections project capital costs, reagent costs, and other operating costs at various levels of production.

3.2.3.1 Major Components

Site specific capital costs such as structures, bins, conveyors, etc., cannot be estimated because they will vary significantly from project to project. However, the pug mill, surge feeder, and reagent delivery system costs will be common to all projects (the surge feeder may not be required in rare instances - see Section 3.2.2). Listed below are projected common component costs at various levels of production.

COMMON EQUIPMENT COMPONENTS

	Project Equipment	Commercial Installations					
Capacity	5 TPH	25 TPH		50 TPH		75 TPH	
Capital Cost							
Pug Mill	25000	40000	60000	60000	80000	80000	100000
Surge Feeder	9000	12000	15000	15000	18000	18000	21000
Reagent System	4000	5000	6000	5000	6000	6000	7000
Total	38000	57000	81000	80000	104000	104000	128000

3.2.3.2 Electrical Control Circuit

The cost of an electrical control circuit is also site specific. The control circuit for the demonstration project cost over $30,000 before installation, but that cost included computer equipment, software, programming services, a separate motor control center, an uninterrupted power supply, a separate lighting circuit, and some transformers and other equipment which would not be required if a Mulled Coal circuit was to be integrated into an existing plant. Also the experimental nature of the demonstration project required a level of sophistication which would not be needed in most commercial installations.

The circuit breakers, motor starters, visible disconnects, emergency stops, lead lines and electrical interlock equipment which would be common to every installation cost less than $10,000 for the demonstration project. That cost would only increase from $1,000 to $3,000 for the higher horsepower and loads on commercial circuits in the 25-75 TPH range.

The level of sophistication and independence for the Mulled Coal electrical control circuit would vary significantly from project to project, but the cost for added sophistication would never exceed $20,000, and it would probably be no less than $5,000. So the capital cost range for electrical controls would be:

	Project Equipment	Commercial Installations		
	5 TPH	25 TPH	50 TPH	75 TPH
Basic Breakers, Starters, etc.	$10,000	$11,000	$12,000	$13,000
Variable Costs For Sophistication	20,000	5,000-15,000	5,000-15,000	5,000-15,000
	$30,000	16,000-26,000	17,000-27,000	18,000-28,000

3.2.3.3 Process Control Circuit

Not every commercial installation will require an automatic process control loop, but when one is used it will require an on-line moisture monitor plus some means of monitoring material flow through the system. Material flow can be monitored with a short weighbelt or some type of noncontact velocity measurement as the wet cake moves through the surge feeder discharge tube extension. The moisture monitor will cost about $25,000. Depending on the type of on-line measurement for material flow, the cost will range between $5,000 and $15,000. The cost of integrating the control loop into the electrical control system would be about $5,000.

3.2.3.4 Reagent Storage

The basic setup for commercial installations will be an outside above-ground storage tank accessible to 6,000 gal tank trucks. The main tank will be designed to hold about a one week supply of reagent. Design capacities for 25 TPH, 50 TPH and 75 TPH are 6,000 gal, 10,000 gal and 15, 000 gal, respectively. The main tank will feed a day tank located in the plant, and designed to hold about a one shift supply of reagent. Design capacities for 25 TPH, 50 TPH and 75 TPH are 500 gal, 1,000 gal, and 1,500 gal, respectively. The cost for storage tanks is as follows:

	25 TPH	50 TPH	75 TPH
Day Tank	$ 500	$ 1,000	$ 1,500
Main Tank	4,500	6,500	8,500
Installation and Pipe Work	2,000	3,000	4,000
	$ 7,000	$10,500	$14,000

3.2.3.5 Capital Cost Summary

Table III below summarizes the costs projected in previous sections. The following assumptions were used in calculating costs for the summary table:

- The type of application is assumed to be a plant addition where the Mulled Coal circuit is integrated into an existing plant, and there are no significant structural changes required for the new equipment.

- The electrical and process central circuit is assumed to be highly sophisticated; with on-line monitors, a separate PLC and a dedicated computer.

- Every time a range was used to project cost in the previous sections, a mid point of that range is used in the summary table.

- The depreciable life for all equipment is assumed to be seven (7) years, and the depreciation method is assumed to be straight line.

- Production is based on operating 15 hours per day for 240 days per year.

Table III

CAPITAL COST SUMMARY

Capacity	25 TPH	50 TPH	75 TPH
Capital Cost			
Pug Mill	$ 50,000	$ 70,000	$ 90,000
Surge Feeder	13,500	17,500	19,500
Reagent Delivery System	5,500	5,500	6,500
Electrical Central Circuit	21,000	22,000	23,000
Process Central Circuit	40,000	40,000	40,000
Reagent Storage Tanks	7,000	10,500	14,000
Equipment Installation	10,000	12,000	15,000
	$ 147,000	$ 177,500	$ 208,000
Annual Production (TONS)	90,000	180,000	270,000
Annual Depreciation	$ 21,000	$ 25,000	$ 30,000
Depreciation Cost per Ton	$0.23	$0.14	$0.11

It should be noted that the cost per ton figures in the summary table represent the cost for Mulled Coal only. If the cost of the Mulled Coal circuit was calculated on the basis of cost per overall clean ton (the accepted way of looking at coal preparation costs), then the capital cost for the Mulled Coal circuit would be down in the $0.03/ton to $0.06/ton range.

There has been no attempt to forecast the structural costs for a Mulled Coal greenfield project because the cost of each project would be significantly influenced by local conditions and local objectives, and there would be very few occasions where the Mulled Coal circuit would stand alone.

To put the magnitude of structural costs into perspective, the Mulled Coal circuit at capacities up to 75 TPH would fit into a plant bay measuring 20' x 20' x 20'.

3.2.4 Operating Cost

Operating costs are made up of labor, maintenance, and reagent costs. Labor and maintenance costs will not vary much from project to project, but cost per ton will vary significantly based on the capacity and annual throughput for the circuit. There are significant economics of scale in labor and maintenance cost. Reagent cost is by far the major cost in operating a Mulled Coal circuit. There are some economics of scale in reagent cost in the form of volume discounts, but the major influences on reagent cost are the type of application, the quality of wet cake and target Mulled Coal handling characteristics.

The following sections describe the nature of operating costs, the basis for some of the cost calculations and some anticipated cost ranges. Cost per ton calculations in the tables are based on a hypothetical model with operating conditions similar to the ones encountered at the Chetopa plant during the demonstration project.

The following assumptions are incorporated into the cost per ton tables:

1. The Mulled Coal circuit is integrated in a multi-circuit plant which is washing to 0" and is preparing a 1 1/4 " x 0 product for the high grade steam market.

2. The overall objective is to improve the handling characteristics of the 1 1/4" x 0 clean coal product by eliminating all handling problems related to wet fine coal.

3. The target quality of Mulled Coal is handling characteristics which are almost equal to those of bone dry coal (excellent quality).

4. The relevant characteristics of untreated wet cake are:

Size	28M x 0
Ash	10%-12%
Moisture	20%

5. The 28M x 0 size fraction makes up 20% of the overall 1 1/4" x 0 clean coal product.

6. The plant is scheduled to operate 15 hours per day for 240 days per year.

7. The reagent dose is the same dose applied in the project when processing 20% moisture.

3.2.4.1 Labor Costs

In most commercial applications the Mulled Coal circuit would be integrated into an existing multi-circuit plant, or it would be the final conditioning step in a new plant designed to rewash slurry pond material with a flotation or combination spiral/flotation circuit. In either case there would not be a full time operator or maintenance man assigned to the Mulled Coal section of the plant. The equipment components are all designed to operate unattended, and based on our experience throughout the demonstration project, there will be very few, if any, breakdowns or interruptions to production which are caused by the Mulled Coal circuit.

Although the equipment can run unattended, in applications where the Mulled Coal circuit stands alone, there would naturally be an operator assigned to the circuit for each scheduled production shift.

Labor costs can be projected for both the integrated and stand alone applications. All labor cost calculations are loosely based on UMWA labor rates as follows:

Scheduled straight time hours (240 x 7.25)	1740
Scheduled overtime hours (240 x 0.75)	180
Total scheduled hours	1920
Hourly pay rate	$ 17.06
Average shift differential	.15
	$ 17.21
Hourly overtime Premium	$ 8.53

ANNUAL LABOR COST

	Cost/Hour	Cost/Year
Straight Time Pay	17.21	33,043.00
Overtime Premium	.80	1,535.00
Paid Days Off	2.53	4,866.00
Payroll Taxes	1.57	4,017.00
Workmans Comp. Ins.	4.94	9,500.00
Health Ins.	3.33	6,400.00
Sickness and Accident Ins.	.31	600.00
Pension and Benefits	.85	1,632.00
Misc. Expenses	.22	421.00
	31.76	62,014.00

Labor cost projections are limited to costs which can be directly assigned to the Mulled Coal circuit. No attempt is made to project site specific costs such as delivering wet cake to the circuit or conveying Mulled Coal away from the circuit. These costs are significant, and they must ultimately be taken into account, but they are too dependent upon local conditions to include in a general forecast.

In an application where the Mulled Coal circuit is only a small part of a multi-circuit plant, one of the regular plant operators would be assigned to watch over the circuit along with his other duties. For instance, this could be a fine coal circuit operator whose duties might also include watching over the operation of spirals, flotation cells, and screen bowl centrifuges.

This type of application would be controlled from a central control room, and the control room operator would spend a small part of his normal day scanning the controls and computer screens related to the Mulled Coal circuit.

Finally a mechanic on an off-production shift will spend a small portion of his day maintaining and servicing circuit equipment.

It is estimated that a plant operator would spend about one hour of each production shift watching over the Mulled Coal circuit. A central control room operator would spend about one half hour scanning circuit controls in each production shift. On the off production shift, a mechanic would spend an average of one hour on circuit equipment for each scheduled production day. Collectively the operators and mechanic would devote 4 hours per production day on the Mulled Coal circuit.

The four hours per day represents the labor cost which can be directly assigned to the Mulled Coal circuit. This, in effect, is the added labor cost related to the circuit. Most integrated plants do not make any attempt to allocate labor costs to specific circuits, but if a Mulled Coal circuit was being considered for a plant addition, it is expected that yearly plant labor costs would increase by about $31,000. Cost per ton calculations, in accordance with the model described in Section 3.2, are as follows:

LABOR COST

Capacity	Annual Cost	Annual Prod. Mulled Coal	Cost/Ton Mulled Coal	Annual Prod. Clean Coal	Cost/Ton Clean Coal
25 TPH	$31,000	90,000	$0.34	450,000	$0.07
50 TPH	$31,000	180,000	$0.17	900,000	$0.03
75 TPH	$31,000	270,000	$0.11	1,350,000	$0.02

Labor cost estimates for a stand alone Mulled Coal plant are shown in the table below. Again the cost shown in the table is only that portion of total labor cost which can be directly assigned to the operation of the Mulled Coal circuit - which will require one full time operator for each scheduled production shift. Obviously there will be significant additional labor costs related to material handling to and from the Mulled Coal circuit. Cost per ton calculations illustrate dramatically the economics of scale as circuit capacity increases from 25 TPH to 75 TPH.

LABOR COST - STAND ALONE APPLICATIONS

Plant Capacity	Annual Cost	Annual Production	Cost/Ton
25 TPH	$124,000	90,000	$ 1.38
50 TPH	$124,000	180,000	$ 0.69
75 TPH	$124,000	270,000	$ 0.46

3.2.4.2 Maintenance Material Costs

The cost of maintenance materials and repair parts will only be an insignificant part of the total cost of operating a Mulled Coal circuit. The pug mill and surge feeder are very simple machines which are operated at a very low RPM, and their variable speed drives are designed to eliminate mechanical and wear problems. The reagent pump is equipped with a magnetically coupled drive which eliminates one of the primary pump maintenance problems, and since we are pumping a refined petroleum product, we do not expect wear problems on the wet end of the pump. Throughout the project, there were no mechanical failures, no replacement parts were used, and there was no measurable wear on any of the equipment components.

Since there was no measurable wear or part failure during the demonstration project, maintenance costs cannot be projected based on historical data. It is estimated that yearly maintenance material costs will not exceed 5% of the total installed cost of new equipment. The tables below show maintenance cost calculations for integrated and stand alone applications.

MAINTENANCE MATERIAL COSTS

Capacity	Annual Cost	Annual Prod Mulled Coal	Cost/Ton Mulled Coal	Annual Prod Clean Coal	Cost/Ton Clean Coal
25TPH	$ 7,000	90,000	$0.08	450,000	$0.02
50TPH	$ 9,000	180,000	$0.05	900,000	$0.01
75TPH	$10,000	270,000	$0.04	1,350,000	$0.01

3.2.4.3 Reagent Cost

The cost of reagent is by far the most significant cost in operating a Mulled Coal circuit. The reagent is a refined petroleum product, so the cost per pound can fluctuate along with crude oil prices. Current prices are in the $0.14 to $0.16 per pound range depending upon annual consumption (0.14/pound in a 75 TPH circuit and $0.16/pound in a 25 TPH circuit).

The quality of wet cake and desired handling characteristics from project to project will dictate required reagent doses and reagent costs, but the reagent cost of Mulled Coal produced for most commercial installations will fall into the range of $0.90 to $2.00 per ton. When the process is integrated into a multi-circuit plant, and is used to treat only 20% of the total product (the 28M x 0 size fraction), then reagent cost will be in the range of $0.18 to $0.40 per overall clean ton.

Figure 4 shows cost per mulled ton at various reagent doses for a 50 TPH circuit. Because of volume discounts, the costs for a 25 TPH circuit will be about $0.06 per ton higher, and the costs for a 75 TPH circuit will be about $0.06 per ton lower. The chart highlights the cost per ton for treating 20% moisture Chetopa wet cake (the moisture content of the model wet cake used for calculations throughout this section). It also highlights the cost per ton at the average reagent dose used in the demonstration project.

Figure 5 shows the same information in terms of costs per overall clean ton when the Mulled Coal circuit is part of an integrated plant and is processing only 20% of the total clean coal product.

The charts in Figures 4 and 5 are extended up to reagent doses of over 2%, with resultant costs as high as $4.75 per ton of Mulled Coal. Such high reagent doses would only be economically feasible in extreme cases where the Mulled Coal process could be used to convert an otherwise unmarketable high moisture/high ash wet cake into a marketable product.

3.2..4.4 Operating Cost Summary

Figure 6 summarizes operating costs in terms of cost per ton of Mulled Coal only, and in terms of overall clean tons in the model integrated plant.

Figure 4

REAGENT COST PER MULLED TON

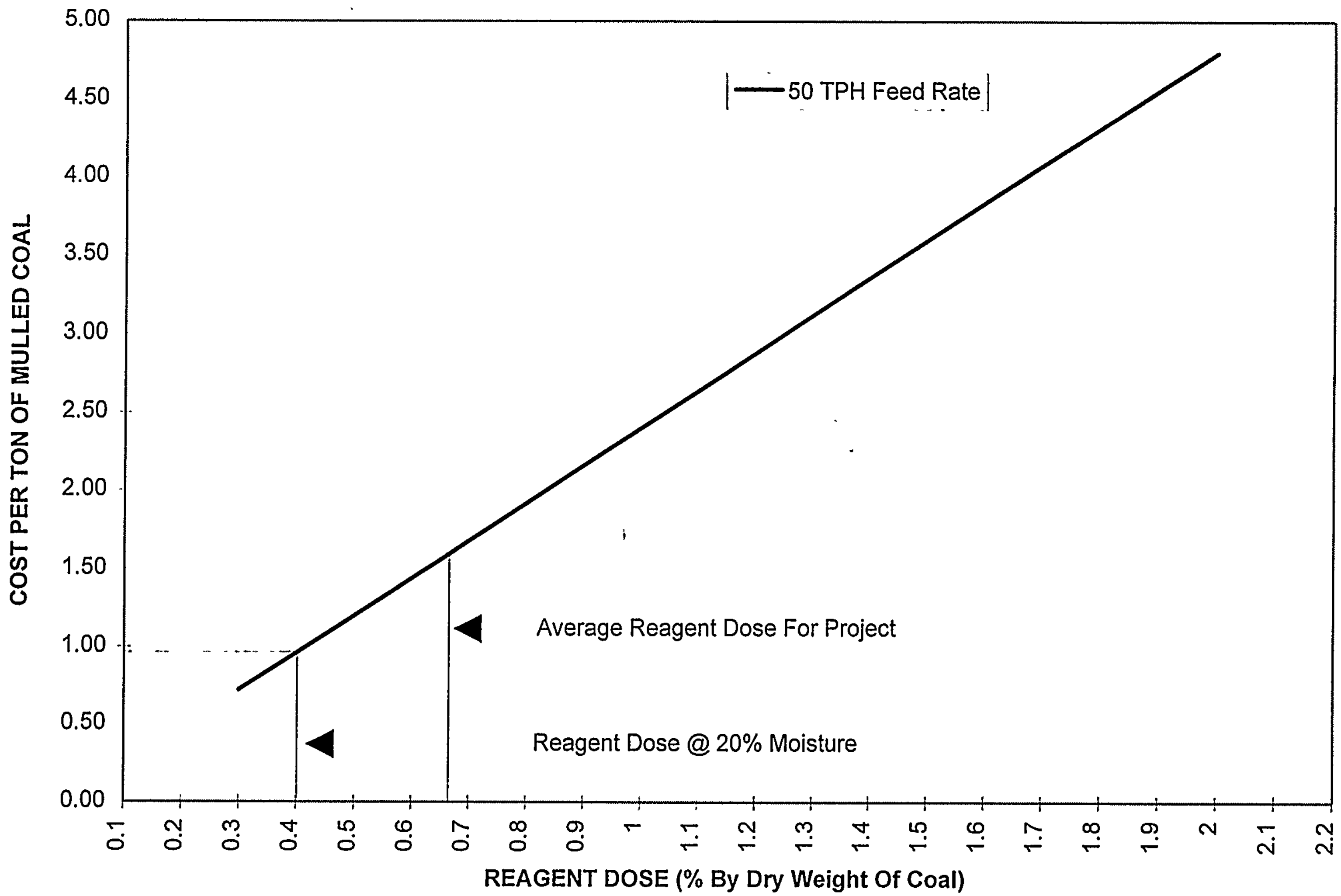


Figure 5

REAGENT COST PER CLEAN TON

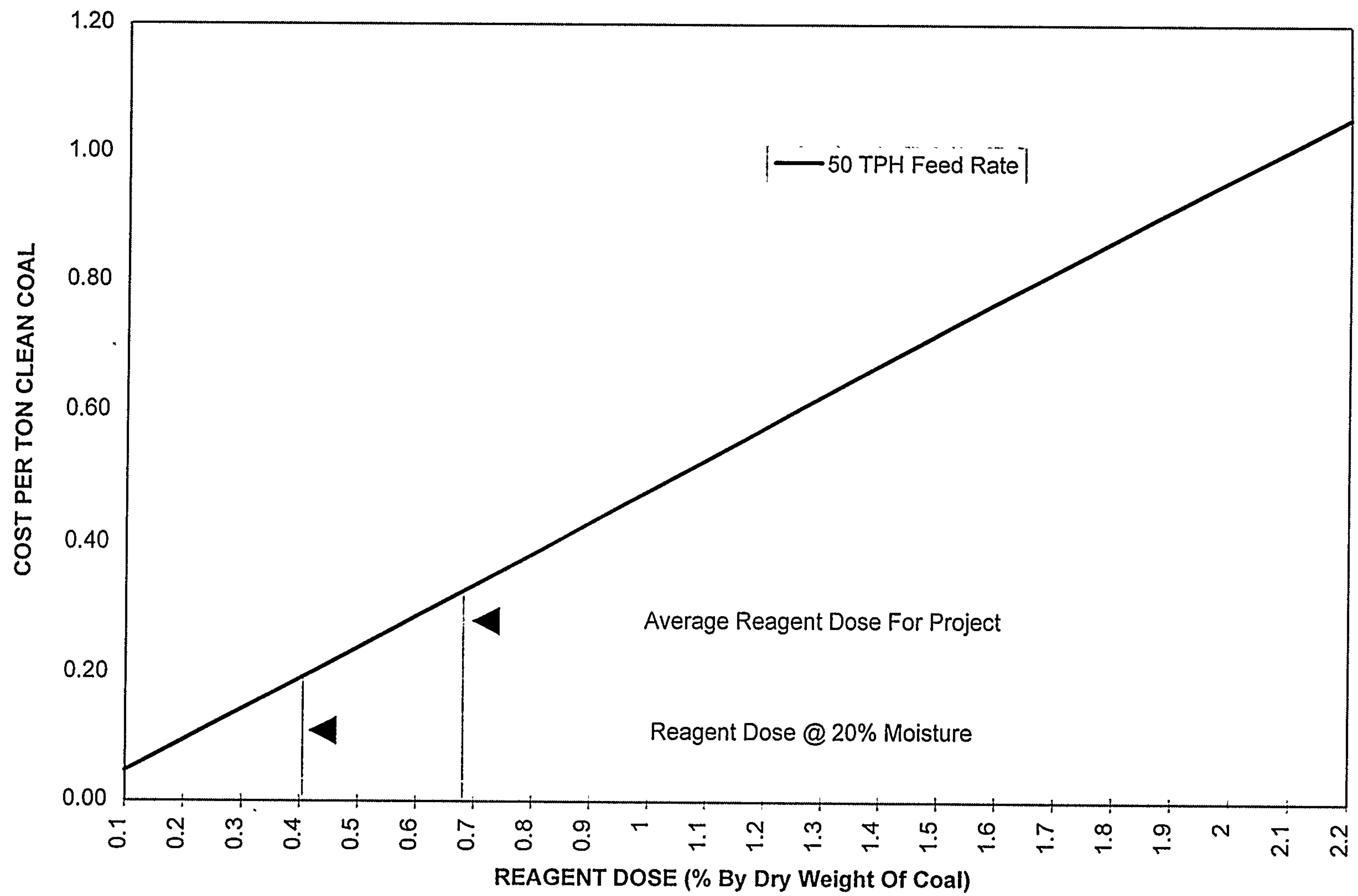
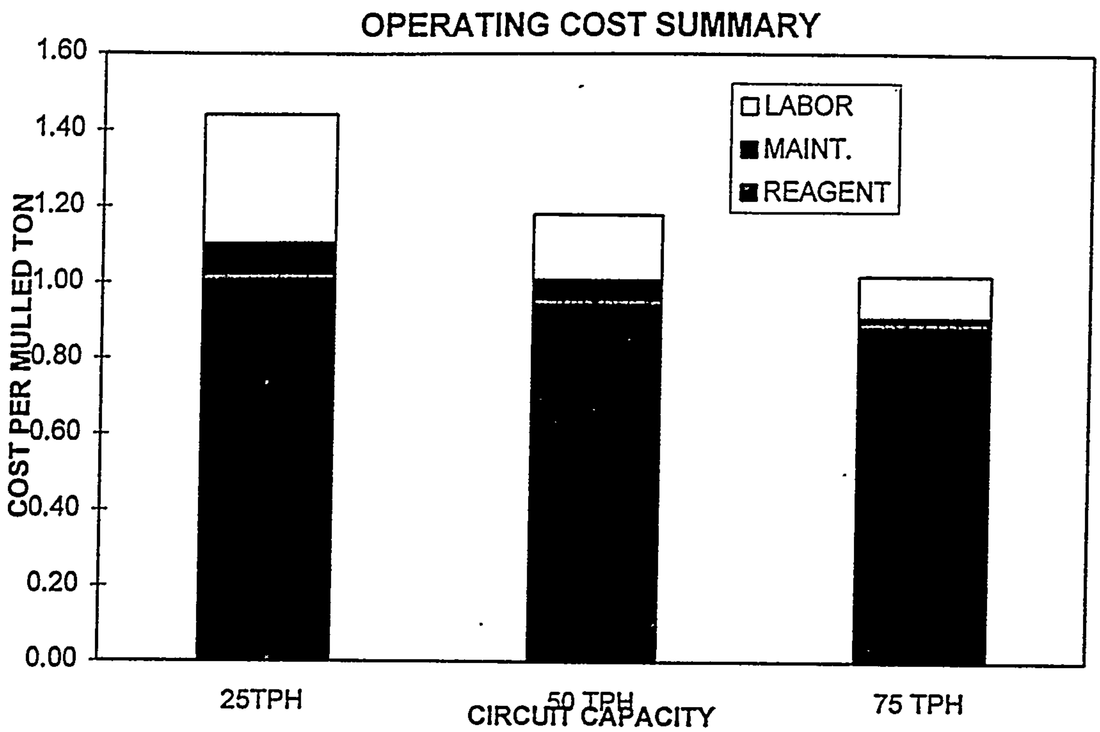
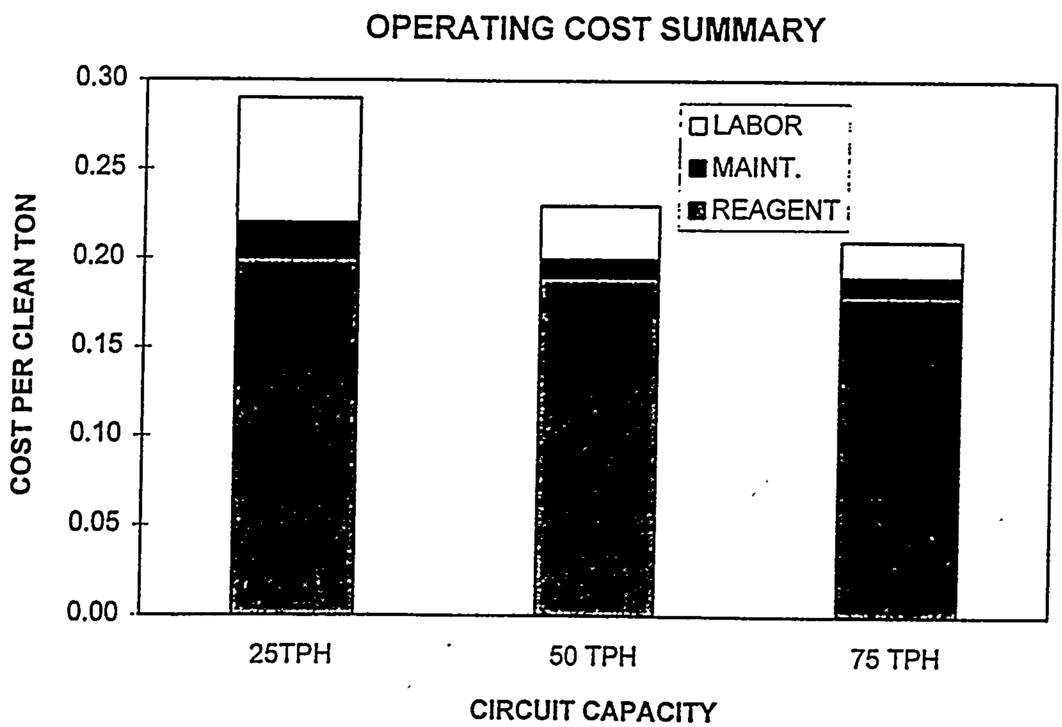


Figure 6


OPERATING COST SUMMARY
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
COST PER MULLED TON
LABOR
MAINT.
REAGENT
25TPH
50 TPH
75 TPH
CIRCUIT CAPACITY


OPERATING COST SUMMARY
0.30
0.25
0.20
0.15
0.10
0.05
0.00
COST PER CLEAN TON
LABOR
MAINT.
REAGENT
25TPH
50 TPH
75 TPH
CIRCUIT CAPACITY

4.0 SUMMARY

During this seventh quarterly period of the contract, activities were underway under Tasks 7 and 8 of the Work Statement. The major activities of the period were the data reduction and technical evaluations of Task 7, and the continuation of preparation of graphics and tables of information that will be usable for the final report. The estimates of costs for Mulled Coal produced in a commercial-scale Mulled Coal circuit within an existing plant were shown to be in the range of $1.10 to $1.65 per mulled ton or in the range of $0.20 to $0.30 per clean ton of Mulled Coal delivered with conventional coarse coal. These estimates include depreciated capital and operating costs.