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ENCOAL MILD COAL GASIFICATION PROJECT:

ENCOAL Project Final Report

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TRADEMARK NOTICE

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INTRODUCTION

This document is the summative report on the ENCOAL Mild Coal Gasification Project. It covers the time period from September 17, 1990, the approval date of the Cooperative Agreement between ENCOAL and the U.S. Department of Energy (DOE), to July 17, 1997, the formal end of DOE participation in the Project.

The Cooperative Agreement was the result of an application by ENCOAL to the DOE soliciting joint funding under Round III of the Clean Coal Technology Program. By June 1992, the ENCOAL Plant had been built, commissioned and started up, and in October 1994, ENCOAL was granted a two-year extension, carrying the project through to September 17, 1996. No-cost extensions have moved the Cooperative Agreement end date to July 17, 1997 to allow for completion of final reporting requirements.

At its inception, ENCOAL was a subsidiary of Shell Mining Company. In November 1992, Shell Mining Company changed ownership, becoming a subsidiary of Zeigler Coal Holding Company (Zeigler) of Fairview Heights, Illinois. Renamed successively as SMC Mining Company and then Bluegrass Coal Development Company, it remained the parent entity for ENCOAL, which has operated a 1,000-ton/day mild coal gasification demonstration plant near Gillette, Wyoming for nearly 5 years. ENCOAL operates at the Buckskin Mine owned by Triton Coal Company (Triton), another Zeigler subsidiary.

SUMMARY

The Liquids From Coal (LFC) technology employed at the ENCOAL Plant was invented by SGI International (SGI) of La Jolla, California and further developed by SMC Mining Company (SMC). The technology utilizes low-sulfur Powder River Basin coal to produce two new fuels, Process Derived Fuel (PDF) and Coal Derived Liquids (CDL).

These alternative fuel sources were intended to significantly lower current sulfur emissions at industrial and utility boiler sites and reduce pollutants causing acid rain. In support of this objective, the following goals were established:

- Provide sufficient products for full scale test burns
- Develop data for the design of future commercial plants
- Demonstrate plant and process performance
- Provide capital and operating cost data
- Support future LFC Technology licensing efforts

Each goal has not only been met, but exceeded. The ENCOAL Plant has been operated for nearly 5 years, during which the LFC process has been demonstrated and refined. Sixteen unit trains of PDF and 189 tank cars of CDL have been delivered using conventional means and have been successfully utilized on a commercial scale. PDF has successfully fueled major U.S. electric utility plants, been shipped overseas for test burns in Japan, tested as a blast furnace injectant, and combined with iron ore as a possible reductant in a direct reduced iron (DRI) process. Data have been collected over the life of the plant for use as a basis for evaluating and designing commercial plants, and the LFC licensing effort now includes several international agreements and prospects for future development.

PROJECT ORGANIZATION OVERVIEW

ENCOAL is the participant with the DOE and the signatory to the Cooperative Agreement and is the owner, manager and operator of the demonstration plant. ENCOAL is responsible for all aspects of the project, including design, permitting, construction, operation, data collection and reporting. ENCOAL managed the design and construction of the project through a project manager, who was assisted by a team of technical and managerial personnel. The engineering, procurement and construction of the plant were contracted to The M.W. Kellogg Company (Kellogg). Coal processed in the ENCOAL Plant is purchased from Triton, which also provides labor and administrative services, access to the site, associated facilities and infrastructure vital to the project. Equity funding, administrative services and product marketing are provided by service subsidiaries of Zeigler. Additional technical development support is provided by TEK-KOL, a general partnership between SGI and a subsidiary of Zeigler, that also has the primary responsibility for commercialization. All physical plant assets are assigned to ENCOAL. The LFC technology is owned by TEK-KOL and licensed to ENCOAL.

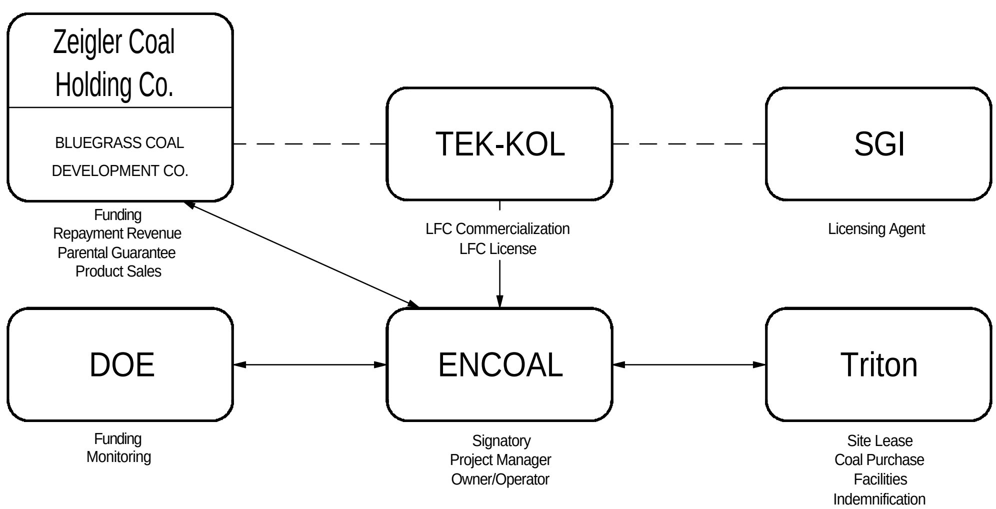


Figure 1: ENCOAL Project Organization.

LOCATION

The demonstration plant is located in Campbell County, Wyoming, approximately 10 miles north of the county seat of Gillette. The site is within Triton's Buckskin Mine boundary, near the mine's rail transportation loop. Active coal mining and reclamation operations surround the demonstration plant site. *(See Figure 2: ENCOAL Project Location)*.

The ENCOAL Plant was located at the Buckskin Mine site to take advantage of the existing mine facilities and to reduce capital and operating costs. The proximity of the ENCOAL project to the mine and subsequent expansion facilities provided optimization opportunities for ENCOAL, but also required some changes in ENCOAL's original plans. Examples were changing grade elevations, moving conveyor supports, using existing buildings and moving temporary construction facilities. The sedimentation pond and sump system also evolved over a course different from what was originally planned, but the end result was an arrangement beneficial to both Triton and ENCOAL. *(See Figure 3: ENCOAL Site Plot Plan)*.

Figure 2: ENCOAL Project Location.

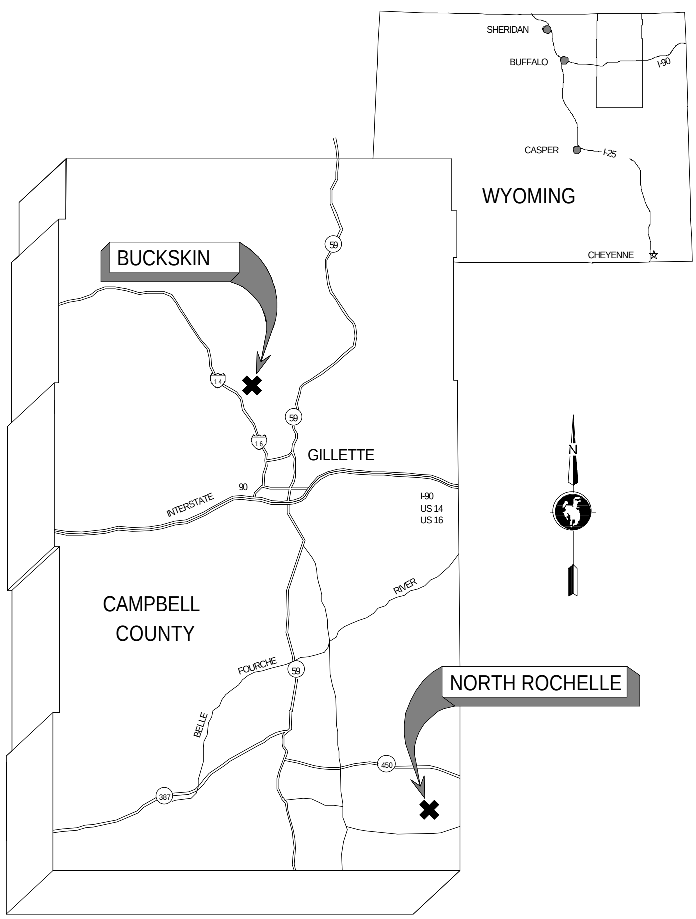
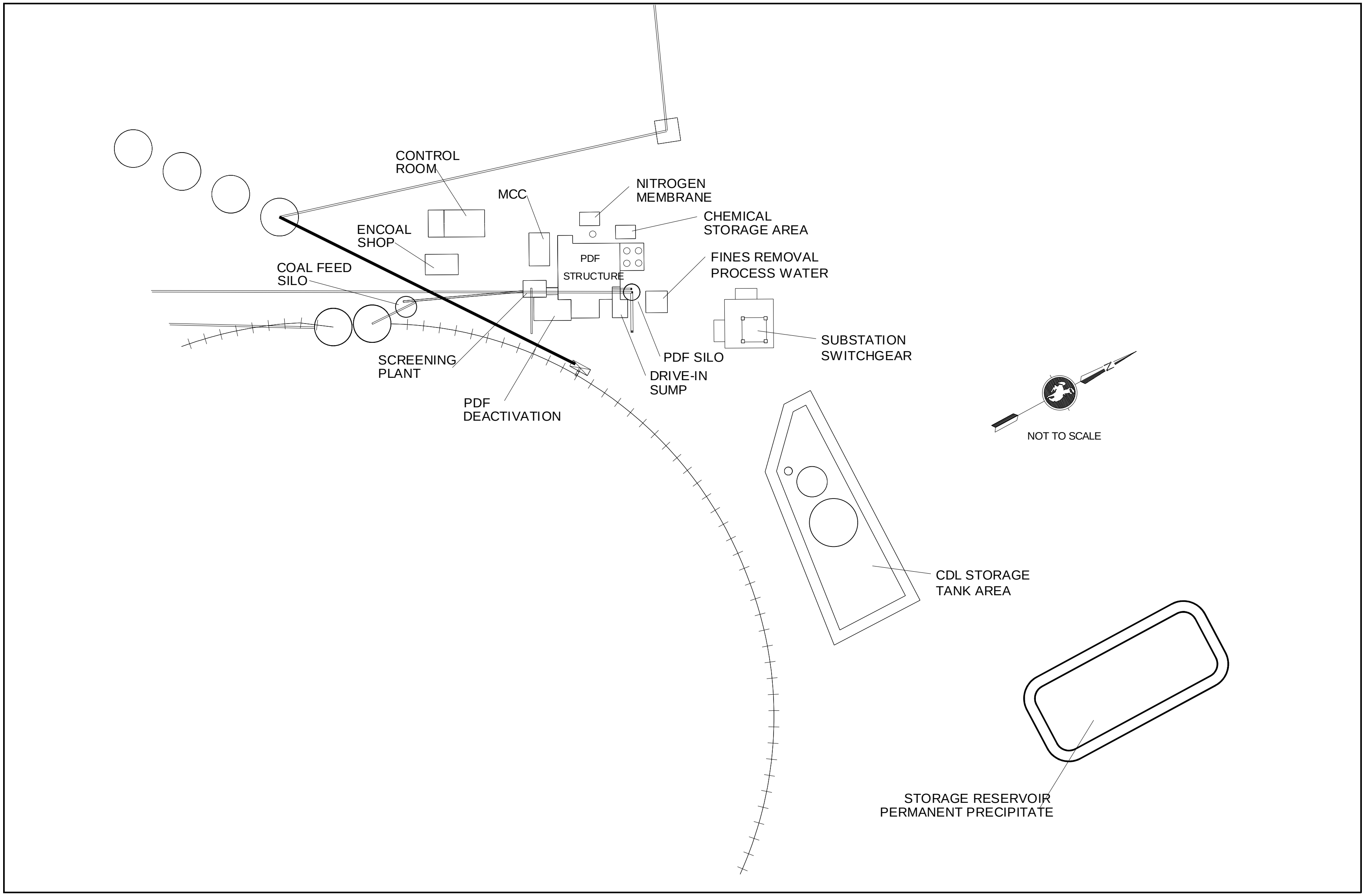


Figure 3: ENCOAL Site Plot Plan.



PROCESS CONCEPT

The LFC technology uses a mild pyrolysis or mild gasification process that involves heating the coal under carefully controlled conditions. The process causes chemical changes in the feed coal in contrast to conventional drying, which leads only to physical changes. Subbituminous coal contains considerable water, and conventional drying processes physically remove some of this moisture, causing the heating value to increase. The deeper the coal is dried, the higher the heating value and the more the pore structure permanently collapses, reducing reabsorption of moisture. However, deeply dried Powder River Basin coals exhibit significant stability problems when dried by conventional thermal processes. The LFC process overcomes these stability problems by thermally altering the solid to create PDF and CDL.

Specification PDF is a stable, low-sulfur, high-Btu fuel similar in composition and handling properties to bituminous coal. CDL is a low-sulfur industrial fuel oil that can potentially be upgraded for chemical feedstock or transportation fuels.

Figure 4 is a simplified flow diagram of the ENCOAL process, which begins when run-of-mine (ROM) coal moves from existing Buckskin Mine storage silos to ENCOAL's 3,000-ton silo. Up to 1,000 tons/day of coal from this silo are continuously fed onto a conveyor belt by a vibrating feeder, crushed and screened to 2" X 1/8", and conveyed about 195 feet to the top of the plant building.

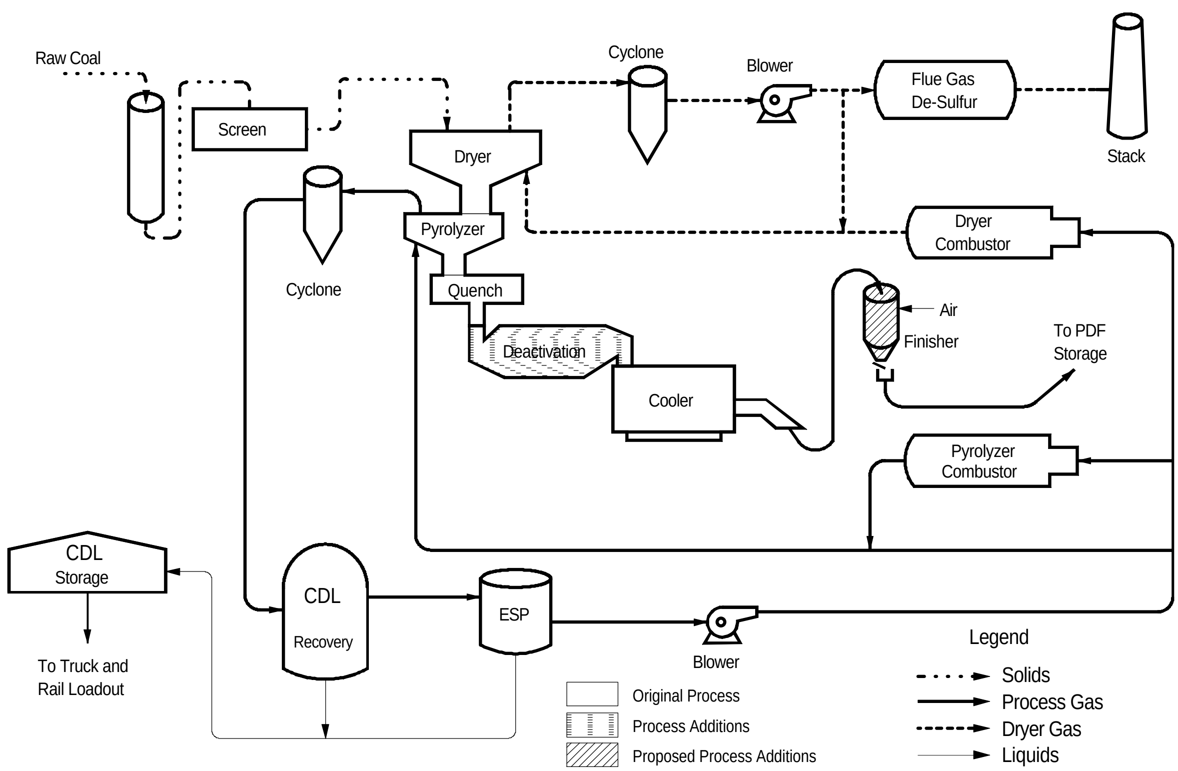


Figure 4: Simplifed Process Flow Diagram

The coal is then fed into a rotary grate dryer and heated by a hot gas stream. The solids residence time and temperature of the inlet gas have been selected to reduce the moisture content of the coal without initiating pyrolysis or chemical changes. The solid bulk temperature is controlled so that no significant amounts of methane, carbon monoxide or carbon dioxide are released from the coal.

The solids then report to the pyrolyzer rotary grate, where a hot recycled gas stream raises the temperature to about 1000°F. The rate of solids heating and the residence time are carefully controlled as these parameters affect the properties of both products. During the processing in the pyrolyzer, all remaining free water is removed, and a chemical reaction occurs in which volatile gaseous materials are released. After leaving the pyrolyzer, the solids are quickly cooled in the quench table to stop the pyrolysis reactions.

In the original process concept, the quench table solids were further cooled in a rotary cooler and transferred directly to a surge bin. A little more than halfway into the project life, extensive testing indicated the need for an addition to the process -- a separate, closed vessel for deactivating the solid product prior to final cooling and storage. The process was then altered to include a vibrating fluidized bed, or VFB, as part of a PDF deactivation loop. In the process as it currently exists, quench table solids are fed into the deactivation loop where they are partially fluidized and exposed to a gas stream in which temperature and oxygen content are carefully controlled. The deactivation gas system consists of a blower to move the gas stream, a cyclone to remove entrained solid fines, a heat exchanger to control gas temperature, and a booster blower to bleed off gas to the dryer combustor. The residence time, oxygen content and temperature of the gas stream have been selected to deactivate the coal within the VFB unit.

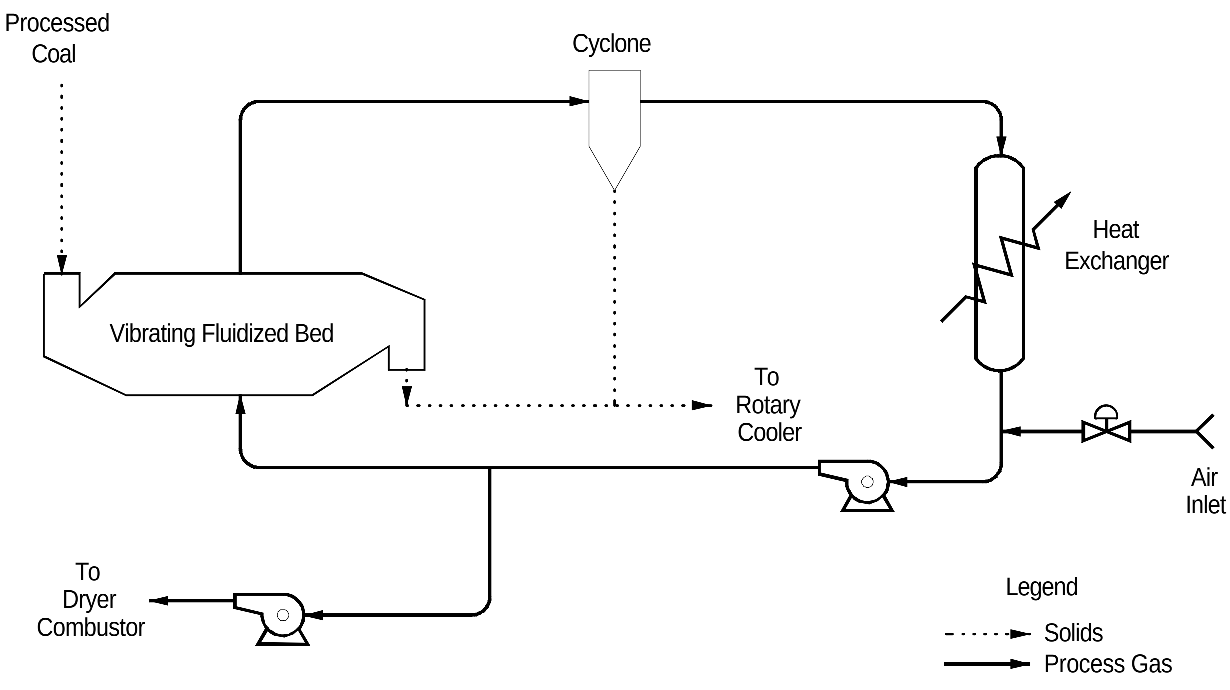


Figure 5: PDF Deactivation Loop Simplified Process Flow Diagram.

After treatment in the VFB system, the solids are cooled in an indirect rotary cooler. A controlled amount of water is added in the rotary cooler to rehydrate the PDF to near its ASTM equilibrium moisture content, an important step in the stabilization of PDF. A final or "finishing" step, the second stage of deactivation, has also been tested as an addition to the original process. In this step, PDF is oxidized at low temperatures, and then transferred to a surge bin. Since the solids have no surface moisture, they require the addition of a dust suppressant. MK, a very effective dust suppressant patented by SMC Mining Company, is added to the solid product as it leaves the surge bin. PDF, the resulting new fuel form, is transferred to storage silos where it is held for shipment by rail through existing Buckskin loadout facilities.

In the liquids recovery section of the plant, the pyrolysis gas stream is sent through a cyclone to remove entrained particles. The gas stream is then cooled in a quench tower to condense the desired hydrocarbons and to stop any additional pyrolysis reactions. The gas temperature is kept above the dew point of the water so that only CDL is condensed, preventing the formation of water in the process and the resulting separation and disposal problems. Electrostatic precipitators (ESP's) recover any remaining liquid droplets and mists from the gas leaving the condensation unit.

Most of the residual gas from the condensation unit is recycled to the pyrolyzer by a blower. Some of this gas is burned in the pyrolyzer combustor and blended with the recycled gas that provides heat for the pyrolyzer.

The remaining gas is burned in the dryer combustor, converting all sulfur compounds to sulfur oxides. Nitrogen oxides (NO_x) emissions are controlled by appropriate design of the combustor, based on evaluation of NO_x control technologies for low-Btu gases. The hot flue gas is blended with the recycle gas from the dryer to provide heat and gas flow necessary for drying. The exhaust gas from the dryer loop is treated first in a wet scrubber followed by a horizontal scrubber, both using a water-based sodium carbonate solution. The wet gas scrubber recovers fine particulates that escape the dryer cyclone, and the horizontal scrubber removes most of the sulfur oxides from the flue gas. The spent solution discharges into a clay lined pond for evaporation.

The operation of the demonstration plant for over 4 years has yielded a mass of process data that is reflected in the design of a commercial plant. In a facility approximately fifteen times the capacity of the demonstration plant, (made up of three modules of five times the demonstration plant capacity), each commercial module will represent a 5-to-1 scale up. Much research and testing have gone into selecting equipment for a commercial venture, in particular, tailoring the PDF deactivation and stabilization process equipment to fit a commercial-size plant. A number of improvements in the production of CDL will also be incorporated into the larger plant design, based on production experience and research, as well as improved knowledge of CDL marketing. Details on the commercial design are discussed in a separate report.[1]

PROJECT DESCRIPTION

Achieving the global objectives of producing, transporting, testing and marketing PDF and CDL required the design, construction and operation of the 1,000-ton/day demonstration plant and support facilities. Work scope and cost of the project were significantly reduced because the host Buckskin Mine owns and maintains coal storage and handling facilities, rail loadout, access roads, utilities, office, warehouse and shop facilities. Operations staff, supervision, administrative services and site security were also contracted with Triton, with the balance of the project requirements provided by ENCOAL and its subcontractors.

The project was divided into three phases:

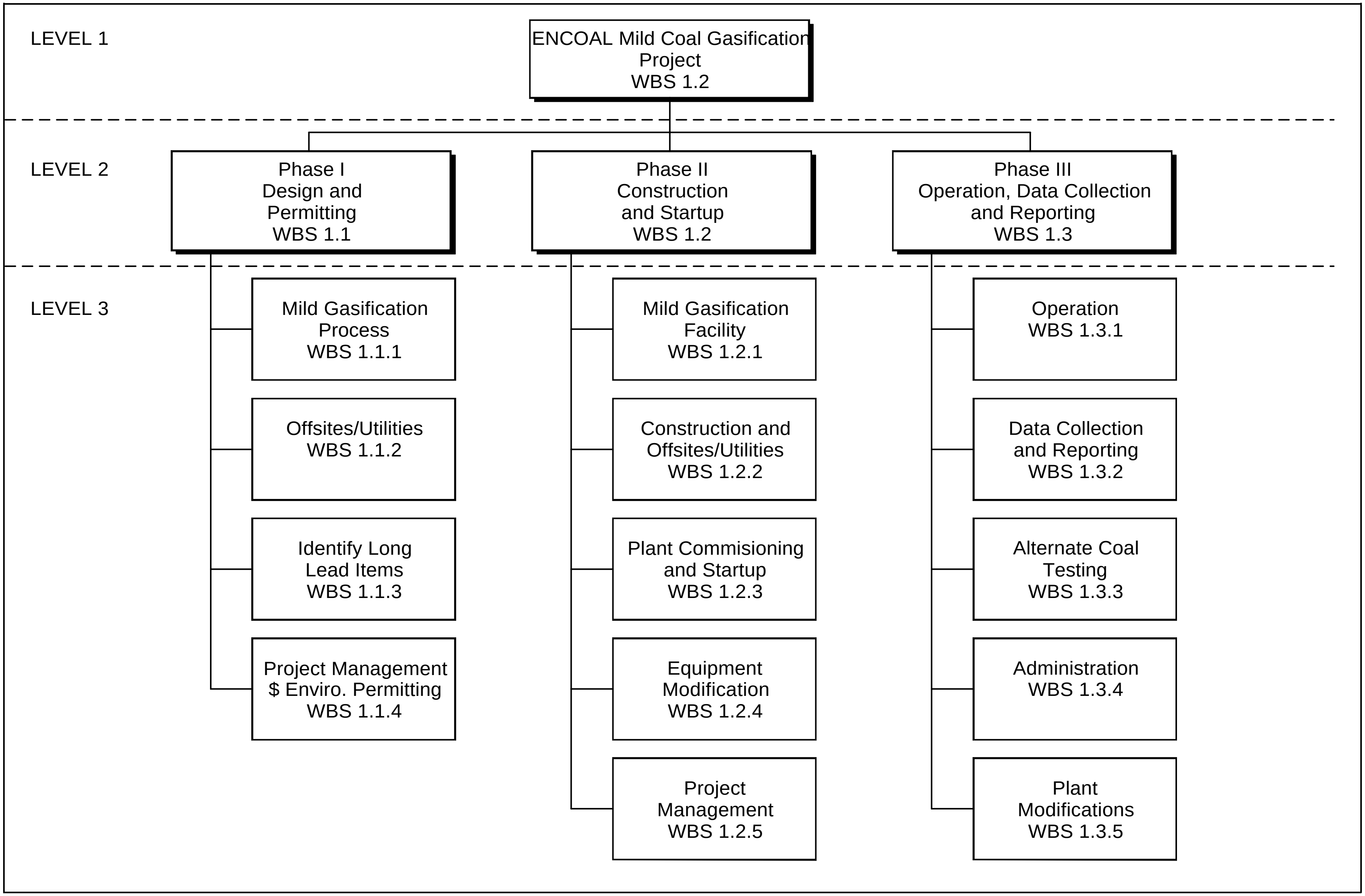
Phase I -- Design and Permitting
Phase II -- Construction and Start-up
Phase III -- Operation, Data Collection, and Reporting

Two budget periods encompassed the work, the first covering Phases I and II, and the second covering Phase III. To organize the work load during these phases, a Work Breakdown Structure was developed for the project. *(See Figure 6: ENCOAL Project Work Breakdown Structure (WBS)).*

Engineering, procurement and construction management for the project were handled by Kellogg. Kellogg's scope of work included home office design, project coordination, field construction supervision, scheduling, project controls, procurement and project management. Kellogg's engineering was considered complete by July 1991, when the project shifted to the field, and remaining engineering tasks were performed by ENCOAL. All permitting requirements were handled by ENCOAL, and field engineering and construction support were handled by ENCOAL's technical team.

Construction was performed by Kellogg Constructors, Inc., (KCI), Kellogg's construction arm, and ENCOAL handled the bulk of remaining Phase II activities: operations planning, training, maintenance planning, staffing, plant commissioning and start-up. DOE approval of the Continuation Application in July 1992 marked the beginning of ENCOAL's Phase III activities: operations, data collection and reporting. Preparation of written plans and manuals was an integral part of both Phase II and III activities.

Figure 6: ENCOAL Project Work Breakdown Structure (WBS).



EXECUTIVE SUMMARY FOR PHASES I AND II -- September 1990 through May 1992.

In September 1990, the Cooperative Agreement between ENCOAL and the DOE was signed, moving the LFC process, in development in laboratory settings since the early 1980s, into the realm of reality. Varied activities took place in the 2 years following the signing, carried out by a number of entities but focused on a single outcome -- the construction of an operable ENCOAL Plant. While there was some overlap of Phase I and II activities, almost all Phase I activities were completed well ahead of the DOE baseline schedule.

PHASE I ACCOMPLISHMENTS -- September 1990 through July 1991

1.0 Design and Permitting

1.1 Process/Plant Design

In anticipation of signing the Cooperative Agreement, the ENCOAL and Kellogg technical team and engineering task forces were mobilized in Houston, Texas, in July 1990. These two groups reviewed the 1988 LFC process release, and updated process and instrumentation diagrams, design basis documents and process flow diagrams.

During this time, SGI completed adaptation of their proprietary control system, and programming of the programmable logic controller (PLC) system moved toward completion.

When design and engineering for the plant were nearing the 60% milestone in October 1990, ground for the ENCOAL Plant was broken. Eight months later, Kellogg had completed 90% of its design and engineering efforts, leaving only some civil engineering, electrical and instrumentation work. All other disciplines were turned over to the ENCOAL field engineering team, and in July 1991, the Kellogg home office engineering task force was demobilized. All Houston engineering operations concluded as well.

In January 1991, computer stations and software were received, and by spring, initial programming of plant control systems was complete. As start-up procedures evolved the program underwent major revisions, but was considered to be about 40% complete by August 1991.

1.2 Off-Sites and Utilities

Because only expensive propane gas was available at the site, ENCOAL negotiated a contract for natural gas service. The contract included a significant reduction in the estimated price of the gas delivered, as well as installation of a major portion of line to the site at a price below the piping contractor's bid. The agreement also requires the gas supplier to maintain the line. During the 10 months of Phase I, Kellogg released all major construction design packages for bid, including off-sites underground piping, off-sites foundation concrete work and four buildings.

1.3 Identify and Design Long Lead Items

ENCOAL and Kellogg teams identified and requisitioned all long delivery items, including critical items such as the dryer, pyrolyzer, quench chamber and associated equipment, PDF cooler and ESPs.

1.4 Project Coordination and Environmental Permitting

Service agreements were finalized with Triton for administrative support and plant operation, with Shell Mining Company for technical and administrative support, and with SGI for technical services. The Project Management Plan and a draft of the Environmental Monitoring Plan were submitted to the DOE in accordance with the Cooperative Agreement.

The Wyoming Department of Environmental Quality, Air Quality Division (WDEQ-AQD) permit application was submitted in June 1988, and approval was received in June 1989. This removed a serious potential obstacle to the project as submitted to DOE. This permit to construct was required to break ground. Coinciding with the ground breaking, the federal environmental review process was completed with the issuance of an Environmental Assessment, a requirement of the National Environmental Policy Act (NEPA). As part of this process, the DOE issued the Finding of No Significant Impact Report. Fulfillment of the NEPA requirements completed Cooperative Agreement requirements and cleared the way for initiation of Phase II construction and start-up activities.

State permitting took place with the Wyoming Department of Environmental Quality (WDEQ). Most early permitting activities centered around the question of a precipitate disposal pond. Because the WDEQ questioned the location of a permanent precipitate disposal pond, ENCOAL submitted an alternative permit application to allow modification of an existing Buckskin mine sediment pond. With the addition of an 18-inch clay liner, this would serve as a temporary storage pond for ENCOAL's precipitates. Approval of the application was critical, as lack of approval would have postponed construction until 1992. The WDEQ approved the application, giving the go-ahead for construction of all facilities except the permanent disposal pond. The temporary pond served into 1997, when the permanent precipitate storage reservoir was completed.

The ENCOAL HazOp review, held to identify any potential operational safety hazards, was completed in the spring of 1991. Several action items were identified and issued to the appropriate groups for implementation. Start-up, operating, and shutdown procedures were written for use in training plant operators and technicians during this time.

PHASE II ACCOMPLISHMENTS -- October 1990 through May 1992

2.0 Construction and Start-Up

2.1 Construct Mild Coal Gasification Facilities

The demobilization of Kellogg's engineering task force in July 1991 marked ENCOAL's assumption of remaining engineering tasks and ENCOAL's and KCI's takeover of construction. Late 1991 saw the erection of the PDF structure and equipment, aboveground piping and steelwork. Considerable effort was put into winterizing the structures for interior work in cold weather: siding and natural gas heating were added to the PDF structure. By March 1992, refractory material had been installed in the combustors, dryer cyclone and large diameter duct, and structural steel for the screening building was complete. By June 1992, ENCOAL and KCI had completed the PDF structure and equipment. The CDL truck/train loadout platform was erected, and the CDL load-out was installed. Also in June, KCI construction personnel and subcontractors finished electrical and insulation work and left the site.

2.2 Construct Off-Sites and Utilities

The off-sites underground piping was almost complete by the fall of 1991. The natural gas company completed installation of the main supply pipeline, and the supply lines to the control room and PDF structure were commissioned and charged with gas during winter of 1992. Off-sites aboveground piping contract work was completed in February 1992, with the exception of the train loadout platform, which was completed in June.

2.3 Plant Commissioning and Start-Up

During this period, the sequencing in programming the PLCs was established, moving the plant further toward commissioning. Work teams wrote a preventive maintenance manual and an operations and training manual, and organized testing and chemical analysis plans. By the end of Phase II, all detailed individual run Test Plans were completed except for those associated with PDF deactivation, third-party stack gas testing, full-design-capacity gas loop flow testing and product test burns, which could not be completed until the onset of operations. SGI completed a preliminary data acquisition procedure for analyzing product samples. Operator training classes began February 1992, and included vital "hands-on" instruction and practice to support classroom work. Also during the winter of 1992, meetings on commissioning and testing procedures became an ongoing activity. An electrical and instrumentation contract was awarded to a small local firm during April 1992, and a mechanical maintenance contract was also awarded. These contracts helped significantly in accomplishing commissioning operations and other mechanical work, and in May 1992, commissioning activities concluded. All Phase I and II statement of work items had been completed except start-up, which began in mid-May and continued until mid-June when ENCOAL achieved its first 24-hour run.

2.4 Plant Modifications

No major modifications were made to the plant at this point, but problems with major equipment were recognized and corrected. For example, testing of the original design of the large bore piping revealed that the explosion doors released at too low a pressure. ENCOAL engineers worked in conjunction with the door manufacturer to design a new latch for the doors, and modified all five doors to hold seals under design pressure. Many platforms, handrails, and access points were added during this time to improve safety and maintenance.

2.5 Project Coordination

The coal purchase agreement with Triton was updated to reflect the method of coal measurement and to allow for the purchase of sized coal from Triton. A Pre-Manufacturing Notice for PDF was submitted to the U.S. Environmental Protection Agency (EPA) in December 1991, and granted during the winter of 1992. Drafts of Material Safety Data Sheets for PDF and CDL were also drawn up, reviewed internally and submitted to the EPA. Early in 1992, meetings were held with the WDEQ to discuss permit stipulations for continuous sulfur dioxide (SO_2) stack monitoring. These meetings resulted in agreements on quality control procedures, reporting requirements, monitoring conditions and equipment, and the WDEQ issued a letter stipulating the agreed conditions in January 1992. Midway through 1992, a formal permit for plant boiler emissions was received from the WDEQ.

EXECUTIVE SUMMARY FOR PHASE III -- Operation, Collection, and Data Reporting -- June 1992 through February 1997

In May 1992, the Continuation Application was submitted to the DOE, and 1 month later, ENCOAL accomplished the first continuous 24-hour run successfully producing PDF and CDL. These benchmarks officially moved the project into Phase III activities on July 17, 1992, 60 days after the submission of the application.

The almost 5 years comprising Phase III were a period of intense activity. As a first-of-its-kind enterprise, design and process difficulties were not unexpected, and much of Phase III was devoted to solving those problems, especially that of PDF deactivation. As ENCOAL teams resolved obstacles, and collected and analyzed operations data, the duration of plant runs lengthened, with some months exceeding 90% availability. PDF and CDL were produced and shipped using conventional equipment and successfully test burned at industrial sites. The operability of the plant and its equipment were proven, and a huge body of data was collected. The commercial plant vision reflects the amassed design, capital and operating cost data.

Although the ENCOAL Plant's tall structures, hot gases and large rotating equipment would seem to create real potential for injury, one of ENCOAL's most important accomplishments is its safety record. Since 1990, only nine reportable accidents and four lost time accidents have been reported for all personnel, including contractors and associated workers. This lost time accident rate is less than one-third the most recent available rate for petroleum and coal processing industries, while the number of reportables is less than one-fifth. As of May 31, 1997, ENCOAL workers amassed 1,600 days -- over 4 years -- without a lost time accident.

Compliance with federal and state environmental regulations has also been an important goal for the ENCOAL Project. Regular Mine Safety & Health Administration (MSHA) inspections since 1990 yielded only 10 minor noncompliance citations. With the exception of one Notice Of Violation issued by the WDEQ-Land Quality Division (LQD) for the land farm, Wyoming state inspections were consistently positive. Ongoing contractor and operations safety meetings, and comprehensive, continuing operator training contributed to these safety and compliance achievements.

3.1 Operation and Maintenance

Table 1 makes the division between early, pre-VFB operations to those after its introduction quite apparent. Because it improved PDF stability, this new equipment made it possible for the first time to ship PDF for test burns. At the same time the VFB was being installed, other major changes paved the way for increased PDF and CDL production: the sand seals in the pyrolyzer were replaced with water seals, and all three ESPs had been fitted with improved insulator design. A third modification, the installation of a process water fines handling system, also contributed to the considerable improvement in plant performance and subsequent production.

Pre-VFB			Post-VFB				
	1992	1993	1994	1995	1996	*1997	SUM
Raw Coal Feed (Tons)	5,200	12,400	67,500	65,800	68,000	28,000	246,900
PDF Produced (Tons)	2,200	4,900	31,700	28,600	33,300	14,200	114,900
PDF Sold (Tons)	0	0	23,700	19,100	32,700	7,400	82,900
CDL Produced (Bbl)	2,600	6,600	28,000	31,700	32,500	14,700	116,100
Hours on Line	314	980	4,300	3,400	3,600	1,944	14,538
Average Length of Runs (Days)	2	8	26	38	44	81	
* *Through May 31, 1997*							

Table 1: ENCOAL Plant Performance

Before VFB Installation (1992-1994)

Production/Operations

ENCOAL's first 24-hour run took place in June 1992. After that landmark event, mechanical problems, system debugging and equipment modifications were the primary focus until September 1992, when the ENCOAL Plant achieved a continuous 1-week run. A month later, the first shipment of 60,000 gallons of CDL was sent to TexPar, Inc., which experienced unloading problems. These experiences prepared ENCOAL to work with other customers, such as Dakota Gas, to handle CDL with heat tracing and tank heating coils. Customers reported no further CDL handling problems.

The months following the first production milestone included equipment problems that frequently shut down production. While some delays in the new facility had been expected, numerous runs were stopped while equipment was modified and repaired. To minimize the impact of these delays, tests were performed during each run, and data were aggregated to provide information for ongoing and future changes. Problem areas such as ESP failures, combustor controls and coal slurry handling were gradually resolved, although some difficulties with the sand seals, PLCs, material handling and process blowers remained. April 1993 saw an extremely successful 16-day run, which was continuous except for a 24-hour stoppage when the dryer sand seal failed. All planned tests were completed within the first 7 days; more were drawn up, and over 5,000 tons of raw coal were ultimately processed. A June run processed over 4,000 tons of coal and produced 2,500 barrels of CDL before ending in a planned shutdown.

Although improved in heating value, early batches of PDF revealed a tendency to self ignite. In an attempt to stabilize PDF using in-plant equipment, ENCOAL engineers first tried manipulating the process: speeds on the rotary cooler were varied; and solids flow, temperature and PDF oxidative deactivation were controlled in three separate stages within the rotary cooler. Mechanical equipment failures shortened the runs, but considerable data were collected for further study. Modifications were made to control solids flow and product cooling, but deactivation remained elusive. Early in 1993, it was concluded that a separate, sealed vessel was needed for product deactivation, and a search for a suitable design began immediately. In June 1993, the first of two planned VFBs was installed in series with the original plant equipment. Installation was completed in December 1993, and the entire system was commissioned in mid-January of the next year. See Section 3.5 Equipment Modification for more detail.

The first shipment of ENCOAL's liquid product to TexPar contained more solids and water than had been hoped for, but was considered usable as a lower grade oil. To reduce water content, ductwork and major equipment such as ESPs and the pyrolyzer cyclone were insulated, allowing temperatures throughout the process to remain above the dew point of water. As insulation was completed, CDL contained less water than previous batches, but still had a slightly higher solids content than desired.

After VFB installation (1994-1997)

<u>Production/Operations</u>

The VFB was designed to handle only half the ENCOAL plant's designed capacity; when proven, a second VFB was to be installed. During the test runs, the plant achieved operation at 50% of the design rate, as predicted.

Operations became notably smoother and more productive. This was attributable not only to the VFB's improved stabilization of the PDF and the subsequent increased ease of handling, but also to the replacement of the pyrolyzer sand seal with a water seal and the installation of the process water fines handling system.

All these improvements combined to produce a major landmark when ENCOAL shipped its first train containing PDF on September 17, 1994 to Western Farmers Electric Cooperative in Hugo, Oklahoma. Three runs in the winter of 1994 processed approximately 4,300 tons of coal, producing nearly 2,200 tons of PDF and 81,000 gallons of CDL.

May 1994 saw the best run to date -- 54 days of continuous operation, followed by a 68-day run in the fourth quarter of the year. However, VFB deactivation was not complete: stabilization still involved "finishing" using pile layering as well as blending with run-of-mine (ROM) coal, increased silo retention time and higher rehydration.

Test Burns

Commercialization of PDF from the ENCOAL Plant took a major step forward in 1994. In the fall of that year, ENCOAL shipped six trains to two customers. Shipments made to the first customer, the Western Farmers Electric Cooperative in Hugo, Oklahoma, started at a 15% blend level and ranged up to 30% PDF, the upper level being determined by the heat content limit of the boilers. Shipments to the second customer, Muscatine Power & Water in Muscatine, Iowa, started at 40% PDF and ranged up to 91%. The rail cars in this shipment, the first full unit train of PDF, contained near-100% PDF with a cap of ROM coal to prevent fines losses. The PDF shipped exhibited no handling, dustiness or self-heating problems.

ENCOAL met all its goals for these first shipments: to demonstrate its ability to coordinate with the Buckskin Mine in loading and shipping consistent blends, to ship PDF with dust generation comparable to or less than ROM Buckskin coal, and to ship PDF blends that were stable with respect to self heating. Furthermore, ENCOAL intended to demonstrate that PDF could be transported and delivered to customers using regular commercial equipment. With respect to utilization, the goal was for customers to burn trial amounts (½ unit train minimum) of PDF blends with minimal adjustment of equipment.

ENCOAL's test burn shipments became international when Japan's Electric Power Development Company (EPDC) evaluated 6 metric tons of PDF in 1994. The EPDC, which must approve all fuels being considered for electric power generation in Japan, found PDF acceptable for use in Japanese utility boilers.

Early 1995 saw much increased plant volume when 13,700 tons of raw coal were processed in a 1-month period. Plant availability reached 89%, with downtime attributable to the replacement of the original quench table heat exchanger with a new, high capacity unit. ENCOAL shipped two additional trains to Muscatine and three trains to its third customer, Omaha Public Power District in Omaha, Nebraska. This customer had been burning Powder River Basin coal in a boiler designed for bituminous coal for some time, and the increased heat content of the PDF blends helped increase plant output.

ENCOAL began shipping unit trains of 100% PDF for the first time in 1996. By the end of October, two 100% PDF unit trains were delivered to two separate utilities for test burns. The first was burned in Indiana-Kentucky Electric Cooperative's Clifty Creek Station, which is jointly owned by American Electric Power. The PDF was blended with Ohio high-sulfur coal at the utility and burned in the Babcock & Wilcox open-path, slag-tap boiler with full instrumentation. Blends tested ranged between 70 and 90% PDF, and burn results indicated that even with one pulverizer out of service, the unit capacity was increased significantly relative to the base blend. More importantly, there was at least a 20% NO_x reduction due to a more stable flame.[2] Completion of this test burn achieved a primary project milestone of testing PDF at a major U.S. utility. The remaining 100% PDF unit train was sent to Northern Indiana Power Services Company and to Union Electric's Sioux Plant near St. Louis, Missouri.

Figure 7: PDF Train

By the end of May 31, 1997, 246,900 tons of coal had been processed into 114,900 tons of PDF and 4,875,000 gallons of CDL. Over 83,500 tons of PDF had been shipped to seven customers in six states, as well as 203 tank cars of CDL to eight customers in seven states. Tables 2 and 3 summarize the PDF and CDL shipments for the life of the project. Further detail on PDF and CDL test burns and shipments can be found in early evaluative reports.[3]

DATE LOADED	CUSTOMER	BLEND (%PDF)	TONS SHIPPED			HEAT CONTENT (Btu/lb)
			PDF	COAL	BLEND	
09/17/94	W. Farmers	14.4	922	5,448	6,370	8,760
09/24/94	W. Farmers	21.2	1,080	4,020	5,100	8,910
10/01/94	W. Farmers	25.1	1,508	4,493	6,001	8,940
10/10/94	W. Farmers	31.9	1,603	3,241	5,024	9,310
10/24/94	W. Farmers	24.0	2,665	8,426	11,091	9,060
11/23/94	Muscatine	39.0	1,957	3,122	5,079	9,630
11/29/94	Muscatine	66.6	3,423	1,713	5,136	9,670
12/13/94	Muscatine	90.7	10,576	1,082	11,658	10,000
04/23/95	Muscatine	33.0	3,979	8,094	12,073	9,127
05/05/95	Omaha PPD	24.4	2,711	8,412	11,123	8,940
05/11/95	Omaha PPD	24.0	2,669	8,464	11,133	8,939
05/13/95	Omaha PPD	26.0	2,952	8,398	11,350	8,854
08/16/95	Muscatine	94.0	6,750	434	7,184	9,873
04/25/96	IKEC (AEP)	100.0	9,739	0	9,739	10,682
07/22/96	Union Electric	100.0	11,260	0	11,260	10,450
11/06/96	NIPSCO & Union Electric	100.0	11,700	0	11,700	11,100
12/10/96	Black Hills Corp.	46.7	700	800	1,500	9,158
3/21/97	IKEC (AEP)	53.0	7,356	6,523	13,879	9,486

Table 2: Summary of Trains Shipped Containing PDF *(Through 5/31/97).*

CUSTOMER	# OF CARS	DESTINATION	USE
Dakota Gas	101	Beulah, ND	Industrial Boiler
Texpar	3	Milwaukee, WI	Small Boilers
3 M Company	14	Hutchinson, MN	Industrial Boiler
Kiesel	2	St. Louis, MO	Blend W/ #6 Oil
US Steel	2	Chicago, IL	Steel Mill Blast Furnace
Michigan Marine	18	Detroit, MI	Blend W/ #6 Oil
M&S Petroleum	40	Lake Charles, LA	Fuel Oil Blend
Baka Energy INC.	23	Houston, TX	Fuel Oil Blend

Table 3: Summary Of CDL Tank Car Shipments *(Through 5/31/97)*.

3.2 Data Collection and Reporting

Monthly and Quarterly Technical Progress Reports and Quarterly Environmental Monitoring Reports have been submitted on a regular basis, while other reports were delivered as scheduled. A draft Design Report was submitted in December 1992, and in July 1994, a draft of the updated Project Management Plan for Phase III activities was submitted, along with an Environmental Information Volume Update. A revised Public Design and Construction Report was drafted to include civil design and construction of the project, and was submitted to the DOE in December 1994, along with the final ENCOAL Evaluation Report.

The organizational changes resulting from the move into Phase III and Zeigler's purchase of ENCOAL were reflected in the updated Project Management Plan, which was submitted in final form to the DOE in September of 1996.

Data collection also included compilation of information from all production runs. ENCOAL developed test plans prior to each start-up, and organized the data collected into "run books." These books contained the data sheets, test results and computer trending information for each plant test to be used as reference for future plant project designs or records. The books were also used to create reports on overall plant performance and to create a summary of significant plant operation run data. This proprietary information is kept at the ENCOAL plant site and is available for review on an as-needed basis for those covered by confidentiality agreements.

Plant operation and test data have been collected since the beginning of the operations phase, and Table 1, p.15 summarizes significant run data for Phase III.

3.3 Alternate Coal Testing

Two major goals of the ENCOAL Project involved demonstrating the LFC technology and collecting data applicable to a commercial plant. In support of those goals, ENCOAL demonstrated the processing of Buckskin coal and sought to test a variety of other coals and lignites. Alternate coal testing first took place in November 1995, when 3,280 tons of North Rochelle mine subbituminous coal were processed at the same plant parameters as those for Buckskin coal. The Plant performed well, but non-typical high ash content in the feed coal limited increases in heating value, the fines rate was doubled, and CDL yield was lower than predicted. *(Ash content of the feed coal during the test was approximately 5.6% compared to an expected 4.6% typical of the mine-wide reserve average)*.

A second alternate coal test took place in December 1996, when the ENCOAL Plant processed approximately 3,000 tons of Wyodak coal, and the Black Hills Corporation reciprocated with a test burn of a mixture of PDF fines and ROM coal. Results from the tests will be analyzed and used to determine the viability of a commercial plant sited at the Wyodak Mine. Initial results by both ENCOAL and Black Hills indicated no operability or handling problems.

Alaskan subbituminous coal, North Dakota lignite and Texas lignites were also considered for alternate coal testing. For North Dakota lignite, laboratory testing was carried out in two stages over a 4-year span. In 1992, a blend of two seams of Knife River lignites was tested at the TEK-KOL Development Center, where a three-step evaluation process has been found to be a reliable predictor for the applicability of the LFC process to different coals.

In the first step, the lignite's physical and chemical properties were compared to technical screening criteria -- good agreement suggested success in the next phase of testing.

The second step comprised small-sample testing using a thermogravimetric analyzer, and analysis of the resulting gases with Fourier Transform Infrared (FTIR) spectroscopy. Combining these results with proximate and ultimate analysis data for the as-received coal and the residual char generated a mass balance suitable for preliminary LFC plant design. Successful completion of this step demonstrated the technical feasibility of using the LFC process to upgrade the North Dakota lignite.

The third step employed large-scale sample testing in the Development Center's sample preparation unit, which is equipped with a CDL recovery system and FTIR analytical capability for gas analysis. The unit provided enough CDL and PDF for the detailed product analysis needed to obtain an accurate mass balance, and for product marketing assessments.

In 1996, Freedom Mine and Knife River lignite samples were also strength tested to determine which coals were more suitable for processing. The 1992 tests verified the applicability of the LFC process, while the 1996 strength tests indicated that the lignite would not break down excessively during processing.

Because the laboratory tests of these lignites appeared promising, ENCOAL solicited joint funding from the North Dakota Lignite Research Council for a North Dakota lignite alternate coal test at the ENCOAL Plant. This application was turned down in November 1996, and the test was abandoned. Based upon the successful laboratory screening test, however, ENCOAL believes that North Dakota lignite is an acceptable candidate for LFC processing.

Tables 4 and 5 summarize the PDF and CDL qualities of the alternate coal tests conducted to date, including laboratory data from North Dakota lignite.

PROXIMATE ANALYSIS	**ENCOAL Plant Run PDF** *Subbituminous* **(Buckskin Mine)** (1995 Average)	**ENCOAL Plant Run PDF** *Subbituminous* **(N. Rochelle Mine)** (11/21/95 - 11/26/95)	**ENCOAL Plant Run PDF** *Subbituminous* **(Wyodak Mine)** (12/14/96 - 12/16/96)	*** Laboratory Produced PDF** ***N. Dakota** Lignite* **(Knife River Mine)** *(Corrected to 8% Moisture)*
Heat Content (Btu/lb)	11,100	11,300	10,900	11,200
Moisture (%)	8.9	8.1	9.3	8.0
Ash (%)	8.9	7.5	9.7	11.3
Volatile Matter	24.5	22.3	25.5	22.5
Fixed Carbon (%)	57.3	61.8	55.0	56.9
Sulfur (%)	0.36	0.30	0.46	1.29
OTHER				
Hardgrove Grindability	47	46	42	51
#Sulfur/MMBtu	0.32	0.27	0.42	1.15
#SO_2/MMBtu	0.65	0.53	0.84	2.30
Ash Mineral Analysis	Same as Coal	Same as Coal	Same as Coal	Same as Coal
Ash Fusion Temperature	2220°F (1216ºC)	2250°F (1232ºC)	2220°F (1216ºC)	Not Measured

* North Dakota lignite information is based on laboratory data only and should not be directly compared to ENCOAL plant run material data.

Table 4: Average Representative Properties of PDF, Including Alternate Coal Tests

	ENCOAL Plant CDL *Subbituminous* **(Buckskin Mine)** (1995 Average)	**ENCOAL Plant CDL** *Subbituminous* **(N. Rochelle Mine)** (11/21/95 - 11/26/95)	**ENCOAL Plant CDL** *Subbituminous* **(Wyodak Mine)** (12/14/96 - 12/16/96)	*** Laboratory CDL** *N. Dakota Lignite* **(Knife River Mine)**
API Gravity (°)	2.3	3	0	-0.6
Sulfur (%)	0.6	0.3	0.5	0.7
Nitrogen (%)	0.7	1.6	1.1	1.0
Oxygen (%)	10.8	8.0	9.0	13.2
Viscosity @ 122°F (50ºC) cSt	240	350	330	326
Pour Point °F (ºC)	80 (27)	77 (25)	85 (29)	65 (18)
Flash Point °F (ºC)	218 (103)	220 (104)	215 (102)	150 (66)
MBtu/gal	140	138	140	126
Water (wt %)	0.6	0.5	0.7	6.8
Solids (wt %)	2 - 4	3.8	4.2	0.57
Ash (wt %)	0.2 - 0.4	0.6	0.7	0.04

* North Dakota lignite information is based on laboratory data only and should not be directly compared to ENCOAL plant run material data.

Table 5. Average CDL Quality, Including Alternate Coal Tests

3.4 Administration

ENCOAL's move into Phase III operations was followed by the transition from Shell Mining Company ownership and administration to that of Zeigler Coal. Zeigler became the source of legal and administrative services, as well as providing funding and Project guarantees through Bluegrass and Triton. Other services once furnished by Shell became the province of ENCOAL's sister subsidiaries. Franklin Coal Sales supplies marketing, Americoal provides accounting and purchasing support, and Triton leases the site, provides utilities and services, sells coal to ENCOAL, and handles accounts payable/receivable, purchasing, payroll and general accounting. These organizational changes were reflected in the updated Project Management Plan. See Section 3.2.

One of ENCOAL's primary administrative tasks was tracking progress toward completing milestones. Late in 1994, it became apparent that the project's primary objectives would not be attainable in the time remaining because of delays caused by construction of the PDF deactivation facilities and other plant modifications. An extension request for 2 years' additional operation with joint funding was submitted to the DOE by ENCOAL in

July 1994, together with an Evaluation Report and Extension Plan. The key objectives of the extension period were those necessary to achieve commercialization of the LFC technology: the collection of cost and design data for commercial plants, testing of alternate coals and test burns to support commercial contracts. The DOE granted a 30-day, no-cost extension to October 17, 1994, while the request was being evaluated, and approved the extension in October 1994, expanding their participation to September 17, 1996. After that time, the DOE granted no-cost extensions to complete alternate coal testing and final reporting by July 17, 1997.

Environmental Compliance

An integral component of demonstrating the LFC technology was to operate the plant while complying with environmental regulations, and considerable amounts of administrative time and effort went toward that goal during Phase III.

Air Quality Issues

Late in 1992, ENCOAL staff members met with the WDEQ to discuss the status of plant operation, notification requirements and the status of stack gas monitoring. As a result of this meeting, a letter was sent to the WDEQ confirming the stack gas monitoring schedule and explaining ENCOAL's temporary noncondensable gas venting arrangements installed for the pyrolyzer quench table. The letter, which also discussed the quench table steam condenser tests scheduled for January, was approved in December 1992.

In mid-1993, ENCOAL submitted a permit application for a vapor collection system exhaust on the process water system. The vapor collection system uses a small blower and an activated carbon filter to collect and filter nuisance odors from the existing process water containment areas prior to exhausting the filtered air outside the building. Although a permit was not required by current regulations, it was agreed that a permit would be prudent, and data were collected from plant runs to support a permit application.

Stack Gas Emissions

In October 1995, a third-party testing firm mobilized to perform emission testing necessary to obtain ENCOAL's permit to operate from the WDEQ. The stack and emissions testing using DEQ-approved protocol was successfully completed in November 1995, and indicated that the plant is operating within permitted limits for NO_x, sulfur oxides, carbon monoxide, volatile organic compounds, and particulates. The SO_2 Continuous Emission Rate Monitoring System for the ENCOAL plant stack gas was certified as a result of the testing.

Air Quality Permit

Revisions to the AQ permit, delayed since the beginning of Phase III by interruptions in plant operation, were reviewed by the WDEQ in March 1996, and ENCOAL responded to the Department's questions. In mid-1996, ENCOAL received a notice of completeness for its application for Section 21 AQ permit from the WDEQ. The permit included a 5½-acre laydown area that was not anticipated in the original application. The application proceeded smoothly through the technical review and was formally approved in November 1996.

Land Quality Issues

Permanent Precipitate Storage Reservoir

A permanent storage reservoir was part of ENCOAL's original plan, but because the WDEQ questioned the location of the permanent precipitate disposal pond, an alternative permit application was submitted, modifying an existing mine sediment pond (see Section 1.0 Design and Permitting). Because the temporary pond proved adequate far longer than originally believed, ENCOAL was allowed to defer permitting and construction of the permanent disposal pond until 1995, when geotechnical survey holes were drilled on the preferred site for the permanent precipitate storage reservoir. After core sample testing indicated that soils were acceptable at the construction site, the design for the pond was completed in cooperation with the WDEQ, and the permit application was finalized in June 1995. When the WDEQ determined that public notice would be required, construction was deferred, this time until 1996, and options to extend the life of the temporary pond were again evaluated. After weighing several options, a system designed to improve the evaporation rate was installed. The system included a portable diesel powered pump, floating platform and a nozzle bank to spray the effluent into the air. It was approved by the WDEQ and started up in September 1995.

The WDEQ reviewed the application for revisions to the permanent pond, and ENCOAL responded to WDEQ questions in March 1996. At that time, a bid package for construction of the permanent reservoir was sent to potential contractors. The permit for construction cleared public comment and was sent to WDEQ's head office; final approval for the reservoir was received in June. Reservoir construction began the first week in July and continued through 1996. This reservoir is scheduled to be commissioned for use in July 1997.

Land Farm

Early in 1993, ENCOAL initiated discussions for construction and permitting of an onsite land farm. The land farm, conceived in response to the collection of greater amounts of process water fines than originally anticipated, would biologically eliminate hydrocarbons from process fines prior to onsite disposal. It was intended as a temporary facility, since the ultimate plan is to transfer fines back into the PDF product.

The first step in the development of the land farm was the collection and testing of fines samples and the gathering of information from plant runs. In the fall of 1993, ENCOAL reviewed a preliminary design for the land farm before submission to the WDEQ, and construction began when preliminary approval from the WDEQ was received. Workers completed earthwork and underground piping installations in November 1993, and final piping and commissioning were scheduled for mid-January of the following year. Final approval was received in August 1994.

In the fall of 1995, the LQD of the WDEQ approved a permit for revisions that included a new concrete holding area for wet fines, a higher retaining dike to improve capacity, and provisions for continuous operation with pit disposal of treated fines. Specifications to complete the modifications were developed, and a bid package was issued. Modifications began in July 1996 and were completed 2 months later, and the facility was commissioned in October of the same year.

Intellectual Property Development

Demonstrating and proving the LFC technology required the resolution of a number of challenging problems: lighting burners in combustors with inert atmospheres, removing particulates and gases from process streams and suppressing dust on PDF, among others. Not only were the problems solved, but many of the innovative solutions qualified as patentable technologies. TEK-KOL currently holds patents on flue gas desulfurization, MK dust suppressant, twin-fluid dust collection system, and low-Btu combustion technology, and other patents have been applied for. The DOE has been informed of these inventions as required by the Cooperative Agreement, and Table 6 lists these technologies and their status.

Table 6: TEK-KOL INTELLECTUAL PROPERTY STATUS 3/12/97
DOE PATENT WAIVER ISSUED FOR ALL

No.	Subject of Invention	Inventors	Responsible Person	Filing Date	Estimated Bar Date	Patent Atty. Location	Status
1	U.S. Patent #5,401,364 a process for treating noncaking, noncoking coal to form char with process derived gaseous fuel having a variably controllable calorific heating value.	F. Rinker	F. Rinker	Filed 3/11/93 Name Change CIP 7/94	April 1994	Larry Meenan Toledo, OH	Issue Date: March 28, 1995
2	U.S. Patent #5,372,497 Process and Apparatus for igniting a burner in an Inert atmosphere. Issue Date: December 13, 1994	F. Rinker D. Coolidge	F. Rinker	Filed in Japan 11/29/95	May 1994	Larry Meenan Toledo, OH	Amended 9 Apr 96 Formal examination by Japanese patent office requested. Patent “Pending.”
3	Process for passivation of reactive coal char. Russian Patent #96105953/Feb 97	D. Coolidge F. Rinker E. Esztergar D. Horne	F. Rinker	Filed 9/8/95 U.S. Patent office.	May 1995	Larry Meenan Toledo, OH	U.S. awaiting examiner’s response to latest amendment filed 5 Dec 96. Filed 8 Apr 96 in Japan Filed 27 March 96 in Russia. Filed 8 May 96 in Uzbekistan. Filed 15 Apr 96 in Kazakhstan. Filed 25 July 96 in Indonesia. Patent “Pending” in U.S., Japan, Uzbekistan, Kazakhstan & Indonesia.
4	U.S. Patent #5,547,548 Pyrolysis Process Water Disposition.	M. Siddoway F. Rinker E. Esztergar	F. Rinker	Filed 7/18/94	May 1995	Ned Randle St. Louis, MO	Issue Date: 20 Aug 96
5	U.S. Patent #5,582,807 Method and apparatus for removing particulate and gaseous pollutants from a gas stream.	M. Siddoway C.F. Liao	F. Rinker	Filed 11/11/94	November 1994	Ned Randle St. Louis, MO	Issue date: Dec 10, 96.
6	Method for creating a hydrocarbon liquid from coal pyrolysis by condensation of the hydrocarbon liquid from the gas phase.	M. Siddoway A. Cover J. O'Donnell C. Chang R. Londrigan J. Frederick E. Manning S. Anderson	F. Rinker	Filed 11/4/94	November 9, 1994	Ned Randle St. Louis, MO	Final rejection received decision made not to pursue with U.S. Patent Office.
7	U.S. Patent #4,582,511 Spray system for MK dust suppression additive. (Issued Apr 15, 1986)	M. Siddoway C.F. Liao	F. Rinker	Filed 7/18/94	May 1995	Ned Randle St. Louis, MO	Original Patent Expires 2003 Decision made to not pursue with US Patent Office.
8	U.S. Patent #5,601,692 Process for treating non-caking coal to form passivated char. Russian Patent #96105954/Feb 97	F. Rinker E. Esztergar D. Coolidge D. Horne	F. Rinker	Filed 12/1/95 U.S. patent office.	April 1996	Larry Meenan Toledo, OH	Issue Date: 11 Feb 97 Filed 12 April 96 in Japan Filed 27 March 96 in Russia. Filed 8 May 96 in Uzbekistan. Filed 15 Apr 96 in Kazakhstan. Filed 25 July 96 in Indonesia. Patent “Pending” in Japan, Uzbekistan, Kazakhstan & Indonesia.
9	Lean Fuel combustion control method.	D. Coolidge T. Kuhn J. Powers F. Rinker	F. Rinker	Filed 10/30/95 U.S. patent office.	September 1995	Ned Randle St. Louis, MO	Formal Examination Requested. Patent “Pending.” Status inquiry to examiner has been sent in Nov 96. Second Letter sent Feb 97.

Commercial Plant

As part of its mission to develop data for a commercial plant, ENCOAL began work in March 1995 on a commercial plant cost and economics study. Teams developed a project definition and timeline schedule, and prepared to review plant design, capital costs, operating costs, CDL and PDF marketing, and overall costs and economics of a commercial venture. By April, the heat and material balance for the commercial plant design was completed, and work on material handling, cogeneration concepts, equipment selection and site infrastructure began. CDL upgrading was also studied to determine its feasibility in a commercial plant design, and upgrading studies continued through contracts with Dakota Gas and Kellogg. Mitsubishi Heavy Industries (MHI) became actively involved in August 1995, when ENCOAL delivered an updated heat and material balance, and MHI assisted by performing preliminary engineering and cost estimating for the LFC commercial plant modules. Preliminary subsystem design, equipment data specifications, motor list and flow sheets for dryer/pyrolyzer system were completed in October 1995. One month later, an initial commercial plant design was assembled for a scoping estimate, and an economics model incorporating the capital and operating costs was completed in December.

This body of information was compiled in three detailed Phase II studies completed by the TEK-KOL/MHI team: the Powder River Basin study that focuses on the North Rochelle mine site near Gillette, and two international studies on Indonesian coal mines operated by P.T. Tambang Batubara Bukit Asam (PTBA) and P.T. Berau.

The Powder River Basin Phase II Study, the cumulation of work by ENCOAL, MHI and TEK-KOL, provided the foundation for the decision to commence permitting for a commercial-size plant at the North Rochelle mine site. To that end, schedules for permit applications for air quality, industrial siting, land quality and Forest Service use have been developed and are being followed, and a hearing with the Industrial Siting Division resulted in issuance of an industrial siting permit in February 1997. Stormwater, surface water discharge and groundwater permits must also be obtained from the State of Wyoming, and federal permits, especially a large water storage reservoir permit, must be obtained.[1]

The Indonesian studies were the culmination of over 5 years work promoting the advantages of the LFC process in meeting many of Indonesia's needs. The PTBA study revealed promising economics, and while the P.T. Berau coal was determined to be an excellent LFC process candidate, local issues, including the price of feed coal, will have to be resolved before a commercial LFC plant can be considered for the area. MHI and Mitsui SRC of Japan are working with TEK-KOL on continuing commercialization efforts in Indonesia and other Pacific Rim countries.

To date, three Phase II studies have been completed, and enormous opportunities await in other areas. China, the world's largest producer and consumer of coal, offers particular potential for commercialization of the LFC technology. Regions of China are experiencing rapid economic growth, with the concurrent appetite for electrical power, and the country possesses huge reserves of subbituminous coal and lignites that are promising candidates for LFC processing. These factors, combined with the potential for environmental problems resulting from burning large quantities of coal, especially high-sulfur coal, make China an ideal candidate for the commercial application of the LFC technology. China's Ministry of Coal Industry has expressed keen interest in the LFC technology, and TEK-KOL's representatives continue to cultivate market potential in that country.

Developments in Russia have included the completion of a Phase I study in late 1995, which indicated that the coals tested were suitable for LFC upgrading. Work on a Phase II study is expected to begin this year, pending Russian agreement to proceed. If successful, this Russian endeavor could be the first of many projects in this country with huge potential reserves.

Other international opportunities await in the Pacific Rim, Southeast Asia, India, Pakistan, Eastern Europe and Australia. Mixed results from coal testing and less favorable economics, however, make these areas less promising than Indonesia, China and Russia, but background work will continue in all areas.

Domestically, Alaska, North Dakota, and Texas hold significant potential. The Beluga fields and Healy deposits in Alaska are considered promising locations for commercial LFC plants. Both have extensive reserves that are largely subbituminous and have low ash and sulfur, but both also involve high transportation costs. Laboratory tests of North Dakota coals from the Williston Basin have indicated that LFC processing would yield good quality PDF and CDL (see Section 3.3), and economics appear attractive. Texas lignites have been tested at the TEK-KOL Development Center as well, and some indicate acceptable PDF quality and CDL recoveries. Existing Texas lignite mines are located close to plants designed to burn ROM material, making the export of upgraded lignites into other markets the most likely possibility.

3.5 Equipment Modifications

Because the ENCOAL Plant is a first-of-its-kind operation, some equipment problems were anticipated; unexpected problems like stabilization were deeper and took much more time and effort than expected.

<u>Equipment Shakedown</u> - June 1992 - September 1992

In June 1992, ENCOAL accomplished its first 24-hour run, producing solid and liquid coproducts. Actual production highlighted needed changes in combustor control, conveyors, pump sizes, piping changes and sumps, and many modifications were made in the first 4 to 6 months of production.

<u>Equipment Design Modifications</u> - September 1992 - June 1993

As production runs lengthened, different problems emerged. Insulators on the ESPs proved to be unreliable, and 1 year after production began, all three had been redesigned with new insulator materials. Pyrolyzer and dryer sand seal problems surfaced late in 1992 as run intervals expanded. Seal design and materials were adjusted many times, but by August 1993, the sand seal in the pyrolyzer had been replaced with a water seal, and eventually, a water seal had replaced the sand seal in the dryer as well. A number of variations on the rotary cooler were tried in attempts to deactivate PDF using existing equipment. When this proved ineffective, the plant was shut down for the installation of the VFB system.

<u>Process Modifications and Optimization</u> - June 1993 - February 1997

A number of plant runs and extensive testing in 1992 and 1993 indicated that a separate, sealed vessel would be needed to deactivate PDF. After considerable study involving ENCOAL, SGI and the Development Center, a vibrating fluidized bed was selected, and the ENCOAL Plant was shut down in June for a 6-month installation period.

Between June and December 1993, the first of two planned 6' x 30' VFBs and support equipment were installed in series with the original plant equipment. The unit was designed to handle half the plant throughput; when it had proven itself, a second VFB could be installed. A process water fines handling system was also installed in 1993 to remove solids and cool the process water stream prior to recirculation. VFB construction and start-up were completed in January 1994, and the unit is still in operation.

By spring of 1994, production runs were considerably smoother and longer, achieving continuous runs of 54 and 68 days by mid-year. Although more than 20 different operating conditions were varied and evaluated during these runs, deactivation still required "finishing" using pile layering before being shipped. Blending with ROM coal, increased silo retention time and higher rehydration also contributed to stabilization.

Extensive study of run data and bench model tests indicated that more oxygen was needed to achieve deactivation. Better oxygen control and subsequent increased concentration of oxygen in the deactivation loop were planned for future test runs, along with stringent control on solids temperatures in the VFB. The decision also was made to "finish" the oxidative deactivation of the solids by laying the PDF on the ground outside the plant. This process, which came to be known as "pile layering," involved spreading the PDF in 12-inch thick layers, allowing PDF particles to react with oxygen in the air and become stable. As each thickness was stabilized, more PDF could be layered.

In-plant stabilization of PDF, however, still eluded the ENCOAL and SGI team. A "cascade oxidative deactivation" (COD) approach was studied extensively at the Development Center and tested in MHI's pot test unit in Hiroshima, Japan. The system involved exposing reactive PDF to a series of controlled temperature and oxygen gas streams, with each successive step being lower in temperature and higher in oxygen content.

In April 1995, a "stability task force" composed of ENCOAL and SGI representatives and selected consultants joined to develop an acceptable in-plant stabilization method and test it in the ENCOAL Plant. The chosen method would be developed in parallel with the ongoing COD work. The task force met with engineers and scientists from the Pittsburgh Energy Technology Center (PETC) and the Morgantown Energy Technology Center (METC) to identify areas where assistance was needed in solving stability problems. As a result of the meeting, a Cooperative Research and Development Agreement (CRADA), a separate, research-oriented accord with PETC, was developed, and a project combining the applied research efforts of ENCOAL, Western Syncoal, PETC and METC was formed. These entities would develop measurement methods, define reaction kinetics and mechanics, and evaluate new stabilization techniques. A Bureau of Mines test, nicknamed "Jar-O-R," was modified to measure product reactivity and is still used to measure the oxygen appetite of upgraded Powder River Basin coal.

By July 1995, the stabilization task force, working with the resources represented by the CRADA, performed successful bench scale tests for oxidizing PDF at low temperatures, and work began in fabricating a pilot-scale stabilization unit. At the same time, the COD unit was dismissed as a possible solution to stabilization problems, and investigations into using spray-on additives were concluded. At this time, the CRADA completed its contributions to stabilization research.

Design and installation of the Pilot Air Stabilization System (PASS) was completed in November 1995, and the unit operated from late November through January of the next year. PASS testing was successful: the PASS unit processed ½ to 1 ton of solids per hour, 24 hours a day, for 2½ months. Even more important, PDF was formed for the first time into stable, uncompacted piles without ground stabilization techniques. *(See Figure 7: Uncompacted PDF piles).* The data obtained were used to develop specifications and design requirements for a full-scale, in-plant PDF finishing unit. As part of the commercialization effort, these same data were then scaled up for application to a larger plant. Financial restrictions have delayed the fabrication and installation of the full-scale unit, but ENCOAL will continue to seek funding for this project. Work on stabilization continues although it is now outside the scope of DOE involvement.

Figure 8: Uncompacted PDF Piles.

CDL Upgrading

The high point of the runs following the VFB installation was the production of better quality CDL. The pour point ranged from 75° to 95°F, and the flash point averaged 230°F, both within the proper range. Water content was down to 1 - 2%, and solids content was 2 - 4% -- improvements attributable to lower pyrolysis temperatures and higher pyrolysis gas flow rates -- both achievable because of a new pyrolyzer water seal. During the first 3 months of 1994, six tank cars were shipped to Dakota Gasification where CDL was blended with their fuel and burned for process heat. During the last quarter of the same year, ENCOAL started compatibility and CDL characterization studies to expand future markets.

Figure 9: Loading CDL Rail Cars

In June 1995, Dakota Gas completed a thorough characterization of CDL, and a kickoff meeting was held with Kellogg to initiate technical feasibility studies for various upgrading processes. A market evaluation indicated the need to upgrade CDL to reach markets other than heavy fuel oil, and Kellogg moved into developing a design and cost estimate for an in-plant CDL upgrading process to produce cresylic acids, petroleum refinery feed stock, oxygenated liquid and pitch. A pilot-size quench tower was acquired in early 1996, and testing was initiated to test the two-stage condensation step of the upgrading process. ENCOAL staff members held discussions with potential consumers of the fractions to learn more about CDL characteristics that would improve quality and marketability.

By the third quarter of 1996, the two-stage quench column pilot was installed and started up. The pilot unit was designed to produce small amounts of CDL separated roughly into two cuts: one with an initial boiling point below 500°F, and another with a boiling point above 500°F. By November 1996, it was decided that the desired product separation could not be proven utilizing the Kellogg design. Communications with potential cresylic acid and pitch customers continued, with customers specifying desired improvements in CDL quality, particularly sediment removal.

After the two-stage quench column project was concluded, ENCOAL engineers tested the effectiveness of a small centrifuge in removing sediment. The centrifuge successfully removed 90% of the solids in the parent CDL. Because ENCOAL believes solids removal to be a key factor in the success of any CDL sales plan, a larger second centrifuge will be extensively tested in March 1997, along with efforts to recover and agglomerate the CDL solids with dryer or pyrolyzer cyclone fines.

Work on CDL upgrading continues: an energy industry consulting firm was contracted to review literature on coal liquids upgrading, perform economic evaluations and make recommendations, and a number of laboratories are currently evaluating raw CDL, as well as pitch and cresylic acid samples. The TEK-KOL Development Center will be performing hydrogenation testing in 1997 as part of continuing investigations into upgrading CDL.

In early 1997, ENCOAL began evaluating laboratories to test the applicability of conventional petroleum processing techniques to CDL. A contract for petroleum testing was awarded to one laboratory, which will attempt to prove that CDL can be refined to produce competitively priced transportation fuels.

Significant modifications are summarized in the table below and are discussed in the ENCOAL Mild Coal Gasification Project Final Design Report.[4]

AREA OF PLANT	DEFINITION OF PROBLEM	SOLUTION
Electrostatic Precipitators	Insulator Failures	Modified Insulators, Improved Temperature Control
Material Handling	Plugging and Spillage	Modified S-belts & Chutes
PDF Quenching and Steam Condenser	Oil and Coal Dust, Too Small	Added Scrubber, Added 2 Larger Exchangers
Dryer and Pyrolyzer	Sand Seal Failures	Replaced With Water Seals
Combustors	Unstable Operation	Revised Control System
Pumps and Blowers	Sizing Problems, Mostly Too Small	Replaced With Larger Equipment
Changing Process Variables	Initial Plant Design Parameters Were Off	Adjusted Operating Set Points
PDF Dust Collection	Dusty Conditions On Product Side of Plant - No Scrubbers	Added Two Wet Scrubbers
PDF Deactivation	Could Not Produce Stable PDF In Original Equipment	Added VFB Deactivation Loop Equipment; Utilized Layered Laydown Techniques; Pilot Tested PDF Finishing
Process Water System	Accumulation Of Oily Fines In Process Equipment	Installed Clarifier, Floc & Vacuum Filter
Cyclone Fines Handling	Loss Of Excessive Amounts Of PDF In Cyclone Fines, Labor Intensive Clean-up	Recovered VFB Deactivation Fines Into PDF Product, Reduced Handling System
VFB Drag Conveyors	Excessive Wear and Maintenance Intensive	Redesigned High Wear Points, Modified Discharges To Reduce Plugging
Plant Operability And Maintenance	Difficult Access, Labor Intensive Clean-up, Inflexible To Operate	Piping Revisions, Access Platforms And Doors, Relocate Valves

Table 7. Summary Of Plant Modifications

TECHNICAL IMPACTS ON SCHEDULE AND MILESTONES

A great number of refinements to the process design and to the function of some process equipment have been effected to produce the highest quality products and improve plant operability. These, especially efforts to stabilize PDF, strongly influenced scheduling and milestones. Numerous attempts were made to stabilize the solid product using in-plant equipment, and when these did not accomplish the task, the VFB was installed during a 6-month hiatus in production. Other delays were incurred when sand seals were replaced with water seals. Construction and testing of the PASS unit was also not in the original plant design and impacted ENCOAL's production schedule.

Because of careful planning, however, much was accomplished during these shutdowns, including training, normal maintenance, and repair activities. Comprehensive operator education in such topics as respirator training, ambient gas monitoring, boiler operations and pyrolyzer dynamics contributed to operators' knowledge and safety.

As the project has neared its close, budget restrictions have affected the schedule as well. The in-plant PDF finishing unit has been placed on indefinite hold and remains subject to available funding. Work on CDL upgrading has continued, and alternative processes for upgrading are being evaluated. Technical and economic feasibility, and market acceptability are important factors that will determine which CDL upgrading scheme is most applicable. The in-plant finishing, deactivation unit testing and CDL upgrading complete the last of the major technical issues.

CONCLUSIONS AND LOOK AHEAD

The goals set for the ENCOAL Project have not only been met, but exceeded. Seventeen unit trains and one truck shipment of PDF have been shipped and successfully burned at seven utilities. PDF has been tested as a reductant (combined with iron ore) in the DRI process, and holds promise as a blast furnace injectant. The LFC process has been demonstrated and improved, both through operational refinements and equipment modifications. Almost 5 years of operating data have been collected for use as a basis for the evaluation and design of a commercial plant. The ENCOAL Project has demonstrated for the first time the integrated operation of several unique process steps:

- Coal drying on a rotary grate using convective heating
- Coal devolatization on a rotary grate using convective heating
- Hot particulate removal with cyclones
- Integral solids cooling and deactivation/passivation
- Combustors operating on low Btu gas from internal streams
- Solids stabilization for storage and shipment
- Computer control and optimization of mild coal gasification process
- Dust suppressant on PDF Solids

The product fuels have been used economically in commercial boilers and furnaces and have reduced sulfur and NO_x emissions significantly at utility and industrial facilities currently burning high sulfur bituminous coal or fuel oils.

Although major DOE objectives have been reached, some issues remain for resolution before a commercial plant project can be completed. As work proceeded in applying the technology from the ENCOAL Plant to a commercial plant, it was determined that a replacement for the VFB, the first stage in PDF deactivation, would have to be found. The VFB operating in the ENCOAL Plant is the largest such unit that is commercially available; scaling up to a plant approximately five times larger would require much larger equipment, or the installation of multiple VFBs. A possible alternative is a Salem grate, a concept which was tested using a slipstream deactivation unit. Further testing will need to be completed before optimal commercial plant design for PDF deactivation can be decided. Additional funding will also enable ENCOAL to install an in-plant finisher that will substantiate the large-scale testing of PDF finishing, the second stage of stabilization. CDL upgrading efforts will continue.

A large-scale commercial plant, the long-term goal of the ENCOAL Project, should move toward implementation at the North Rochelle Mine site. An Industrial Siting Permit has already been issued, and the WDEQ-AQD is expected to issue an Air Quality Construction Permit in July 1997. Other regulatory approvals must be received before construction and start-up of the commercial plant: a groundwater well permit, a WDEQ-LQD mining permit, WDEQ-WQD's stormwater permit, a National Pollutant Discharge Elimination System permit, approval from the U.S. Forest Service for use of the proposed plant site land, and MSHA's permit for large water impoundments. As investment participants commit to the project, permitting will continue, and detailed design, procurement and construction will commence.

The ENCOAL Demonstration Plant will continue to test the viability of alternate commercial-scale equipment, deliver additional test burn quantities of products, train operators for the commercial plant and provide additional design and economic data for the commercial plant.

Efforts to license the technology will proceed under the auspices of TEK-KOL, both domestically and internationally.

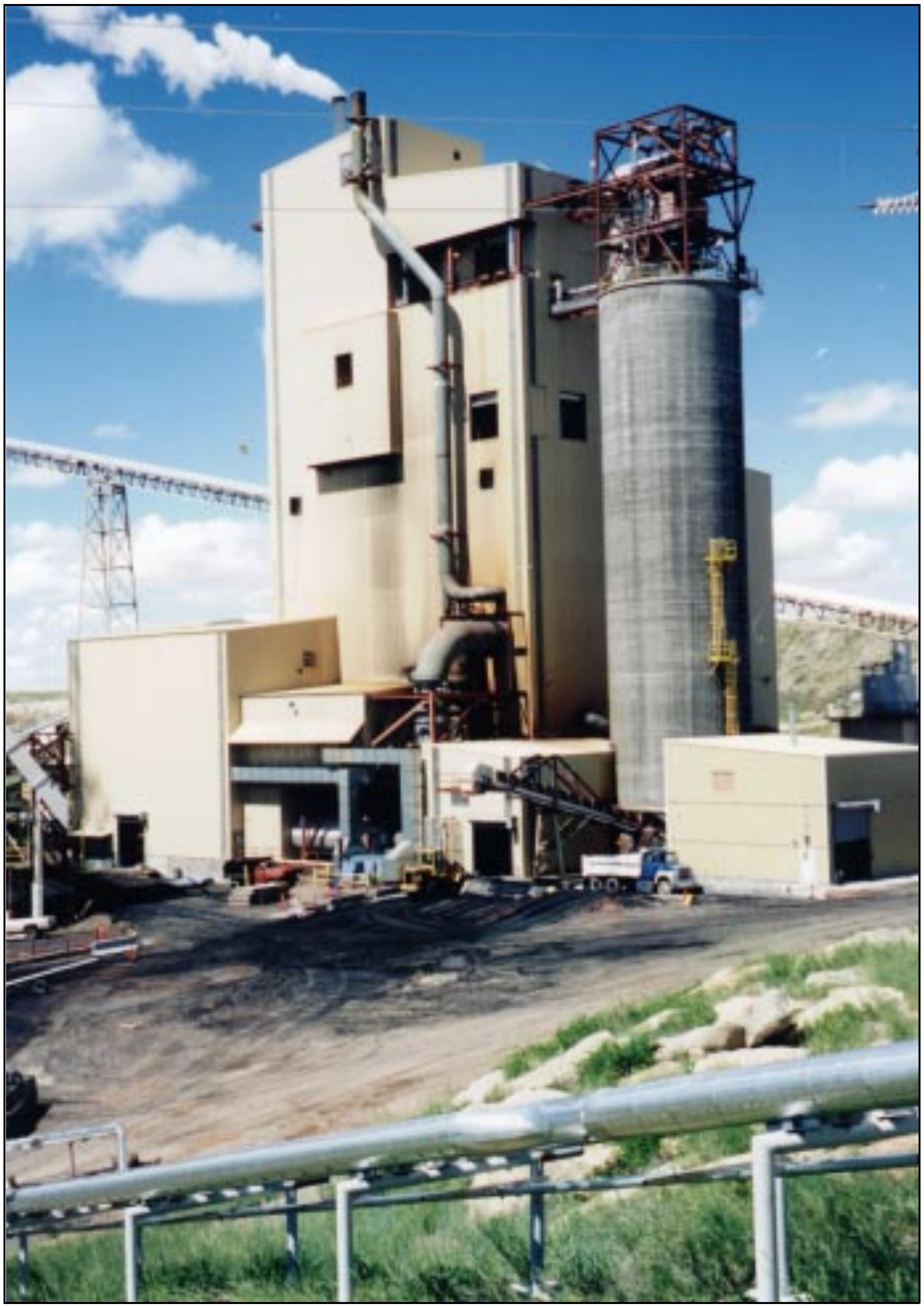


Figure 10: ENCOAL Mild Coal Gasification Plant

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GLOSSARY

ASME	American Society of Mechanical Engineers
BS&W	Basic Sediment & Water
Btu	British Thermal Units
CDL	Coal Derived Liquid
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DOE	U.S. Department of Energy
ENCOAL	ENCOAL Corporation, wholly-owned subsidiary of Bluegrass Coal Development Company
ESP	Electrostatic Precipitators
^{0}F	Degrees Fahrenheit
ft.	Feet
ft.^{2}	Square Feet
HP	Horsepower
H_2O	Water
H_2S	Hydrogen Sulfide
in.	Inches
Kellogg	The M. W. Kellogg Company
lb/hr	Pounds per Hour
LFC Technology	Liquid From Coal Technology
MM Btu/hr	Million British Thermal Units per Hour
Max	Maximum
MSHA	Mine Safety and Health Administration
NO_X	Nitrogen Oxides
O_2	Oxygen
PDF	Process Derived Fuel
PLC	Programmable Logic Controller
%	Percent
pH	Measure of alkalinity and acidity on a scale of 0 to 14
psia	Pounds per Square Inch Absolute
psig	Pounds per Square Inch Gauge
RPM	Rotations per Minute
SMC	SMC Mining Company, renamed Bluegrass Coal Development Company, wholly owned subsidiary of Zeigler Coal Holding Company
SO_2	Sulfur Dioxide
SO_X	Sulfur Oxides
turnkey	Subcontracting method that includes design, furnishing and installation responsibility
vol	Volume