FINAL

TECHNICAL REPORT

Advanced Coal Conversion Process Demonstration

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Prepared for:

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1.0 INTRODUCTION

This is the final technical report on the Advanced Coal Conversion Process (ACCP) Demonstration, a project funded under Round I of the U.S. Department of Energy's (DOE) Clean Coal Technology (CCT) program. The CCT program seeks to offer the energy marketplace more efficient and environmentally benign coal utilization technology options by demonstrating these technologies in industrial settings.

The Cooperative Agreement, originally between DOE and Western Energy Company and later between DOE and the Rosebud SynCoal Partnership (RSCP), defining this project was awarded on September 21, 1990. Following is a brief history of the development of this project. Montana Power Company was the common parent corporation of a group of directly and indirectly owned subsidiaries. One of Montana Power Company's wholly-owned subsidiaries was Entech, Inc., which, together with its subsidiaries (Entech Group), comprised the non-utility businesses of Montana Power Company. One of Entech Group's subsidiaries was Western Energy Company, a coal mining company. Western Energy Company was the original proposer for the ACCP Demonstration Project and Cooperative Agreement participant. To further development of the ACCP technology, Entech created Western SynCoal Company, which joined Scoria, Inc., an indirect, non-utility subsidiary of Northern States Power. After the formation of the Rosebud SynCoal Partnership, Western Energy Company formally novated the Cooperative Agreement to the Rosebud SynCoal Partnership to facilitate continued participation in the Cooperative Agreement. Western SynCoal Company (WSC), a subsidiary of Montana Power Company's Energy Supply Division, was the managing general partner of Rosebud SynCoal Partnership.

Western SynCoal Company, Montana Power's research and development arm for enhanced coal technologies and products, reorganized its activities on December 31, 1999, to create more value by reducing administrative costs and better aligning its interests with those of Western Energy Company, an affiliated coal mining company. Under the new structure, Western SynCoal and two other entities, SynCoal Inc. (which had previously taken over Scoria's interest) and the Rosebud SynCoal Partnership, joined to form Western SynCoal LLC, a limited liability company.

In 2000, Westmoreland Coal Company acquired all of the capital stock of Entech's five coal related direct subsidiaries, including Western Energy Company and its wholly owned entity, Western SynCoal LLC. The SynCoal® plant was permanently closed in 2001. EnPro, LLC, of Wyoming purchased Western SynCoal and three associated DOE contracts from Westmoreland on January 3, 2003.

The ACCP plant demonstrated an advanced, thermal, coal upgrading process that, coupled with physical cleaning techniques, is designed to upgrade high-moisture, low-rank coals to a high-quality, low-sulfur fuel. This technology is registered as the SynCoal® process. The coal is processed through three stages (two heating stages followed by a cooling stage) of vibrating fluidized bed reactors that remove water, carboxyl groups, and volatile sulfur compounds. After thermal upgrading, the coal is subjected to a deep-bed stratifier cleaning process to separate pyrite-rich ash from the coal.

The SynCoal® process enhances low-rank, Western coals, usually with a moisture content of 25-55%, sulfur content of 0.5-1.5%, and heating value of 5,500-9,000 British thermal units per pound (Btu/lb), by producing an upgraded coal product with a moisture content as low as 1%, sulfur content as low as 0.3%, and heating value up to 12,000 Btu/lb. The 45-ton-per-hour unit was located adjacent to a unit train loadout facility at Western Energy Company's Rosebud coal mine near Colstrip, Montana. The demonstration plant was sized at about one-tenth the projected throughput of a commercial facility, which would consist of multiple process trains.

1.1 History of the Project

The initial concept of thermally processing low-rank coal with low pressure, superheated, recycled gas was presented to Western Energy Company by an independent consultant in 1981. It was hoped that this fuel would be an alternative to high-priced oil and gas. Under contract to Western Energy, the consultant continued to develop the concepts necessary to show the potential benefits of this approach to coal upgrading technology. As those benefits were defined and explored, Western Energy developed a laboratory design. Equipment was procured, installed, and operated to substantiate the theoretical concepts in a bench-scale, batch mode operation. The results were sufficiently positive to warrant further development.

This led to a contract between Western Energy and the Montana College of Mineral Science and Technology to construct and operate a 150 lb/hr continuous pilot plant. The plant was constructed in 1984 at Montana Tech's Mineral Research Center in Butte, Montana, and operated through 1992. The primary purpose of the experimental work was to develop a method for thermally processing subbituminous coal and lignite using low pressure, superheated, recycled gas derived from the feed coal to produce a clean stable product.

About 12 different coals were tested in the pilot plant. The combined processing experience (mainly on Rosebud coal) was in excess of 300 tons of coal and 4,000 operating hours. The product was tested for storage, handling, transportation, and combustion characteristics. In addition, Combustion Engineering carried out a comprehensive characterization of the product and concluded that it had reduced moisture content, ash slagging potential, abrasiveness, and sulfur content.

The process that was under development was referred to as the Advanced Coal Conversion Process (ACCP). A needed incentive to construct a plant that would use the ACCP technology was provided by Section 29 of the Internal Revenue Code, which provides a credit for the production and sale of alternative fuels, including the production and sale of solid synthetic fuels produced from coal. One of the requirements for favorable treatment under Section 29 is that the coal which is converted to a solid synthetic fuel must undergo a substantial chemical change. In 1987, Western Energy received a private letter ruling which stated that the ACCP technology and the fuel resulting from its operation would qualify for favorable treatment under Section 29.

Since the ACCP technology required further high-cost development to test its commercial feasibility, a critical component of the development strategy was the construction of a plant based on the ACCP technology. The Entech Group, therefore, sought significant funding to assist in the development of a multimillion-dollar, 300,000-ton-per-year ACCP plant at Colstrip, Montana.

In pursuing the needed funding, the Entech Group sought independent investors and funding through DOE's CCT program. The primary goal of the CCT program is to develop and demonstrate means for economically utilizing coal while minimizing the release of carbon dioxide, sulfur dioxide, oxides of nitrogen, particulate matter, and ash. The clean coal commitment represents a public and private sector partnership that can make coal an environmentally attractive fuel for the future, a fuel for energy security, and a fuel for continued economic growth.

DOE approved funding for an ACCP plant in CCT Round I and awarded a Cooperative Agreement in 1990 to Western Energy Company. The Cooperative Agreement provided for the DOE to contribute (up to a specified maximum amount) approximately one-half of the cost of developing, constructing, and operating the plant. The government funding was in the nature of an investment, not a grant, because the agreement with DOE provided for repayment of the government's investment out of profits from the successful commercialization of the ACCP technology. Specifically, for essentially a 20-year period, the government has the right to receive a specified amount per ton of production from any next-generation facility using the ACCP technology.

The eventual result of Western Energy's efforts to seek financing was that Northern States Power Company agreed to invest in the ACCP technology. This resulted in the formation of a general partnership, known as the Rosebud SynCoal Partnership, with the partners being (1) Western SynCoal Company (WSC), a wholly-owned subsidiary of Western Energy, and (2) Scoria, Inc., a wholly-owned subsidiary of NRG Energy, Inc., which, in turn, was a wholly-owned subsidiary of Northern States Power. Pursuant to a novation agreement, Rosebud SynCoal Partnership assumed Western Energy's obligations under the Cooperative Agreement with the DOE. Relying on the private letter ruling received from the IRS by Western Energy, the Rosebud SynCoal Partnership constructed an ACCP plant with the assistance of funding from the DOE.

The design basis for the ACCP was developed from data collected during operation of the pilot scale unit. The pilot plant used a single reactor for the conversion process, which is markedly different from the two-reactor system employed at the ACCP. This modification was implemented to improve thermal efficiency. The ACCP uses a natural gas fired heater for thermal process requirements. The major energy requirement of the conversion process is for the removal of the moisture from the raw coal. While some chemical reactions transform the coal during processing, the thermal contribution of these reactions is usually neglected, as their contributions are considered negligible. The moisture content of the raw coal and the SynCoal® are of considerable importance, as each will impact the process energy required.

The design basis developed from the pilot plant considered the reduction of the moisture content and the loss of fine material, defined as particles smaller than 20 mesh (0.83 mm), to the particulate removal system (PRS). On the basis of that data, each ton of raw coal was expected to produce 0.69 tons of SynCoal® to be delivered to the cleaning system and 0.07 tons of material that would be collected by the PRS system.

Following the construction of the ACCP plant, the IRS reexamined the definition of substantial chemical change, and the private letter rulings of many synthetic fuel producers (including the private letter ruling of Western Energy) were revoked. After having completed its review of the matter, however, the IRS reinstated Western Energy's favorable ruling. The reinstated ruling noted that the ACCP plant had been constructed in reliance on the original ruling. The reinstated IRS ruling also noted that, although the chemical changes arising from the actual operation of the

ACCP plant (owned by Rosebud Partnership) were not as dramatic as outlined in the original ruling, nevertheless, the changes were sufficient to satisfy the chemical change standard.

DOE contributed approximately 48% of the funds used for the construction of the ACCP plant and continued to provide funding for the first months of operation in accordance with the original Cooperative Agreement. After this, the DOE had no further obligation to provide funding for plant operations. However, the DOE judged the plant a success, and in regard for the promise of the ACCP technology, the DOE modified the Cooperative Agreement to provide further financial assistance. Under the modified Cooperative Agreement, the DOE provided additional operations-related funding (to cover a portion of the cash-flow deficit of the operation of the plant). DOE's funding to supplement operating costs ended in November 1997.

In late 1997, Scoria withdrew from the Rosebud SynCoal Partnership. In order to maintain the partnership's existence, Western Energy formed an additional subsidiary, SynCoal Incorporated, to become the other general partner of the Rosebud SynCoal Partnership. At the beginning of 2000, Western SynCoal Company and SynCoal Incorporated were effectively merged into a new Colorado limited liability company, Western SynCoal LLC, to streamline the organizational structure.

On December 4, 2001, Western SynCoal LLC was assigned US Patent 6,325,001, "Process to improve boiler operation by supplemental firing with thermally beneficiated low rank coal," which summarizes the SynCoal program pursuant to the terms of the Clean Coal Technology program. Essentially, the patent claims that, if a boiler is using high moisture, low ranked coal feedstock, the ACCP can be used to improve boiler efficiency while reducing NOx and SOx. Waste heat from the power station can be used to drive the ACCP process, thereby saving power consumption in cooling loops. The milling process needs less heat to dry the feed, and the total boiler emissions are reduced by the amount of water removed during the conversion. Utilizing a technology, such as or similar to the Aeroglide reactor, the SynCoal® process capital and operating cost would be reduced substantially.

2.0 PROCESS DESCRIPTION

This section is divided into two parts. First, the process as originally designed is described. Then, the changes made as the demonstration proceeded are discussed.

2.1 Original Design

The ACCP is a thermal conversion process that uses combustion products and superheated steam as fluidizing gas in vibrating fluidized bed reactors. Two fluidized stages are used to thermally and chemically alter the coal; and a water spray stage, followed by a fluidized stage, is used to cool the coal. Subsystems that make up the ACCP plant include:

- Raw Coal Handling
- Coal Conversion
- Coal Cleaning
- Product Handling
- Emission Control
- Natural Gas Fired Heater

- Heat Rejection
- Utility and Ancillary

A simplified process flow diagram of the ACCP plant as originally designed is depicted in Figure 1. The following sections discuss the original plant design and expected results. Modifications are summarized in Section 2.2, and operating results are discussed in Section 3.0.

2.1.1 Raw Coal Handling

Raw coal from the existing stockpile is screened to provide 1½-by-½ inch feed for the ACCP process. Coal rejected by the screening operation is conveyed back to the active stockpile. Properly sized coal is conveyed to a 1000-ton raw-coal storage bin, which feeds the process facility.

2.1.2 Coal Conversion

Coal conversion is performed in two parallel processing trains. Each train consists of two 5-feet-wide by 30-feet-long vibratory fluidized bed thermal reactors in series, followed by a water spray section and a 5-feet-wide by 25-feet-long vibratory cooler. Each processing train is fed up to 1,139 lb/min (34.17 tons/hr) of 1½ -by-½ inch coal.

In the first-stage dryer/reactor, the coal is heated by direct contact with hot combustion gases mixed with recirculated dryer makegas (gaseous products evolved from the feed coal and that, for the first-stage loop, is nearly 100% steam). This primarily removes surface water from the coal. The coal exits the first-stage dryer/reactor at a temperature slightly above that required to evaporate water (about 205^{o}F) and is gravity fed to the second-stage thermal reactor, which further heats the coal using a recirculating gas stream. In the second stage, water trapped in the pore structure of the coal is removed, and chemical dehydration, decarbonylation, and decarboxylation are promoted. The water making up the superheated steam used in the second stage is actually produced from the coal itself. Particle shrinkage that occurs in the second stage liberates ash minerals and imparts a unique cleaning characteristic to the coal.

As the coal exits the second-stage thermal reactors, it falls through a vertical quench cooler where process water is sprayed onto the coal to reduce its temperature. The water vaporized during this operation is drawn back into the second-stage reactor. After water quenching, the coal enters the vibratory cooler, where it is contacted by cool inert gas. The coal exits the vibratory cooler at less than 150^{o}F and enters the coal cleaning system. The gas exiting the vibratory coolers is sent to a twin cyclone for dust removal and cooled by water sprays in a direct contact cooler before being recirculated to the vibratory cooler. Particulates are removed from the first-stage process gas by a pair of baghouses in parallel. The second-stage process gas is treated by a quad cyclone arrangement, and the cooler-stage process gas is treated by a twin cyclone arrangement. These particulate collection devices protect the fans and, in the case of the first-stage baghouses, prevent any fugitive particulate discharge.

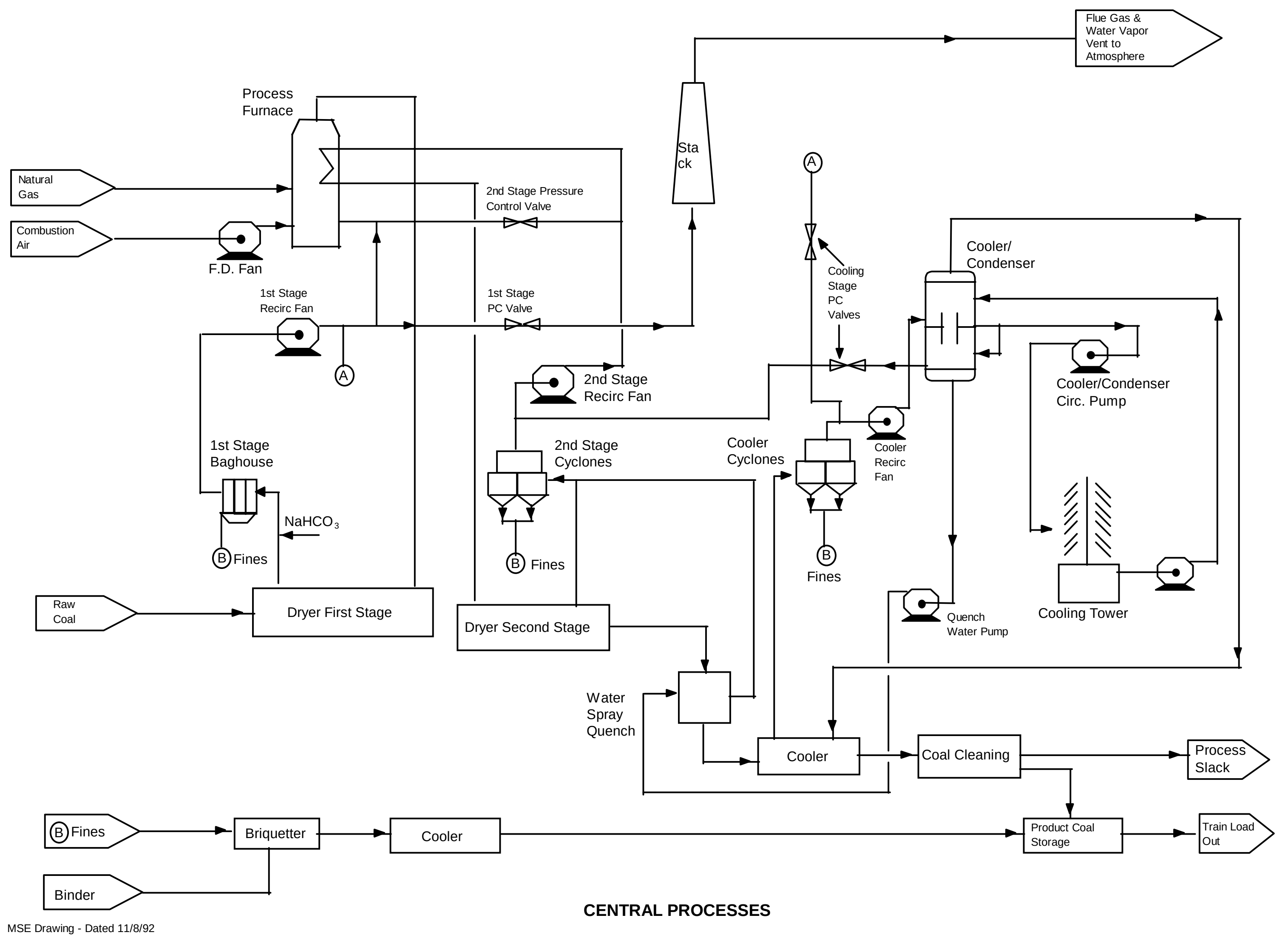

Flue Gas & Water Vapor Vent to Atmosphere
Process Furnace
Stack
Natural Gas
Combustion Air
F.D. Fan
2nd Stage Pressure Control Valve
1st Stage Recirc Fan
1st Stage PC Valve
Cooling Stage PC Valves
Cooler/ Condenser
2nd Stage Recirc Fan
Cooler/Condenser Circ. Pump
1st Stage Baghouse
2nd Stage Cyclones
Cooler Cyclones
Cooler Recirc Fan
$NaHCO_3$
Fines
Fines
Fines
Raw Coal
Dryer First Stage
Dryer Second Stage
Quench Water Pump
Cooling Tower
Water Spray Quench
Cooler
Coal Cleaning
Process Slack
Fines
Briquetter
Cooler
Product Coal Storage
Train Load Out
Binder
CENTRAL PROCESSES
MSE Drawing - Dated 11/8/92

Figure 1

Three interrelated recirculating gas streams are used in the coal conversion system: one for each of the thermal reactor stages and one for the vibratory cooler. Gases enter the process from either the natural gas-fired process furnace or from the coal. Combustion gases from the furnace are mixed with recirculated makegas in the first-stage dryer/reactor after indirectly exchanging some heat to the second-stage gas stream. The second-stage gas stream is composed mainly of superheated steam, which is heated by the furnace combustion gases in the heat exchanger. The cooler gas stream is made up of cooled furnace combustion gases that have been routed through the cooler loop.

A gas route is available from the cooler gas loop to the second-stage thermal reactor loop to allow for inert blanketing of the system during startup and shutdown. The second-stage makegas contains various hydrocarbons resulting from the mild pyrolysis and devolatilization occurring in the second stage. A portion of the makegas, equal in volume to the volume of gas evolved from the coal, is routed to the process furnace for use as an additional fuel source. The final gas route follows the exhaust stream from the first-stage loop to the atmosphere.

Gas exchange from one loop to another is governed by pressure control on each loop and, after startup, is minimal from the first-stage loop to the cooler loop and from the cooler loop to the second-stage loop. Gas exchange from the second-stage loop to first-stage loop (through the process furnace) may be substantial, since the water vapor and hydrocarbons driven from the coal in the second-stage thermal reactor must leave the loop to maintain a steady state.

2.1.3 Converted Coal Cleaning

The treated coal entering the cleaning system is screened into four size fractions: plus ½ inch, ½ by ¼ inch, ¼ inch by 8 mesh, and minus 8 mesh. These streams are fed in parallel to four deep-bed stratifiers (stoners), where a rough specific gravity separation is made using fluidizing air and a vibratory conveying action. The “light” (lower specific gravity) streams from the stoners are sent to the product conveyor, and the “heavy” (higher specific gravity) streams from all but the minus 8 mesh stream are sent to fluidized bed separators. The heavy fraction of the minus 8 mesh stream goes directly to the waste conveyor. Each fluidized bed separator, using air and vibration to effect a gravity separation, splits the coal into light and heavy fractions. The light stream is considered product, and the heavy or waste stream is sent to a 300-ton, storage bin to await transport to an off-site user or, alternatively, back to a mined out pit disposal site. The converted, cooled, and cleaned SynCoal® product from coal cleaning enters the product handling system.

2.1.4 Product Handling

Product handling consists of the equipment necessary to convey the clean, granular SynCoal® product into two 6,000-ton concrete silos and to allow train loading with the existing loadout system. Additionally, to recover the maximum energy content, the SynCoal® fines collected in the various particulate collection systems are combined and transferred to a 50-ton surge bin that feeds the fines “hot” to a briquetter for reintroduction with the granular SynCoal® or to a diverter to a ground level truck.

2.1.5 Emissions Control

Sulfur dioxide emission control philosophy was based on injecting dry sorbents into the ductwork to minimize the release of sulfur dioxide to the atmosphere. Sorbents, such as trona or sodium bicarbonate, could be injected into the first-stage gas stream as it leaves the first-stage dryer/reactor to maximize the potential for sulfur dioxide removal while minimizing reagent usage. The sorbents, having reacted with sulfur dioxide, are removed from the gas streams in the particulate removal systems. A 60% reduction in sulfur dioxide emissions was expected.

Fugitive dust in the coal cleaning area is controlled by placing hoods over the sources of fugitive dust and conveying the dust laden air to fabric filters. The bag filters can remove 99.99% of the coal dust from the air before discharge. All SynCoal® fines report to the fines handling system and ultimately to the SynCoal® fines stream.

2.1.6 Natural Gas-Fired Furnace

The heat required to process the coal is provided by a natural gas-fired process furnace, which uses process makegas from the second-stage coal conversion reactor as supplemental fuel. This system is sized for a heat release rate of 74 million Btu/hr. Process gas enters the furnace and is heated by radiation and convection from the burning fuel.

2.1.7 Heat Rejection

Heat removed from the coal in the coolers is rejected indirectly through cooling water circulation using an atmospheric, induced-draft, cooling tower. A substantial amount of the heat added to the system is actually lost by releasing water vapor and flue gas into the atmosphere through an exhaust stack. The stack height, coupled with the vertical velocity resulting from a forced draft fan, allows for vapor release at an elevation great enough to maximize dissipation of the gases.

2.1.8 Utility and Ancillary Systems

The fines handling system consolidates the coal fines that are produced in the conversion, cleaning, and material handling systems. The fines are gathered by a tubular drag conveyor and transported to a surge bin, which feeds the fines to a briquetter and cooler for blending with the granular SynCoal® or sends them directly into a truck on the ground.

Inert gas is drawn off the cooler loop for other uses. This gas, primarily nitrogen and carbon dioxide, is used as an inert purge gas and for baghouse bag cleaning (pulsing). The makeup gas to the cooler loop is combustion flue gas from the stack. The cooling system effectively dehumidifies and cools the stack gas, producing inert gas for the system. The cooler gas still has a relatively high dew point (about 90^{o}F). Due to the thermal load this puts on the cooling system, no additional inert gas requirements can be met by this approach.

The common facilities for the ACCP Demonstration include a plant and instrument air system, a fire protection system, and a fuel gas distribution system. The power distribution system includes a 15 kV service; a 15 kV/5 kV transformer; a 5 kV motor control center; two 5 kV/480 V transformers; a 480 V load distribution center; and a 480 V motor control center.

The process is semi-automated, including dual control stations, dual programmable logic controllers, and distributed plant control and data acquisition hardware. Operator interface is necessary to set basic system parameters, but the control system automatically adjusts to changes in the process measurements.

The originally designed and installed major equipment for the ACCP Demonstration Facility is listed in Table 1.

2.2 Design Modifications

The ACCP facility has been modified as necessary during start-up and operation. Equipment has been improved; additional equipment installed; and new systems designed, installed, and operated to improve the overall plant performance. Table 2 shows the equipment that has either been modified or replaced from plant startup. If replacement was required, the new equipment is listed. The following sections describe the significant modifications that were made to the original design.

2.2.1 Raw Coal Handling

A number of different raw coal screen sizes were tried, but the best configuration for the combined mine and plant operations was found to be 2-by-½ inch feed for the ACCP process.

2.2.2 Coal Cleaning

Modifications were made in 1992 that allow product to be sent to the waste bin with minimal reconfiguration.

2.2.3 Coal Conversion

In 1992, several modifications were made to the vibratory fluidized bed reactors and processing trains to improve plant performance. The vibratory fluidized bed reactors were repaired to eliminate an internal process gas bypass, and the seams were welded shut to reduce system leaks. Also, the reactor bed deck holes were bored out in both the first-stage dryer/reactor and the vibratory coolers to increase process gas flow and reduce system pressure drop.

The originally designed, two-train, fines tubular drag conveying system could not keep up with fines production. To operate closer to design conditions on the thermal coal reactors and coolers, obtain tighter control over operating conditions, and minimize product dustiness, the ACCP plant was converted to single train operation to reduce overall fines loading prior to modifying the fines handling system during the 1993 summer outage. One of the two process trains was removed from service by physically welding plates inside all common ducts at the point of divergence between the two process trains. This forced process gases to flow only through the one open operating process train.

Table 1. Advanced Coal Conversion Process As Constructed Major Plant Equipment

System Description	Equipment Vendor	Type
Thermal Coal Reactors/Coolers	Carrier Vibrating Equipment, Inc.	PE
Belt Conveyors	Willis & Paul Group	MH
Bucket Elevators	FMC Corporation	MH
Coal Cleaning Equipment	Triple S Dynamics, Inc.	CC
Coal Screens	Hewitt Robbins Corporation	MH
Loading Spouts	Midwest International	MH
Dust Agglomerator	Royal Oak Enterprises, Inc.	DH
Silo Mass Flow Gates	SEI Engineers, Inc.	MH
Vibrating Bin Dischargers	Carman Industries, Inc.	MH
Vibrating Feeder	Kinergy Corporation	MH
Drag Conveyor	Dynamet	DH
Process Gas Heater	G.C. Broach Company	PE
Direct Contact Cooler	CMI-Schneible Company	PE
Particulate Removal System	Air-Cure Howden	EC
Dust Collectors	Air Cure Environmental, Inc.	EC
Air Compressors/Dryers	Colorado Compressor, Inc.	CF
Diesel Fire Pumps	Peerless Pump Company	CF
Forced Draft Fans	Buffalo Forge Company	PE
Pumps	Dresser Pump Division Dresser Industries, Inc.	PE
Electrical Equipment-4160	Toshiba/Houston International Corporation	CF
Electrical Equipment-LDC	Powell Electric Manufacturing Company	CF
Electrical Equipment-480v MCC	Siemens Energy & Automation, Inc.	CF
Main Transformer	ABB Power T&D Company	CF
Control Panels	Utility Control & Equipment Corporation	CF
Control Valves	Applied Control Equipment	CF
Plant Control System	General Electric Supply Company	CF
Cooling Tower	The Marley Cooling Tower Company	PE
Dampers	Effox, Inc.	PE
Dry Sorbent Injec. System	Natech Resources, Inc.	EC
Expansion Joints	Flexonics, Inc.	PE
MH - Materials Handling CF – Common Facilities	PE - Process Equipment CC - Coal Cleaning	EC - Emissions Control DH - Dust Handling

Table 2. Advanced Coal Conversion Process Modified Major Plant Equipment

System Description	Equipment Vendor	Type	Modified	Replaced With
Thermal Coal Reactors/Coolers	Carrier Vibrating Equipment, Inc.	**PE**	Yes	
Belt Conveyors Product Sampler	Willis & Paul Group Inner Systems	MH MH	 Added	
Bucket Elevators	FMC Corporation	MH		
Coal Cleaning Equipment	Triple S Dynamics, Inc.	CC		
Coal Screens	Hewitt Robbins Corporation	MH	Yes	
Loading Spouts	Midwest International	MH		
Dust Agglomerator	Royal Oak Enterprises, Inc.	DH		Eliminated
Silo Mass Flow Gates	SEI Engineers, Inc.	MH	Yes	
Vibrating Bin Dischargers	Carman Industries, Inc.	MH		
Vibrating Feeder	Kinergy Corporation	MH		
Drag Conveyor	Dynamet	DH	Yes	PFHS
Screw Conveyor	Farm Aid Equipment Company	MH	Added	PFHS
Processed Fines Handling Sys. Bucket Elevators Screw Conveyors Drag Conveyors Processed Fines Cooler Slurry Tank Agitator Slurry Tank Slurry and Pit Pumps Processed Fines Load Out Bin	 Continental Screw Conveyor Corp. Continental Screw Conveyor Corp. AshTech Corporation Cominco Engineering Services, Ltd. Chemineer, Inc. Empire Steel Manufacturing Co. Goulds Pumps/Able Technical P & S Fabricators	 DH DH DH DH DH DH DH DH	 Added Added Added Added Added Added Added Added	
Process Gas Heater	G.C. Broach Company	PE	Yes	
Direct Contact Cooler	CMI-Schneible Company	PE	Yes	
Particulate Removal System	Air-Cure Howden	EC	Yes	
Dust Collectors	Air Cure Environmental	EC		
Air Compressors/Dryers	Colorado Compressor, Inc.	CF	Yes	
Diesel Fire Pumps	Peerless Pump Company	CF		
Forced Draft Fans	Buffalo Forge Company	PE	Yes	
Pumps	Dresser Pump Division Dresser Industries, Inc.	PE		
Electrical Equipment-4160	Toshiba/Houston International Corp.	CF		
Electrical Equipment-LDC	Powell Electric Manufacturing Corp.	CF		
Electrical Equipment-480v MCC	Siemens Energy & Automation, Inc.	CF		
Uninterruptible Power Supply	Best Power Technologies Company	CF	Added	
Main Transformer	ABB Power T&D Company	CF		
Control Panels	Utility Control & Equipment Corp.	CF		

Table 2. Advanced Coal Conversion Process Modified Major Plant Equipment (cont'd.)

System Description	Equipment Vendor	Type	Modified	Replaced With
Control Valves	Applied Control Equipment	CF		
Plant Control Systems	General Electric Supply Company	CF	Yes	
Cooling Tower	The Marley Cooling Tower Company	PE	Yes	
Dampers	Effox, Inc.	PE		
Dry Sorbent Injection System	Natech Resources, Inc.	EC		Eliminated
Expansion Joints	Flexonics, Inc.	PE	Yes	
Truck Loadout System Truck Silo Steel Silo Gate & Discharge Spout Bin Weigh Scales Bucket Elevator Erection	Wm. Kronmiller Midwest International Kissler Morris Power Transmission & Equipment Cop Construction/L.H. Sowles/ Sagebrusy	MH	Added	
Inert Gas System Air Cooled Heat Exchanger Inert Gas Compressor Inlet Filter Knock-Out Drum Regenerative Desiccant Dryers Erection	 Ambassador Heat Transfer LeROI/Energy Equipment & Supply Air-Cure Environmental Ambassador Heat Transfer Pioneer/Industrial Tool & Supply Sagebrush/L.H. Sowles	CF	Added	
Tramp Iron Magnet	Bunting Magnetics, Co.	MH	Added	
MH - Materials Handling PE - Process Equipment EC - Emissions Control CF - Common Facilities CC - Coal Cleaning DH - Dust Handling				

In addition to removal of one process train, the processed fines conveying equipment was simultaneously modified to reduce the required throughput on the drag conveyors. This was accomplished by adding a first-stage screw conveyor and straightening and shortening the tubular drag conveyors.

The ACCP design included a briquetter for agglomeration of the process fines. However, initial shakedown operation of the plant as designed would have required that the briquetting system be completely operational. Since it was desired to delay operation of the briquetting operation to focus on successfully operating the plant, the process design was changed to include temporary fines disposal by slurry transport to an existing pit in the mine. During 1992, a temporary fines slurry disposal system was installed, and the redesigned process fines conveying and handling system was commissioned. Design of a replacement fines conveying system was completed to deliver fines to a truck loadout, slurry, or briquetter.

The main rotary airlocks were required to shear the pyrite and "bone" (rock that is interspersed with the coal); however, the design rotary airlocks were insufficient to break this non-coal material and tripped the entire process each time one of the eight rotary airlocks jammed. Therefore, the drive motors were retrofitted from 2 to 5 horsepower for all eight process rotary airlocks. Also, an electrical current sensing circuit that reverses the rotary airlock rotation was designed, tested, and applied to the rotary airlocks. This circuitry was able to sense a rotor stall and reverse the motor to clear the obstruction before tripping the motor circuit breaker. This concept and apparatus was patented by Western SynCoal (U.S. Patent 5,575,085).

To handle the occasional receipt of wet sticky feed coal, the rotors were modified from eight-pocket to four-pocket by removing every other blade.

The original plant startup tests revealed explosion vent discrepancies in all areas, thus preventing extended operation of the plant. Design development for the vents was a cooperative effort between an explosion vent manufacturing company and ACCP personnel and resulted in a unique explosion vent sealing system that was completed during 1993. The new explosion vent design was implemented during 1993 and has performed well since it was installed.

The vibratory fluid bed reactors suffered from stress cracking in the base on two occasions. The first cracking occurred about November, 1992. A combination of dynamic and thermal stresses caused cracking of the structural welds connecting the vibratory drives to the dryer plenum. This problem was mitigated by reducing the thermal stresses on the welds by insulating the inside of the plenum and removing the insulation from the weld areas on the outside of the dryers.

The second set of cracking problems was, to some extent, a result of the solution to the first set of cracking problems. Again, cracking occurred on the plenum bottom, adjacent to the vibratory drives. This time, the cracks were not generally in the vibratory drive structural welds; rather they began and propagated through the parent steel of the plenum. A specimen of the failed steel was removed and sent to a metallurgist for failure root cause analysis. The metallurgist reported that the failure was caused by stress corrosion cracking (SCC). The insulation installed on the inside of the plenum had caused the parent steel temperature to fall into the chlorine ion attack range, while simultaneously supplying enough chlorine to cause SCC. New parent steel was installed inside the plenum, along with a sacrificial aluminum sheet and chlorine free insulation.

During 1992 to 1994, the ACCP facility experienced chronic failure of the bearings on the first stage and cooler circulating gas fans. A primary failure mode was never identified, but the failures were attributed to a combination of too low a load on the original roller bearings, contamination of the bearing lubricating oil, and heating of the bearings by conduction through the fan shafts. The original bearings were oil lubricated with a small oil reservoir internal to the bearing. In the second quarter of 1995, a lubricating oil system was installed for the first stage and cooler fans, along with new bearings that accepted a forced lubrication system. The lube oil systems included lube oil temperature control, filters, and flow controls. These changes essentially eliminated bearing failure.

2.2.4 Product Handling

Work continued during the life of the project on testing and evaluating technologies to enhance product stability and reduce fugitive dusts. During 1992, a liquid carbon dioxide storage and vaporization system was installed for use in testing product stability and to provide inert gas for storage and plant startups and shutdowns. During the Fourth Quarter of 1994, an additional inert gas system was installed that provided inert gas by cooling and drying a portion of the combustion gas from the exhaust stack.

The clean product SynCoal® is conveyed to two 5,000-ton-capacity concrete silos, which allow train loading with the existing loadout system. (The relatively low density of the SynCoal® reduced the capacity of the silos from the 6,000-ton design value to approximately 5,000 actual tons.) During the first quarter of 1995 an automatic sampler was installed to obtain representative daily production samples.

Due to increasing truck sales volume, a truck loadout system was designed; installation was completed in October 1995. Previously, trucks were loaded through the existing train loadout tipple, but the tipple system was not adequate for large truck volumes due to long load times, inaccurate loading, excessive labor charges, and interference with train loading. The new truck loadout system included handling equipment to transfer SynCoal® to a new 70 ton truck loadout bin from the 5,000 ton silo and a weighing system for accurately loading trucks.

From the start of the ACCP demonstration, the tendency of SynCoal® toward spontaneous combustion required storage of the product under an inert gas atmosphere or in tightly sealed vessels to prevent air infiltration. A CO_2 inerting system was developed for silo storage of the SynCoal® product, and later an inert gas system was installed.

The as-built silo gates were 48-inch by 48-inch, designed to allow about 5,000 tons/hr of raw sticky coal to flow to the conveyor. Since SynCoal® flows more easily than raw coal, the gates were substantially oversized. Furthermore, the gates were designed with large moving clearances. These “gaps” allowed either infiltration of air or significant leakage of CO_2. Efforts in the past to tighten the clearances and reduce the gaps did not solve the problem of lost CO_2. During the first quarter of 1997, the six original 48-inch by 48-inch gates and the two center mass flow gates, along with the attendant chutes, were replaced with four 15-inch by 15-inch gates on the silos and two 24-inch by 24-inch gates, one in the center of each silo.

In the last quarter of 1997, two Bunting MG 450 series grain faced style standard plate magnets, one for each silo, were installed in the product feed chutes to the silos to remove tramp iron prior to product discharge into the silos. Any magnetic material inadvertently contained in the product stream on the conveyor is removed by these magnets, which are composed of a high density ceramic permanent magnetic energy source, placed in a stainless steel housing that is hinged at the product chute for easy cleaning.

2.2.5 Emissions Control

It was originally assumed that sulfur dioxide emissions would have to be controlled by injecting chemical sorbents into the ductwork. However, preliminary data indicated that sulfur dioxide production was significantly less than anticipated, meaning that the injection of sorbents would not be necessary to control sulfur dioxide emissions under operating conditions. A mass spectrometer was installed to monitor emissions and process chemistry, but the injection system was initially left in place in case a change should occur that required sulfur dioxide emissions to be reduced.

2.2.6 Process Gas Heater

The vibration and conversion system problems discussed above initiated the removal and redesign of the process gas fans shaft seals to limit oxygen infiltration into the process gas. In 1995, several modifications were made to the process gas heater. Significant damage had occurred to the old heat exchanger from high temperature creep and embrittlement. Half of the process gas heat exchanger was replaced with modules made of a higher quality stainless steel. Two additional modifications were made to help protect and enhance the performance of the heat exchanger. A soot blower was installed to keep the heat exchanger from fouling, and refractory brick baffles were added to block radiant heat from reaching the heat exchanger face.

2.2.7 Heat Rejection

An evaluation in 1993 indicated that the cooling tower limitation issues could be resolved by providing additional makeup water to the system. A 2-inch valve was installed on the water line to the cooling tower to provide the necessary makeup water.

2.2.8 Utility and Ancillary Systems

The power distribution system was upgraded by installing an uninterruptible power supply (UPS) during 1993. The UPS system does not keep the plant running if there is a problem; however, it does keep the control system, emergency systems, and office lights operating. Graphic interface programs were continually modified and upgraded to improve the operator interface and provide more reliable information to the operators and engineers.

2.2.9 Inert Gas System

The inert gas system (IGS), which provides cooled, dehumidified, and compressed stack gas, was designed and installed in 1994, mainly for the purpose of SynCoal® product storage inerting. The inert gas, which contains mainly nitrogen and carbon dioxide, is used by the first-stage baghouse cleaning blowers and is also used as a blanket gas in the product and fines storage silos. The makeup gas to the cooler loop is combustion flue gas from the stack. The cooling system also effectively dehumidifies and cools the stack gas that makes up the inert gas for the system; however, the cooler gas still has a relatively high dew point (about 90^{o}F). Due to the thermal load the additional inert gas demand would put on the cooling system, no additional inert gas requirements could be met by this approach; therefore, a new inert gas system was required.

The IGS is comprised of a stack connection (take-off), gas cooling heat exchanger, water knock-out drum, particulate removal, compressor, compressed gas desiccant dryer, gas receiver, and distribution piping. The IGS starts at the ACCP plant stack and is connected via an 18" diameter pipe. A hand valve is used to operate the inert gas into the main process heat exchanger.

The process heat exchanger is a two-cell fin-tube exchanger, 30 feet long and 12 feet wide with approximately 81,850 ft^2 of heat exchange surface area. The heat exchanger (designated Model Number PCS-315) was designed and manufactured in May 1994 by Ambassador Heat Transfer Company. Two fans are driven by 30 HP variable frequency drives (VFD) based on process temperature of the gas exiting the exchanger. The exchanger was designed to cool a wet gas stream (1,506 SCFM on a dry basis) from 270°F to approximately 100°F. The temperature of the inert gas is designed to be no higher than 115°F.

The inert gas, after cooling, passes through a knockout (KO) drum complete with mist eliminator (demister pad) packing. Water droplets and liquid condensate are contained in the lower portion of the KO drum, which allows storage of the liquid and feed to a pump delivering the condensate liquid to the slurry system. Dry inert gas proceeds to either the IGS compressor or the ACCP first stage PRS baghouse blowers.

Two particulate filtration systems clean the inert gas prior to compression. The first filter is located above the IGS skid and consists of parallel filter canisters, Solberg Model CSL-485P(2)-1200F. The elements are designed to remove 5 micron particulate. The second particulate filter is located at the inlet to the compressor and consists of two Stoddard F65V-6 canisters in parallel, complete with bypass valving. The elements used are Stoddard F64-6, 99% efficient at 1 micron particulate removal.

The inert compressor skid system is a self contained package supplied by Energy Equipment and Supply of Casper, Wyoming, and is comprised mainly of LeROI components. The inlet gas first flows through an inlet scrubber to remove any remaining moisture prior to the compressor, which is a G series LeROI oil flooded single screw compressor (Model No. 2A219-131) with a 200 HP, 4,160 V motor. Approximately 983 ACFM (actual cubic feet per minute at the compressor inlet) of inert gas flow into the screw compressor along with lubricating oil returning from the air/oil separator sump. The compressed gas flows to the air/oil separator, where the oil disengages from the compressed gas. Approximately 703 SCFM of compressed inert gas is kept at 100 psig as it passes through the Kimray regulator prior to gas cooling. The gas and the oil are cooled through individual sections of a Fin-X, Incorporated, fin-fan heat exchanger with air actuated shutters. A 5 HP fan supplies the cooling air through the heat exchanger. After cooling, the gas passes through a final moisture separator which discharges to the floor drain.

After the compressor moisture separator, the compressed gas proceeds to the regenerative desiccant drying system. The inert gas regenerative desiccant drying system was supplied by Pioneer Air Systems, Incorporated. The unit consists of twin Pioneer PHE-1000 desiccant towers. One unit is always in service, while the other tower is in the drying mode. The PHE dryer is equipped with an external heater to aid in drying the desiccant. The unit is supplied with pre- and post-filters to eliminate the carryover of droplets/mists of liquid water and compressor lubricant, as well as particulate from the regenerative drying system.

After the regenerative desiccant dryer system, the inert gas is stored in a 400 gallon receiver tank. The inert gas is controlled and distributed through the distribution manifold system located at the north end of the ACCP plant. This distribution manifold incorporates oxygen measurement and control, such that if the inert gas oxygen content is higher than allowed, a valve shuts, stopping inert gas flow.

The inert gas is provided at 80 psig (high pressure) and controlled at 25 psig prior to the low pressure distribution for either the plant location or the silo. The inert gas is available to the soot blowers and the infeed rotary air-locks at system pressure of 80 psig. After the 25 psig control point at the regulator, low pressure inert gas is available for purging at the second stage reactor deck, located centrally to the plant, or to the silo.

Each silo has five locations with 2" diameter piping for inerting that were initially installed with the carbon dioxide supply system:

1. The No. 1 silo pipe feeding the top ring consisting of sixteen ¾-inch pipe penetrations located 10 feet from the top of the silo.
2. The No. 2 silo pipe feeding the top ring consisting of sixteen ¾-inch pipe penetrations located 35 feet from the top of the silo.
3. The No. 3 silo pipe feeding the hoppers (three per silo).
4. The No. 4 silo pipe feeding the mid-point of the silo on the south side.
5. The No. 5 silo pipe feeding the mid-point of the silo on the north side.

On top of the silo, Line Location No. 2 has valving to supply either the 35 foot ring (No. 2B) or distribution to the very top of the silo (No. 2A).

2.2.10 Aeroglide Pilot Reactor

In October 1999, SGI International and Western SynCoal signed a join research and development agreement to test an Aeroglide tower reactor design for product char treating (finishing) and coal processing. This project included installation and operation of a small Aeroglide tower at the ACCP Demonstration plant. Construction of the test system was completed in May 2000, and testing of char treating was completed in August 2000. Immediately following the conclusion of the finishing tests, coal thermal processing tests were initiated. Two runs were attempted (August and September 2000), with both runs being prematurely stopped (i.e., before steady state conditions were established) due to overheating problems in the cooling section of the test unit.

The tower test unit consisted of a 6 ft by 6 ft by 60 ft tall modified tower “grain dryer,” manufactured by Aeroglide Corporation of Carry, NC. The complete unit includes a surge bin, two indirect water cooling sections, seven direct gas contacting reactor sections, and a discharge assembly. The reactor sections allow gas to continuously contact the coal while the coal flows downward through the test reactor. Solids flow and residence time in the test reactor are controlled by the speed of three rotary discharge valves in the discharge assembly. The surge bin at the top of the test reactor serves as a gas seal to atmosphere for the process gas and as a control point for inlet solids. Gas can be circulated through the system by a process fan.

3.0 RESULTS

Western SynCoal’s ACCP Demonstration Facility entered Phase III, Demonstration Operation, in April 1992 and operated in an extended startup mode through August 10, 1993, when the facility began service as a commercial plant. Western SynCoal instituted an aggressive program to overcome startup obstacles and focused on supplying product to customers. Significant accomplishments in the history of the SynCoal® process development are shown in Appendix A.

During the life of the ACCP Demonstration project, nearly two million tons of SynCoal® products, including regular, fines, blend, dust and stability enhanced (DSE) treated, and special high sulfur SynCoal®, were shipped to various customers. Efforts to reduce operating costs on a per ton basis were pursued with a goal of achieving positive cash flow after DOE's financial support ended in 2001. Towards the end of the project, all customers were receiving a composite SynCoal® product.

During the life of the project, the ACCP demonstration supplied more than a dozen commercial customers with SynCoal®. In several applications, SynCoal® was used in a blend with petroleum coke in direct fired cement and lime kilns to produce a stable flame and allow efficient use of the inexpensive waste fuel. The use of SynCoal® in this application also improved the cement and lime product qualities while increasing the overall thermal efficiency. In another application, SynCoal® was used as a green sand binder additive in the metal casting industry, where it provided a reducing agent and improved the "peel" quality of the casting produced.

3.1 Operations

The ACCP was designed to process 68 tons of raw Rosebud Mine coal per hour with an availability of 75%. Each ton of feed was expected to produce 0.61 tons of cleaned SynCoal®, 0.10 tons of fines collected in the particulate removal system (PRS), and 0.07 tons of waste material containing high concentrations of ash and pyrite. (The unaccounted for material is lost moisture and gases.) Construction of the ACCP was complete in March of 1992.

Plant operations commenced in 1992 with equipment shakedown and process trials. Innovative technology demonstration plants inherently encounter start-up difficulties, and the ACCP was no exception. Equipment applicability and operational questions were addressed well into the second quarter of 1993. In May 1993, operations shipped nearly 500 tons of SynCoal® product to customers. In June 1993, SynCoal® deliveries were initiated to several industrial customers. By August 1993, the facility was evaluated by the State of Montana and found to be in compliance with the Air Quality Permit. The plant was able to reliably provide product to the market and was placed in service as a SynCoal® Production Facility on August 10. By January 1994, SynCoal® was being supplied to Ashgrove Cement under a long-term contract.

Production and sales of SynCoal® continued through 1998 but were constantly limited by product storage capacity. An agreement in 1998 with the Colstrip Unit 2 generation station provided sales and consumption of all production not sold to other customers, allowing the facility to operate with greater overall availability. For the two years following this agreement (1999 and 2000), when operations were not constrained by product storage capacity, plant availability was 71.4%, very close to the target of 75% availability.

The agreement with Colstrip additionally outlined provisions to assess and monitor the performance of the product in terms of power generation and environmental parameters. Significant trends in both arenas indicated the beneficial characteristics unique to SynCoal® beyond just increasing the traditional heating value rating.

Final efforts focused on production optimization and high return product applications. SynCoal® was evaluated as a low-end activated carbon supplement to reduce or remove hydrocarbon contaminants from water sources in a joint effort with the DOE. Niche markets in metallurgy and industrial processing were also developed.

At startup, the ACCP demonstration did not meet the design product yields. In 1999, the reported loss was about 5.5% as a percentage of the raw coal feed. For the first three quarters of 2000, the reported loss was about 5.1%. This is the result of normal operations and spillage. Each time the ACCP is put into service, there is a period when the raw coal is not adequately processed, and the product does not meet specifications. The same is true during shutdowns. These startup and shutdown losses appear to represent about 3.5% of the total feed coal, but should be reduced as the number of startup/shutdown sequences is reduced. Spillage occurs at various points and is not necessarily limited to product.

Records of the operations for 1999 and 2000 indicate that processing consumed about 41 kWh of electricity and 1,000 ft^3 of natural gas (approximately 41 pounds or one million Btu) per ton of raw coal feed. Normal operations require the fired heater and the centrifugal fans (representing the majority of the electrical load) to be operational throughout startup, operations, and shutdown. It is, therefore, imperative that operations proceed quickly through the startup and shutdown periods. Based on the design calculations, the ACCP has been well managed, as the energy requirements reflect the actual consumption rather well. Improving availability and extending the duration of campaigns, thereby reducing the frequency of plant startups, reduces losses.

Table 3 provides a summary, by quarter, of operating data for the ACCP demonstration for the life of the project. The information in Table 3 was calculated using the following relationships:

period, hr = days in reporting period x 24 hr/day

availability rate, % = 100 x operating hr/period hr

average feed rate, tons/hr = tons fed/operating hr

rated design capacity, tons = days in reporting period x 1,232.88 tons/day

capacity factor, % = 100 x tons processed/rated design capacity

forced outage rate, % = 100 x forced outage hr/(forced outage hr + operating hr)

The difference between the feed coal and the amount of clean coal produced is due to water loss, samples removed for analysis, and processed fines that are captured in the dust handling system and returned to the mine for disposal. Very little dust is actually lost to the atmosphere. Overall, the plant had an availability of 58.1% and an average feed rate of 63 tons/hr. The plant operated for 46,676 hours, processed 2,939,240 tons of raw coal, and shipped 1,980,279 tons of product.

Table 3 Summary of Operating Data

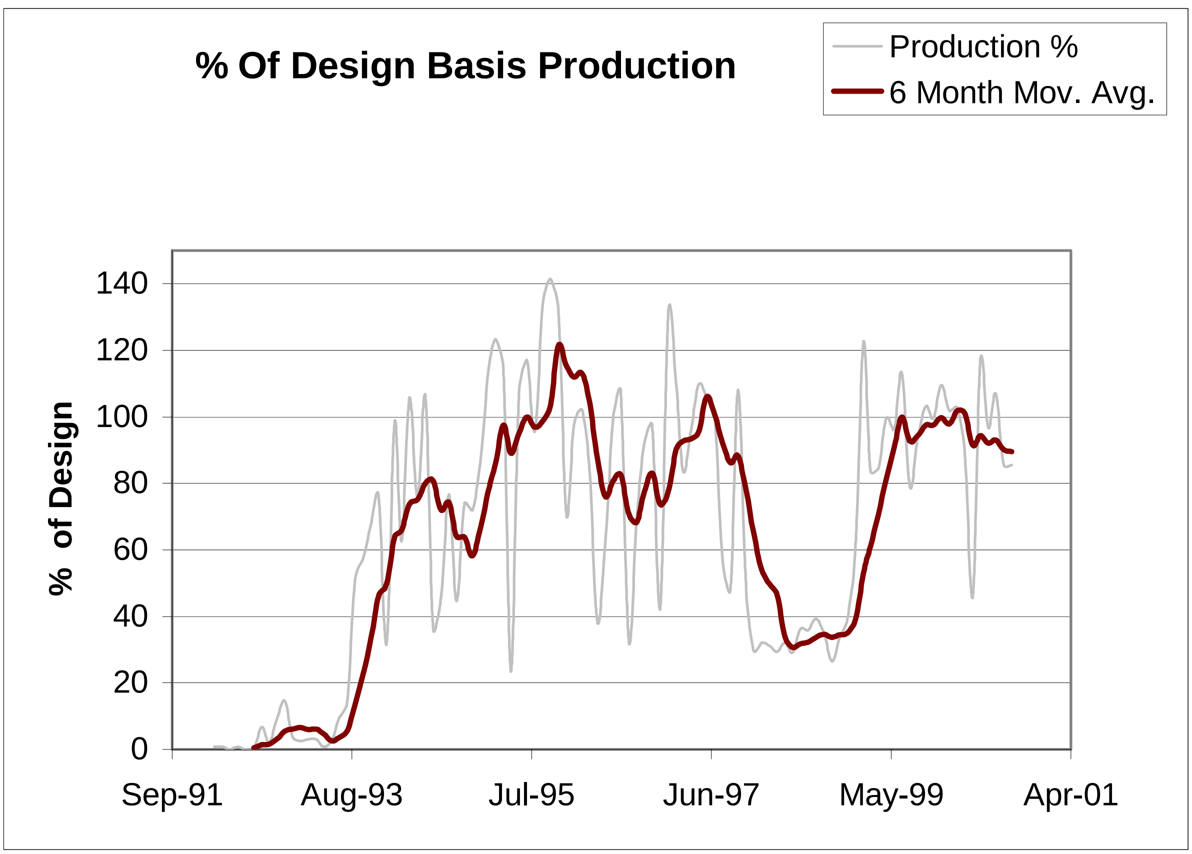
Period	Hours			Rate		Feed, tons	Average Feed Rate, tons/hr	Capacity Factor, %	Shipments, tons
	Operating	Planned Maint.	Forced Outage	Availability, %	Forced Outage, %				
1st Qtr '92	33	711	0	4.4	0.0	700	21.2	1.8	181
2nd Qtr '92	231	1,074	879	10.6	79.2	5,664	24.5	5.1	426
3rd Qtr '92	492	408	1,308	22.3	72.7	12,021	24.4	10.6	1,733
4th Qtr '92	601	656	951	27.2	61.3	10,301	17.1	9.1	3,226
Total '92	1,357	2,849	3,138	18.5	69.8	28,686	21.1	7.6	5,566
1st Qtr '93	1,020	373	767	47.2	42.9	21,735	21.3	19.6	5,202
2nd Qtr '93	811	413	960	37.1	54.2	20,441	25.2	18.2	1,712
3rd Qtr '93	973	157	1,078	44.1	52.6	36,703	37.7	32.4	6,561
4th Qtr '93	1,828	153	227	82.8	11.1	78,542	43.0	69.3	44,053
Total '93	4,632	1,096	3,032	52.9	39.6	157,421	34.0	35.0	57,528
1st Qtr '94	1,599	181	380	74.0	19.2	106,117	66.4	95.6	50,475
2nd Qtr '94	1,640	145	399	75.1	19.6	109,066	66.5	97.2	58,070
3rd Qtr '94	1,153	565	490	52.2	29.8	78,522	68.1	69.2	47,062
4th Qtr '94	1,336	135	737	60.5	35.6	77,084	57.7	68.0	49,840
Total '94	5,728	1,026	2,006	65.4	25.9	370,789	64.7	82.4	205,447
1st Qtr '95	1,665	79	416	77.1	20.0	112,725	67.7	101.6	68,223
2nd Qtr '95	1,439	662	83	65.9	5.5	98,712	68.6	88.0	65,360
3rd Qtr '95	1,896	24	288	85.9	13.2	134,530	71.0	118.6	80,010
4th Qtr '95	1,844	111	253	83.5	12.1	133,654	72.5	117.8	102,095
Total '95	6,844	876	1,040	78.1	13.2	479,621	70.1	106.6	315,688
1st Qtr '96	1,556	0	628	71.3	28.8	100,062	64.3	89.2	67,568
2nd Qtr '96	1,115	820	249	51.1	18.3	75,095	67.4	66.9	46,445
3rd Qtr '96	1,361	581	266	61.6	16.4	85,006	62.5	74.9	60,035
4th Qtr '96	1,720	78	410	77.9	19.3	110,232	64.1	97.2	64,718
Total '96	5,752	1,479	1,553	65.5	21.3	370,395	64.4	82.1	238,766
1st Qtr '97	1,438	0	722	66.6	33.4	96,928	67.4	87.4	59,976
2nd Qtr '97	1,710	13	461	78.3	21.2	117,411	68.7	104.7	72,570
3rd Qtr '97	1,487	296	425	67.4	22.2	98,624	66.3	87.0	229,321
4th Qtr '97	1,182	541	485	53.5	29.1	82,486	69.8	72.7	51,308
Total '97	5,817	850	2,093	66.4	26.5	395,449	68.0	87.9	413,175
1st Qtr '98	587	1,538	35	27.2	5.6	39,292	66.9	35.4	23,228
2nd Qtr '98	624	1,499	61	28.6	8.9	38,508	61.7	34.3	22,653
3rd Qtr '98	755	1,364	89	34.2	10.6	51,844	68.7	45.7	27,841
4th Qtr '98	509	1,654	45	23.1	8.1	33,628	66.1	29.7	23,852
Total '98	2,475	6,055	230	28.3	8.5	163,272	66.0	36.3	97,574
1st Qtr '99	1,244	515	401	57.6	24.4	85,567	68.8	77.1	55,462
2nd Qtr '99	1,566	324	294	71.7	15.8	105,769	67.5	94.3	66,875
3rd Qtr '99	1,656	359	193	75.0	10.4	113,309	68.4	99.9	72,150
4th Qtr '99	1,661	333	214	75.2	11.4	114,651	69.0	101.1	74,163
Total '99	6,127	1,531	1,102	69.9	15.2	419,296	68.4	93.2	268,650

Table 3. Summary of Operating Data (continued)

Period	Hours			Rate		Feed, tons	Average Feed Rate, tons/hr	Capacity Factor, %	Shipments, tons
	Operating	Planned Maint.	Forced Outage	Availability, %	Forced Outage, %				
1st Qtr '00	1,665	315	204	76.2	10.9	115,750	69.5	103.2	78,577
2nd Qtr '00	1,417	518	249	64.9	15.0	97,330	68.7	86.8	62,884
3rd Qtr '00	1,604	241	363	72.6	18.5	111,358	69.4	98.2	72,455
4th Qtr '00	1,712	241	255	77.5	13.0	116,942	68.3	103.1	77,688
Total '00	6,398	1,315	1,071	72.8	14.3	441,380	69.0	97.8	291,604
1st Qtr '01	1,234	140	766	57.1	38.3	90,434	73.3	81.5	56,860
2nd Qtr '01	312	338	70	43.3	18.3	22,497	72.1	60.8	29,421
Total '01	1,546	478	836	53.7	35.1	112,931	73.1	76.3	86,281
Project Total	46,676	17,555	16,101	58.1	25.7	2,939,240	63.0	71.2	1,980,279

Figure 2 shows production rate as a function of design capacity. Averaged over the life of the project, the ACCP facility operated at 71.2% of rated capacity.

Figure 2. Production as Function of Design Capacity



3.1.1 Material and Energy Balances

A typical material and energy balance around the ACCP is shown in Figure 3, based on testing conducted in May, 1994. The results are for Rosebud coal that was normally processed through the ACCP Demonstration Facility. An energy conversion of 87.1% was achieved. Loss of moisture from drying the coal accounts for the weight difference of input versus output.

Figure 3. General Material and Energy Balance

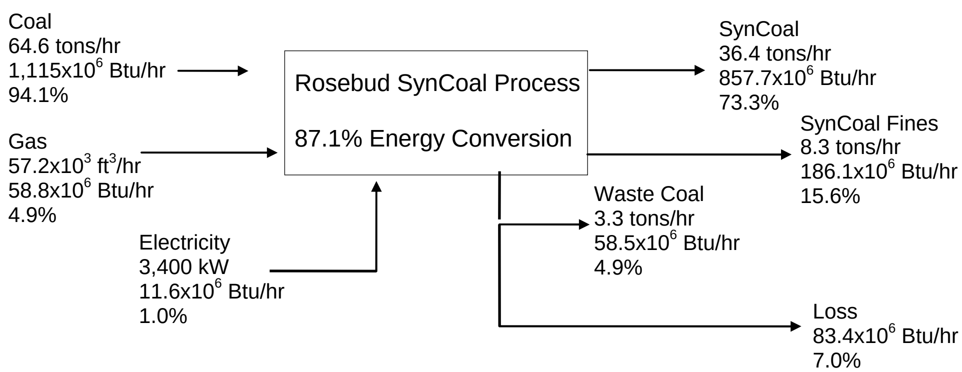


Table 4 provides mass balance information on an annual basis for 1995 through 2001. This information is based upon total quantities into and out of the demonstration process facility. The known weight loss is the water removed from the raw coal. The unknown weight loss is all the other unaccounted for losses.

Table 4. Yearly Material Balance

	Input, tons	Output, tons				
Year	Feed Coal	SynCoal®	Fines	Waste	Water	Unknown
1995	479,621	258,187	52,167	23,771	115,777	29,719
1996	370,395	198,274	44,409	18,520	86,852	22,340
1997	395,449	213,600	47,466	23,484	93,175	17,724
1998	163,272	87,679	19,485	9,751	38,824	7,533
1999	419,297	226,314	50,292	25,148	94,384	23,159
2000	441,380	292,052*	---	27,424	95,006	26,898
2001	112,931	73,500*	---	7,757	25,754	5,920
Total (1995-2001)	2,382,345	1,349,606	213,819	135,855	549,772	133,293
Average, %	100.0	53.9**	11.7**	5.7	23.1	5.6

* SynCoal®/fines blend
** Based on estimated fines production for 2000 and 2001

Table 5 shows the energy balance for the plant on an annual basis for the years 1995 through 2001. All energy losses are identified as unknown. The overall average for these years was 83.7% of the energy input converted to salable product.

Table 5. Yearly Energy Balance

Year	Input, million Btu			Output, million Btu			
	Coal	Gas	Power	SynCoal®	Fines	Waste	Loss
1995	8,361,713	472,615	91,211	6,613,440	1,188,365	387,515	736,219
1996	6,462,652	363,793	77,989	4,774,438	1,037,661	310,613	781,722
1997	6,891,100	383,218	77,355	5,036,035	1,115,166	404,136	796,336
1998	2,950,229	158,497	37,566	2,065,936	444,122	171,788	464,446
1999	7,319,458	423,452	81,600	5,311,816	1,046,149	436,142	1,030,403
2000	7,824,788	337,092	86,919	6,916,424*	---	430,552	901,823
2001	2,026,749	98,153	21,654	1,744,193*	---	148,586	253,777
Avg, %	93.9	5.0	1.1	69.6**	14.1**	5.1	11.2

* SynCoal®/fines blend
** Based on estimated fines production for 2000 and 2001

3.1.2 Feed Coal and Product Analyses

Although most of the feed to the ACCP plant was Rosebud coal, other coals were tested during the demonstration. Table 6 presents the results of some of these tests.
Four products are sampled at the ACCP plant: the SynCoal® discharged from the conversion process, the product collected by the PRS, the cleaned SynCoal®, and the material removed in the cleaning process that contains elevated concentrations of ash and pyrite. The cleaned product and the waste are derived from the SynCoal® produced by the conversion process. Table 7 provides average annual analyses of raw coal, SynCoal® product, fines, and waste material for 1995 through 2001. These results indicate that the quality of the product remained essentially constant for the life of this project.

3.1.3 Product Sales and Deliveries

During the life of the ACCP Demonstration project, almost two million tons of SynCoal® products, which include regular, fines, blend, and DSE treated SynCoal®, were shipped to various customers. The plant maintained a perfect delivery record with customers by providing the amount of product requested in accordance with the sales agreements. Table 3 lists shipments by quarters for the life of the project, and Table 8 lists sales to customers by category and by year.

3.1.4 Process Improvements

Market awareness and acceptability for both the product and the technology were primary goals. During the life of the demonstration, the ACCP Project team focused on improving operations, developing commercial markets, and improving the SynCoal® product, as well as the product's acceptance. Marketing efforts were targeted at developing markets for the SynCoal® fines and longer term industrial contract sales. Several unforeseen product issues, which were only identified by the demonstration project operation, changed the required activities for the ACCP Demonstration Project. These activities included:

Table 6. Feed Coal and SynCoal® Analyses for Selected Coals

Feed Coal Source	Rosebud Coal			Center Mine Lignite			Powder River Basin		
Analysis	Raw Coal	SynCoal®	SynCoal® fines	Raw Coal	SynCoal®	SynCoal® Fines	Raw Coal	SynCoal®	SynCoal® fines
Proximate Analysis, wt% (as received)									
Moisture	25.24	2.63	5.59	36.17	7.35	10.26	28.11	4.51	6.22
Volatile matter	29.16	36.98	35.32	27.13	39.39	36.33	31.78	41.40	39.00
Fixed carbon	36.68	51.19	49.65	30.16	46.74	43.92	35.25	47.48	48.48
Ash	8.92	9.20	9.44	6.54	6.52	9.49	4.86	6.61	6.30
HHV, Btu/lb	8,634	11,785	11,194	7,064	10,718	9,914	8,727	11,805	11,339
Equil. Moisture	24.9	14.7	20.2	34.98	20.12	21.92	28.38	14.04	20.2
Ultimate Analysis, wt% (moisture free)									
Carbon	67.61	70.00	68.64	66.19	69.24	65.94	69.13	70.13	69.20
Hydrogen	4.45	4.83	4.63	4.10	4.44	4.17	5.13	5.16	4.86
Oxygen	14.00	13.88	14.65	16.86	17.50	17.10	17.42	16.12	17.57
Nitrogen	1.02	1.26	1.16	0.92	0.95	1.04	1.09	1.20	1.14
Sulfur	0.99	0.58	0.92	1.68	0.83	1.18	0.47	0.47	0.51
Ash	11.93	9.45	10.00	10.25	7.04	10.57	6.76	6.92	6.72
C/H molar ratio	15.18	14.50	14.83	16.13	15.61	15.82	13.47	13.58	14.23
Petrographic Analysis, vol%									
Huminite	68.1	69.5	68.7	73.4	85.1	74.5	73.4	85.1	74.5
Liptinite	7.8	6.0	4.4	4.2	4.4	5.2	4.2	4.4	5.2
Inertinite	16.2	18.9	21.1	16.2	6.4	14.1	16.2	6.4	14.1
Mineral matter	7.9	5.6	5.8	6.2	4.1	6.2	6.2	4.1	6.2
Reflectance	0.38	0.45	0.44	0.33	0.36	0.36	0.35	0.38	0.40
Other Analyses									
-COOH, wt%	0.85	0.26	0.46	0.53	0.17	0.31	1.02	0.15	0.41
ASTM classification	Subbituminous C	High vol. C bituminous	High vol. C bituminous	Lignite A	High vol. C bituminous	Subbituminous A	Subbituminous C	High vol. C bituminous	High vol. C bituminous

Table 7. Annual Average Feed and Product Analyses

Stream	Moisture , %	Ash, %	Sulfur, %	HHV, Btu/lb	SO_2, lb/10^6 Btu
1995					
Raw Coal	25.67	9.01	0.72	8,710	1.63
SynCoal®	1.86	9.12	0.80	11,936	1.33
Fines	4.80	10.30	0.83	11,257	1.47
Waste	1.55	32.04	4.00	8,519	9.96
1996					
Raw Coal	25.14	8.71	0.74	8,722	1.69
SynCoal®	1.95	8.88	0.71	12,114	1.17
Fines	N.A.	N.A.	N.A.	N.A.	N.A.
Waste	N.A.	N.A.	N.A.	N.A.	N.A.
1997					
Raw Coal	25.17	9.13	0.81	8,713	1.86
SynCoal®	1.72	10.00	0.96	11,869	1.62
Fines	N.A.	N.A.	N.A.	N.A.	N.A.
Waste	1.66	38.36	6.82	7,863	19.26
1998					
Raw Coal	24.69	9.63	0.99	8,766	2.26
SynCoal®	1.92	9.45	0.77	11,837	1.30
Fines	5.87	15.25	0.92	10,345	1.78
Waste	2.11	31.68	6.10	8,809	14.03
1999					
Raw Coal	24.46	9.96	0.91	8,723	2.08
SynCoal®	1.96	10.47	0.76	11,704	1.29
Fines	5.74	14.51	0.88	10,401	1.69
Waste	2.52	32.44	5.18	8,659	11.84
2000					
Raw Coal	24.17	9.30	0.78	8,864	1.76
SynCoal®	2.18	9.17	0.71	11,841	1.19
Fines	6.51	10.68	0.84	10,956	1.53
Waste	2.08	37.90	5.92	7,850	15.79
2001					
Raw Coal	24.20	8.65	0.72	8,976	1.60
SynCoal®	1.95	9.33	0.72	11,868	1.21
Fines	7.06	10.18	0.84	10,947	1.53
Waste	3.22	23.37	3.86	9,787	7.89

N.A. = Not Available

.

Table 8. Summary of SynCoal® Shipments

Customer	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Industrial											
Ash Grove Cement			34,686	28,677	35,468	42,589	42,852	40,645	33,237	12,341	270,495
Bentonite Corporation		2,437	10,172	9,734	9,241	11,755	14,476	8,730	9,278	4,379	84,581
Wyoming Lime Producers		90	25	2,367	11,785	14,405	20,293	17,138	18,449	6,860	91,412
Continental Lime		226	7,564	1,160	10,673		19,803	27,463	22,735		89,624
Holnam Cement			1,580	3,287				43,559	52,257	19,401	120,084
Empire Sand & Gravel			2,368	1,399	2,316	946	150				7,179
Packaging Corporation				641							641
Univ. of North Dakota				209							209
Stillwater Mine					10						10
Western Sugar			188								188
NSP Sherburne			400								400
EG&G			15								15
Pete Lien & Sons					36	1,355					1,391
Graymont										8,455	8,455
Nonindustrial											
Department of Energy					25						25
Barrick Goldstrike									1,866	495	2,361
Utility											
Colstrip Units 1 & 2					97,902	179,020		131,115	153,782	34,350	596,169
Colstrip Units 3 & 4	2,029	39,853	62,420	110,506	8,073						222,881
MPC J.E. Corette Plant	3,144	13,281	84,243	156,564	60,857						318,089
CELP	393			317							710
Northern States Power		1,641									1,641
Dairyland Power			410								410
Fremont Utilities			1,376	465	2,380						4,221
Minnkota Power Coop.				362							362
Western Energy Co.						163,105					163,105
Total	5,566	57,528	205,447	315,688	238,766	413,175	97,574	268,650	291,604	86,281	1,980,279

- Identifying efficient and effective handling techniques.

- Demonstrating the benefits of SynCoal® in smaller, more constrained industrial boilers and older, smaller utility boilers.

- Reducing operating costs on a per ton basis with a goal of achieving positive cash flow when DOE financial support ended. Some of the items included in the analysis were inert gas consumption/price reduction, optimizing feed size distribution for efficient processing, optimizing feed rate versus energy requirements, nontraditional marketing investigations, operator education and training programs, and loss analysis and recovery.

Several debottlenecking opportunities were identified that required some capital investment, including supplemental coal firing for process heat, All Mineral jig to replace high maintenance multicomponent system, removal of heat exchanger for fired heater optimization, Aeroglide reactor design for low-cost, high-availability production, and enhanced piping to contact condensers for increased efficiency. Improvements in these areas had the capacity to boost production to more than 500,000 tons/yr of product with minimal plant downtime.

3.1.5 Product Test Burns

During the course of this project, a series of test burns were performed by a variety of potential customers. The more important of these are discussed below.

3.1.5.1 Montana Power Company's J.E. Corette Plant

Test burns were conducted intermittently at MPC's J.E. Corette Plant during the period from March 1, 1994, through May 31, 1994. The objective was to determine the effect of burning SynCoal® on boiler performance and SO_2 emissions. The test consisted of baseline operation on Area D coal plus runs with 50% DSE conditioned SynCoal®/50% Area D coal and 79% DSE conditioned SynCoal®/21% Area D coal. The level of SO_2 emissions decreased when burning SynCoal®. When burning 100% coal, SO_2 emissions were 1.45 lb/10^6 Btu. This rate was reduced by 12% when burning the 50/50 blend and by 23% when burning the 79/21 blend. Boiler efficiency also improved, by 1% with the 50/50 blend and by 1.5% with the 79/21 blend. During the 79/21 blend test, the unit maintained a load of 170 MW gross for a 24-hour period and did not have to reduce load to deslag. A test burn with a 95% SynCoal® blend was not continued due to "skidding" problems with the mills.

3.1.5.2 Western Sugar Company

In December 1994, three open-topped rail cars, loaded with a 75% DSE conditioned SynCoal®/25% Area D Rosebud subbituminous coal were shipped to Western Sugar Company. Trouble was experienced unloading one car that was severely frozen at the bottom due to over treatment of the SynCoal®. The No. 2 boiler operated well on the SynCoal® blend and produced 10-20% more energy than the No. 3 and No. 4 boilers burning raw coal. Because the operator had not adequately compensated for the higher heating value of the SynCoal® blend, the No. 2 boiler was providing more than its typical 33% of the total steam requirement. Later, this imbalance was corrected. From observations of the boiler's interior, it was apparent that the No.

2 boiler was burning hotter. The SynCoal® appeared to ignite and combust faster than raw coal. The coal feeders operated satisfactorily with the SynCoal®; the operator indicated that a better spread would be possible with some adjustments, but these were not made because of the short duration (one day) of the test. The ash layer on the grate was slightly thinner than for the boilers fired on raw coal. The ash appeared to be fusing slightly more than the raw coal ash but not to an extent that concerned the operator.

3.1.5.3 Holnam Cement, Inc.

Eighteen cars (1,644 tons) of SynCoal® were tested at Holnam Cement November 16-24, 1994. The SynCoal® was shipped in four-door, closed-cover, hopper cars. No adjustments were made to the coal mill during grinding of the SynCoal®. Fineness averaged 99.86% passing 50 mesh, 98.68 % passing 100 mesh, and 79.51 passing 200 mesh. A change was required in the kiln feed due to SynCoal's® reduced ash content. A change was also required in kiln operation due to SynCoal's® reduced moisture content, which reduced the heat requirements in the coal mill and required water to cool the air in the cooler dust collector system.

The SynCoal® test burn was started while burning Type I-II clinker and continued for the next four days before changing to Type I-II SR clinker for the next four days and then changing back to Type I-II for the final day. Kiln operations were very steady, the burning zone was easily controlled, power required to turn the kiln stayed low, and dust loss was consistent and about average. The amount of heat used was about the same, or possibly slightly better, than for Kirby Coal. The fuel was very consistent with almost no fluctuations in quality; Holnam commented that it was somewhat like burning gas.

On March 22, 1999, Holnam Cement completed a 1,942-ton SynCoal® test burn. Holnam stated that preliminary results of the test burn were favorable, and they would evaluate using SynCoal® as their primary fuel rather than natural gas.

3.1.5.4 Dairyland Power

In June 1994, two carloads (approximately 181.5 tons) of DSE-conditioned SynCoal® were delivered to Dairyland Power's J.P. Madgett Plant. This shipment was a blend of approximately 85% SynCoal® and 15% stabilization/dust control medium. Both cars were probed for hot spots upon arrival. Measurements taken down the middle of the cars at varying distances from the front and at varying depths showed a spike of 191°F, but the average temperature was around 140°F. The cars were tested in the same manner four days later, and no spikes were found. In fact, at some test sites, the temperature actually decreased. However, overall, the temperature in the cars increased over the time between tests. Just before dumping the next day, the cars were again tested at various depths at one point, and the highest temperature recorded was 174°F.

The SynCoal® was conveyed towards the silo and eventually the stock pile. No dust was seen in the conveyor system. As the coal built up under the discharge chute on the stock pile, it was bulldozed away from the main pile and compacted. Little or no dust was seen. Following completion of the stocking out, samples were collected for a sieve test to determine particle size and degradation due to handling. Approximately 33.3% of the SynCoal® in the cars was in pieces larger than 1/4 inch in diameter, and 21% was smaller than l/l6 inch in diameter. The crusher was not needed to break down the SynCoal®, and it was able to be fed to the mills as it came from the rail cars. Dumping caused many of the particles to decrease in size. After dumping, only 13% of the particles was larger than ¼-inch, and 73-90% was smaller than 1/16 inch. The particle size did not decrease significantly during the conveyor trip from the dumper to the stock pile.

Analyses of the SynCoal® indicated a total moisture content of 11.61% and a HHV of 10,347 Btu/lb. A preliminary summary of the test burn shows that the coal typically used contained 27.14% moisture and had a HHV of about 8,817 Btu/lb. Thus, SynCoal® showed a marked decrease in moisture content and an increase in heating value compared to the fuel normally used. About a month later, the SynCoal® pile in the coal yard was evaluated and sampled. A temperature traverse was also done. The readings indicated the pile was not exceedingly hot, with the highest value at 130^{o}F; however, deep readings were not taken due to the coal pile's hardness. Temperatures in the pile are cooler than those that were recorded for the coal in the rail cars. No test burn information was made available.

3.1.5.5 University of North Dakota

The University of North Dakota (UND) purchased 92 tons of SynCoal® and conducted a test burn from March 30 through April 2, 1995. They originally planned to blend SynCoal® with raw coal in a 1:1 ratio to prevent overheating the fire box and damaging the refractory and grates. Because of the fineness of the SynCoal®, the ratio was decreased to 1:3 and finally to 1:5 to allow proper distribution on the grates. The spreader had problems distributing the SynCoal®, and it would pile up on the front of the bed and cause hot spots in the dry ash handing system.

A cold boiler coal distribution test was conducted at UND's steam plant on June 7, 1995, to determine if SynCoal® could be adequately distributed into UND's boiler using the existing feeder/distributors with little or no modifications. The test indicated that the feeders are inadequate to effectively distribute SynCoal®. An air assisted spreader was identified but was not installed.

3.1.5.6 Packaging Corporation of America

A three-day test in March 1995 was conducted at Packaging Corporation of America to determine the handling characteristics of SynCoal® with the existing coal handling system and SynCoal's® performance in a coal-fired cyclone furnace. Dust problems were encountered as the SynCoal® was unloaded and conveyed into the plant. To alleviate the hazards, a water spray was used at the inclined belt prior to the crusher and a vacuum truck at the crusher chute. It was determined that a pneumatic system would be the best way to handle SynCoal®. With such a system, there would be even less dust than the current handling system would generate with even the most dustless coal. The combustion testing demonstrated that SynCoal® reacted consistently and uniformly during large load swings.

3.1.5.7 Fremont Department of Utilities

Five covered hopper cars of SynCoal® (465 tons) were delivered to Fremont Department of Utilities for testing a blend with their current coal for a ten-day test burn. The blend used was

20% SynCoal® and 80% current coal. They experienced very little dust when conveying the blended product into their system. The HHV of the blend was about 8,500 Btu/lb.

3.1.5.8 Minnkota Power Cooperative

Minnkota burned a shipment of SynCoal® fines in their boilers to test the use of this material in deslagging operations. Initial results indicate that it was very successful in deslagging; however, some equipment modifications would need to be done to further test the product for this application.

Minnkota tested injecting SynCoal® fines into its Unit 1 boiler to determine the effect on unit operation of displacing fuel oil with SynCoal® fines while maintaining constant load. Test results were compared to predictions from Minnkota's in-house boiler model. The objective was met in that the use of SynCoal® in one feeder for cyclone No. 1 was successful during this test in removing a visible slag deposit and preventing its reappearance.

3.1.5.9 Colstrip Energy Limited Partnership

In August 1995, a blend of coal screen rejects and process waste coal, along with a small amount of SynCoal® fines, was delivered to the Montana One Plant, owned and operated by Colstrip Energy Limited Partners (CELP). This plant is a qualified waste combustion facility and uses waste coal to produce electricity. Due to permitting issues by the Montana State Air Quality Bureau, deliveries were stopped. SynCoal® was found to be a viable fuel source for the plant provided the operating, environmental, and legal issues are resolved.

3.1.5.10 Wyoming Lime Producers

Wyoming Lime Producers received a shipment of SynCoal® fines by truck on September 30, 1995. After using SynCoal® for several weeks, they modified their delivery handling equipment to enable their plant to take both regular SynCoal® and fines.

3.1.5.11 Pete Lien & Sons

Pete Lien & Sons tested 36 tons of SynCoal® in their quick lime facility during October 1996. They experienced no problems in unloading the SynCoal®, and they were impressed with its burning capacities. They did a small blend test, blending their raw coal with SynCoal® to see how long it would remain stable. After six days, they reported that the center of the pile was getting warm.

3.1.5.12 Barrick Goldstrike

In March 2000, Barrick Goldstrike received their first shipment of SynCoal® for use in their roaster operation at their gold mining facility. The SynCoal® was screened to 6-mesh. During initial testing, one roaster operated for 36 hours on SynCoal® at 4,000 tons per day versus the design rate of 6,000 tons per day. SynCoal® appeared to work very well in this application. The operator anticipated that the fuel requirement would decrease as they would be using a different ore blend with a higher fuel value (higher sulfides and higher carbonaceous matter). The roasters are designed to operate autogenously with ore fuel values of 240 Btu/lb, but they are predicting that this will increase to 290 Btu/lb for the next 4-5 years.

3.1.5.13 Colstrip Unit 2

Unit 2 started demonstrating SynCoal® as a supplemental fuel in February 1999. Baseline testing indicated that Unit 2 was typically producing 2.9 fewer net MWs than Unit 1. In late May and June, Unit 1 was overhauled, increasing its performance from an average of 281 MW (net) to 288 MW (net). Baseline testing for the second half of 1999 indicated that Unit 2 would have produced 5.4 fewer net MWs than Unit 1, if not for the addition of SynCoal®. Actual performance showed that Unit 2 outperformed Unit 1. Unit 2 averaged 285.7 MW (net) versus 281.4 MW (net) for Unit 1 through June, and 288.8 MW (net) versus 288.4 MW (net) during July through December (after the overhaul). If only the days SynCoal® was used are included in this comparison, the differences increase to 285.7 MW versus 278.4 MW through June and 292.7 MW versus 287.3 MW for the second half of the year.

When adjusted for the expected shortfall of Unit 2 production versus Unit 1 from the baseline testing, an average of 3.7% (10.2 MW net first half and 10.8 MW net second half) additional power was generated from Unit 2 on days that SynCoal® was used as a supplemental fuel. It is interesting to note that the improvement in net generation increased in the second half, even though the percentage of heat input represented by SynCoal® decreased from 16.6% to 15%. Over the entire period, the heat rate improved by 85 Btu/kWh when firing SynCoal®, with slightly more improvement in the second half, increasing from about 82 to 87.6 Btu/kWh, even though the percentage of SynCoal® declined slightly.

Based upon a review of Montana Department of Environmental Quality continuous emission monitoring (CEM) data for 1999, sulfur dioxide (SOx) emissions were reduced by approximately 430 tons or 8% (compared to the Unit 1 emission rate), and nitrogen oxides (NOx) emissions were reduced by approximately 826 tons or 19% (compared to the Unit 1 emission rate).

The impact on auxiliary power was very noticeable, averaging about a 1.0 MW decrease during the first half of the year and about a 1.9 MW decrease on a unit to unit comparison. There were additional benefits that have not been fully evaluated, resulting from approximately 191,000 fewer tons of raw coal handled, approximately 3,300 fewer tons of ash through the systems, and approximately 430 fewer tons of sulfur to be scrubbed than if the same amount of power were produced using only raw coal.

3.2 Environmental Results

The coal-cleaning area's fugitive dust was controlled by placing hoods over the fugitive dust sources and conveying the dust laden air to fabric filters. The bag filters effectively removed coal dust from the air before discharge. The Department of Health and Environmental Sciences completed stack tests on the east and west baghouse outlet ducts and the first-stage drying gas baghouse stack in 1993. The emission rates of 0.0013 and 0.0027 grains/dry standard cubic foot (limit of 0.018 gr/dscf) and 0.015 gr/dscf (limit of 0.031 gr/dscf), respectively, are well within the limits stated in the air quality permit.

A stack emissions survey was conducted in May 1994. The survey determined the emissions of particulates, sulfur dioxide, oxides of nitrogen, carbon monoxide, total hydrocarbons, and hydrogen sulfide from the process stack. The principal conclusions based on averages are:

- The emissions of particulate matter from the process stack were 0.0259 gr/dscf (2.563 lb/hr). (Limit: 0.031 gr/dscf.)

- The emissions of nitrogen oxides were 4.50 lb/hr (54.5 parts per million). (Limit: 7.95 lb/hr estimated controlled emissions, and 11.55 lb/hr estimated uncontrolled emissions based on vendor information.)

- The emissions of carbon monoxide were 9.61 lb/hr (191.5 parts per million). (Limit: 6.46 lb/hr estimated controlled emissions, and 27.19 lb/hr estimated uncontrolled emissions based on vendor information.)

- The emissions of total hydrocarbons as propane (less methane and ethane) were 2.93 lb/hr (37.1 parts per million).

- The emissions of sulfur dioxide were 0.227 lb/hr (2.0 parts per million). (Limit: 7.95 lb/hr estimated controlled emissions, and 20.27 lb/hr estimated uncontrolled emissions for sulfur oxides.)

- The emissions of hydrogen sulfide were 0.007 lb/hr (0.12 parts per million).

4.0 PRODUCT IMPROVEMENT TESTING

Considerable effort was expended during the life of the project on controlling spontaneous combustion of the cleaned coal product and reducing dust formation. The product produced was exceptionally close to the design basis product from a chemical standpoint but was not acceptable from a commercial standpoint due to instability (spontaneous heating) and dustiness.

If SynCoal® is stored in more than a small pile (more than 1-2 tons) in contact with air for from 18-72 hours, it reaches temperatures at which spontaneously combustion can occur. Spontaneous heating of run-of-mine, low-rank coal is a common problem but usually occurs only after open air exposure for periods of days to weeks, not hours. However, thermally upgraded low-rank coals have universally displayed spontaneous heating tendencies to a greater degree than raw low-rank coals. During the life of the project, work continued to try to overcome dust formation and spontaneous heating, and although some progress was made, these problems were never fully solved without enclosed handling and inerted storage. Some of the tests conducted were:

- Treatment of SynCoal® with CO_2 and shipment to customers.
- Bench testing to characterize SynCoal® oxidation.
- Treatment of SynCoal® with pore blocking compounds and shipment to customers.
- Blending of SynCoal® with raw coal and shipment to customers.
- Rehydration of SynCoal® and shipment to customers.

- Full-scale testing of pile management practices.

Some of these tests are more fully described below.

4.1 Product Stability

Early in the project, the Butte pilot plant was operated to confirm that the reactivity of the SynCoal® produced by the ACCP plant was the same as that of the pilot plant. The spontaneous heating characteristic was not detected at the pilot plant stage because the pilot plant produced product at a relatively low rate. This allowed sufficient time for the SynCoal® to naturally passivate before being covered by subsequent product.

Tests were performed on a bench scale to determine the completeness of oxidation, the potential for accelerating the rate of oxidation, and the thermodynamics of oxidation. From these tests, the mass uptake of oxygen was determined, as well as the typical SynCoal® oxidation rate expression. Once the oxidation test results were calculated, the values were used to design the stabilization pilot-scale equipment.

From a literature search on methods for controlling spontaneous combustion, carbon dioxide was described as a method to control spontaneous heating. Testing was performed to determine the effectiveness of using carbon dioxide to prevent or delay spontaneous heating and to optimize the rate of application. The results from the testing indicated a two- to four-fold increase in SynCoal® product life. Unfortunately, carbon dioxide is expensive and not an economical solution to the spontaneous combustion problem.

The literature search also identified several commercially available compounds that were reported to prevent spontaneous combustion by blocking the reactive sites on the surface of coal. Several chemicals were tested on SynCoal® at varying flow rates and concentrations. Both spray application and a pilot-scale blender application technique were tested. The trials indicated that extremely high chemical applications showed only a marginal improvement in product stability.

A market analysis indicated that blending SynCoal® with raw coal might be an effective method of delivering SynCoal® to market. Testing was performed to determine the effectiveness of blending SynCoal® with raw coal in achieving a stable product, the optimum blend ratio, and the resulting fuel characteristics. Preliminary results indicated a significant increase in the life of the SynCoal® product at certain blend ratios; however, the product was extremely dusty.

As a result of the blending trials, rehydration tests were conducted to determine the effectiveness of using water to control spontaneous combustion and to determine the optimum moisture content and water application method. Results indicated an 8- to 16-fold increase in SynCoal® stability. However, the fuel value of the coal was reduced, and visible water vapor was evident upon delivery of the treated product.

Pile management tests were performed to determine whether periodic heat rejection would result in a stabilized product. Observations indicate that SynCoal® can be stabilized with pile management over a two-week period. However, a large land area would be required at commercial scale, and variable weather conditions could affect product quality.

After ensuring operability of the equipment, process variables, including residence time, air flow, material temperatures, feed coal size, and flow rate, were tested. Under operating conditions, the process variables were found to be interdependent, and care was required not to operate in a "run-away" mode. Results indicated that treated SynCoal® can be six times more stable than product just off the process. Based on the successful test results, a full demonstration-scale stabilization process step was designed for retrofit to the ACCP plant. Two different designs, a slip stream at 8 tons per hour (tph) and a full throughput design at 48 tph, were cost estimated. Complete construction of this plant addition would take 13 months, followed by a full year of process and product testing.

In January 1995, a Cooperative Research and Development Agreement (CRADA) was initiated with the U.S. Bureau of Mines and U.S. Department of Energy, to determine the effect of different processing environments and treatments on low-rank coal composition and structure. Specific objectives were to study the explosivity and flammability limits of dust from the process and to identify the causes of spontaneous heating of upgraded coals. Other participants in this study were the Amax Coal Company and ENCOAL, who have also experienced similar effects with their upgraded products.

The stabilization equipment from the ENCOAL facility in Wyoming was assembled at the ACCP facility, since the ENCOAL plant had been shut down. Testing was planned as time and manpower were available.

ENCOAL had constructed a clean coal demonstration plant near Gillette, Wyoming, to demonstrate a proprietary process for upgrading coal and extracting oil using mild pyrolysis (the “LFC Process”). Tek-Kol, an affiliate of SGI International, a California based company, is the inventor of the LFC Technology. ENCOAL operated the demonstration plant under a license granted by TEK-KOL. In 1998 a Joint Research Agreement was signed between TEK-KOL and Western SynCoal® LLC to study and share information related to understanding the mechanism of spontaneous combustion and possible solutions.

In October 1999, a Research Development Agreement and a Services Agreement was signed between SGI International and Western SynCoal® LLC. SGI is interested in gaining information on the field performance of an Aeroglide tower dryer test unit for coal drying and finishing. RSCP has agreed to install, commission, and operate an Aeroglide Tower dryer at the ACCP facility in Colstrip, Montana.

The Aeroglide reactor represents a novel method for allowing process gases to contact the solids in a mechanically gentle environment. Solids are fed to the unit and flow downward, assisted only by gravity, through a system of baffles that gently mix the solids during their migration from the inlet to the outlet. The flow is controlled using a rotary valve at the discharge of the unit. Successive rows of baffles are configured perpendicular to each other. Process gases are introduced using alternate horizontally configured baffles and distributed into the solids uniformly. Process gases migrate to adjacent baffles and exit the process bed of solids. The Aeroglide reactor was configured to rehydrate processed SynCoal®, remove the heat of reaction, and partially oxidize the product in an effort to promote product stability. This process scheme was intended to modify the characteristics of the final SynCoal® product, thus allowing traditional transportation techniques to be employed.

4.2 Product Dustiness

Due to numerous steps in which the coal is fluidized in process gas or air that entrains and removes dust-sized particles, the product is basically dust free when it exits the processing facility. As is typical of coal handling systems, each handling activity performed on the product after it leaves the process degrades particle size and produces some dust. The drop into the product silos, which can be up to 90 feet, can be especially degrading to the coal. Quantifying dustiness is difficult, but once the product coal has passed through the nine transfer points between the process and a rail car, the SynCoal® is visibly dustier than run-of-mine coal. Actually, the SynCoal® is no dustier than the raw coal, but the dust is more fugitive. Because SynCoal® is dry, there is no inherent ability of small particles to adhere to the surface of larger particles. This allows any dust-sized particles that are generated by handling to be released and become fugitive. Transfer points were modified to reduce impacts, methods of reducing degradation in the silos were examined, and dust suppression options were tested.

The problem of SynCoal® dustiness was reviewed to determine a dust control strategy based on results obtained from attrition testing. Initial tests were conducted with standard, water-based chemicals, which included surfactants, inorganic salts, and lignosulfonate-based suppressants. None of the products tested at economic concentration levels were effective in mitigating SynCoal® dustiness. After water-based compounds proved to be ineffective, more exotic and expensive compounds were tested. These compounds included oil, anionic polymers, latex polymers, and various oil-based emulsions. Oil was found to be an effective, although expensive, dust suppressant; however, due to environmental concerns, oil was removed from consideration. An ionic polymer was found to be an effective, environmentally safe suppressant. However, this chemical is expensive and negatively impacts overall process economics. As a result of rail car testing, an effective car topping compound was located. No dust suppressant was found to work adequately on product blends with raw coal without first rehydrating the SynCoal®.

In addition to spray application of chemicals, a pilot-scale, zigzag blender was tested to apply dust suppressant compounds. The objective of these tests was to maximize compound efficiency and to ensure that spray application test results were not biased by inconsistent coating. The zigzag blender test confirmed the results obtained by the spray method and indicated that expensive compounds could be substantially diluted with water if a more efficient application technique was used.

Tests involving adding water to the SynCoal® product in lieu of blending yielded the most promising results. Total inundation of SynCoal® with water reduced the amount of dust liberated at the point of transfer. This technique has allowed SynCoal® to be shipped out of the ACCP plant. Negative aspects appear to be a reduced fuel value, difficulty of winter application, and reduced acceptance because of visible water vapor liberation upon delivery.

4.3 Dust and Stability Enhanced (DSE) Conditioning

Based on the results of the various stability tests, a procedure was developed which resulted in an 8- to 16-fold increase in product stability. This procedure, known as Dust and Stability Enhanced (DSE) Conditioning, consisted of applying an anionic polymer (DT100A), obtained from O'Brien Chemicals in Ohio, diluted with water. This polymer neutralized the static charge on the SynCoal®

and partially rehydrated it to reduce dustiness and the tendency toward spontaneous combustion. DSE treatment permitted shipping SynCoal® to users in the Midwest. DSE treated SynCoal® can be blended with raw coal without causing dust problems.

4.4 Meeting Customer Needs

A three pronged approach was used to satisfy customer needs for a safe, effective way to handle SynCoal®. The first method was to subject the SynCoal® to DSE treatment, which allowed conventional bulk handling for a short period (about one week) but degraded the heating value. Eventually, the product become dusty and again susceptible to spontaneous combustion.

The second technique was contained storage and transport with minimal exposure to air. This technique provided maximum product quality and actually enhanced the material handling performance for many industrial customers; however, transportation required equipment not conventionally used in coal delivery systems and was impractical for large bulk customers, such as conventional utility plants.

The third approach was to develop a stabilization process step. SynCoal's® previous work has been of great benefit in the collaborative research with ENCOAL. SynCoal® had hoped to incorporate its stabilization process in the next generation facility or develop a smaller pilot operation in direct response to a specific customer requirement. Unfortunately, no specific customer was identified before the project ended.

5.0 ECONOMICS

To evaluate the commercial potential of the SynCoal® Advanced Coal Conversion Process, a Reference Plant Design (RPD) was developed based on information from the following sources: engineering and research data from the Rosebud SynCoal® plant, experience gained from operation of the 72 tons/hr Rosebud plant, engineering and market studies on the application of SynCoal® at various facilities, a "Center SynCoal® Plant Impact Study," prepared by Black & Veatch on the feasibility of adding two 100 tons/hr feed rate SynCoal® trains at the M.R. Young power station, and data from a field test burn of 700 tons of lignite-derived SynCoal® at the M.R. Young plant. The RPD Report illustrates integration of 100-ton/hr SynCoal® modules into Units 1 and 2 of the M.R. Young plant.

There are a number of differences between the demonstration unit and the RPD, the major differences being: the RPD uses static bedplate fluid bed units for the dryer and reactor, whereas the demonstration plant uses vibratory fluid bed units; the RPD incorporates indirect cooling in a rotary drum, while the demonstration plant uses direct cooling in a vibratory fluidized bed; the RPD does not include the gravity coal cleaning step present in the demonstration plant, and the RPD derives its process heat needs from steam provided by the power plant in contrast to the demonstration plant that uses natural gas combustion.

The above illustrates a difference in philosophy between the demonstration plant and the RPD. The demonstration plant was designed to be a standalone unit. Therefore, it needed an independent source of heat. Also, it was desirable to be able to produce a cleaned product, as that might be important for some applications of SynCoal®. On the other hand, the RPD plant was designed to be located at the site of a coal-fired power plant. Therefore, its heat requirements could be integrated into the power plant's operations. Furthermore, cleaning the SynCoal® is not of great significance, since whether the ash comes from the cleaning process or from the furnace, it will still have to be disposed of at the same place. Therefore, the capital required to provide SynCoal® cleaning may not represent a profitable investment.

Engineering assumptions for the M.R. Young Power Station version of the RPD were:

- Design availability was 80%.
- Plant would be constructed adjacent to an existing power station that would provide 2,400 psig, 1000^{o}F steam, with condensate returned to the boiler feed water system.
- Other utilities would also be tied into the power plant's systems.
- Process gas from the SynCoal® facility would be incinerated in the power plant furnace.
- Operating and maintenance crews would be integrated with those of the power plant.
- Feed lignite would be provided by the existing raw lignite feed system at approximately 1,000 tons/hr at about 36% moisture and stored in a 1,800 ton capacity bin.
- All process material captured by particulate removal systems would be blended into process streams on a continuous basis.
- A cooling tower, air compressor, and a desiccant drying system would be furnished with the SynCoal® facility.
- No product stabilization facilities would be provided.

5.1 SynCoal® Reference Plant Description

Lignite is discharged from a 1,800-ton storage bin at the rate of 100 tons/hr, crushed to minus ¾ inch by a single roll crusher, and sent to the dryer. The dryer and reactor are heated by steam; 2,400 lb, 1,000^{o}F steam goes first to the reactor and then to the dryer, and condensate is returned to the boiler feed water system. Steam heating requires the process to be coupled to a power station or industrial boiler. The process could also be heated by hot gas, but that would require the integration of a furnace into the design.

Crushed lignite enters the fluidized bed dryer at ambient temperature and 36% moisture and leaves at 230^{o}F and 18% moisture. To avoid loss of fluidizing gas, the entrance and exit utilize double dump valves to provide a gas-tight seal. Recirculated drying gases at 550^{o}F are introduced below the bedplate of the dryer to fluidize the lignite. Gas exiting the dryer enters a system of multiclones that provide entrained particulate removal prior to the gas's entering the recirculation fan. From the fan, the gas is reheated in steam heat exchangers and returned to the dryer. Excess gas is vented to the vent gas handling system.

Product from the dryer enters the reactor at 230^{o}F and 18% moisture and leaves at 550^{o}F and 3% moisture. In addition to water, the reactor removes some hydrocarbon and sulfur products. The reactor is a fluidized bed similar to the dryer and utilizes the same type of double dump valves. Recirculated gas at 750^{o}F is introduced below the reactor bedplate. Exit gas passes through multiclones for particulate removal, and excess gas is vented to the vent gas system.

The cooler uses two indirect coolers to reduce the temperature of the SynCoal® below its autoignition point. Hot SynCoal® is introduced into the cooler system at 550°F and 3% moisture and exits at 150°F. Cooling is provided by chilled water on the outside of the cooling drum. Nitrogen is used to maintain an inert atmosphere in the cooler to prevent SynCoal® oxidation. Cooling water is chilled in a cooling tower from 110°F to about 75°F and recirculated to the plant. The rotary tube cooler consist of a series of tube sections comprising a slowly rotating, horizontal drum that is partially submerged in a tank of water. Water flows through the tank in the opposite direction to the solids flowing through the drum to provide countercurrent cooling. Excess inert gas from the cooler is vented to the inlet of the reactor gas recirculation fan.

The design of the storage and feed systems for the SynCoal® produced by a reference-type plant would depend upon the needs of the particular plant where the SynCoal® facility is located. For the reported case, once the SynCoal® is discharged from the cooler, it would be sized to meet the needs of the M. R. Young Power Station cyclone burners and transported to the product storage bins by conveyors. Each boiler would have an individual SynCoal® storage bin. The amount of SynCoal® added to each storage bin is monitored so that consumption by each boiler can be determined. These storage bins would be located near the SynCoal® facility.

From the individual storage bins, SynCoal® is transported through a pneumatic transport system to individual surge bins for each cyclone burner. These surge bins are located near the cyclone burners within the boiler structures. A rotary feed system meters the SynCoal® into a gravity feed line that intersects each cyclone burner lift line. The amount of SynCoal® fed to each burner is adjusted by the boiler operator by controlling the speed of the rotary airlock. In the event of a boiler trip, the main fuel trip (MFT) valves located at the end of each lift tube delivery pipe would activate and stop flow to the cyclone burner.

All open materials handling equipment is provided with dust collection hoods routed through a tapered duct ventilation system to the SynCoal® baghouse. Material collected by this baghouse is introduced back into the SynCoal® product system as it enters the storage bins. Gases used for pneumatic transport are also filtered prior to discharge.

SynCoal® process exhaust gases consist primarily of water vapor, a light loading of fine particulate material, and volatile organic compounds (VOCs). For the Reference Plant Design, analyses have shown that, if this stream were vented into the radiant section of the boiler, it would be beneficial to M.R. Young unit efficiency. The increased mass flow would decrease flue gas temperature and increase heat transfer in the convection sections of the boiler.

The combined dryer, reactor, and cooler vent gases would be routed to a common vent gas header at the SynCoal® processing plant. The composition of the gas is expected to be 95% H_2O, 4% N_2, 0.1 % CO, 0.5% O_2, 0.1% hydrocarbons, and 100 ppm of H_2S and other combustibles. The vent gas temperature at the boilers is expected to be approximately 251°F. All of the vent gas would be routed to the Unit 2 gas recirculation fan inlet and injected into the boiler radiant section.

In the event of a boiler trip, the trip signal would activate MFT valves located at the boilers to shut off the process vent gas. An additional valve would close at the SynCoal® processing plant to shut the process vent gas supply to the vent gas header while diverting the process vent gas. A process upset of this type would immediately shut off steam flow to the process heat exchangers, as well as the lignite supply. It is envisioned that the off-gassing of the process would continue through the emergency vent to the atmosphere for approximately 20 minutes per event. Treatment of this gas prior to release to the atmosphere would be according to local environmental requirements.

5.2 Stabilization, Rehydration, and Cleaning

It was decided not to include SynCoal® stabilization in the RPD because the need for long-term storage was not anticipated. The SynCoal® would either be burned as soon as it was produced or else stored for a short time in an inert gas blanketed storage silo. However, although stabilization, rehydration, and cleaning were not to be included in the plant, designs for these operations were included in the RPD report so that they could be added at a later date, if desired or if needed at an alternative site.

Stabilization, the process by which the potential for spontaneous combustion of SynCoal® is reduced, involves mild oxidation of the SynCoal®. Stabilization equipment consists of a specialized variation of the dryer and reactor fluid beds. Its purpose is to oxidize and cool the SynCoal® in a controlled manner. The stabilization fluid bed reactor would be comprised of a dual fan, high and low temperature gas supply system to provide fluidization and oxidation of SynCoal® within a baffled fluidized bed reactor (including gas recirculation and particulate removal from the exhaust gas) wherein SynCoal® would be alternately heated and cooled to facilitate the stabilizing oxidation reaction. The system would be designed to maintain a SynCoal® residence time of 45 minutes at a maximum reactor gas inlet oxygen concentration of 20% with an oxygen sorption of 1.5% by weight of SynCoal®. A stabilization cooling centrifugal fan supplies ambient air to the two cooling sections of the reactor to simultaneously fluidize and cool the SynCoal® to maintain very low product moisture and decrease the exit temperature from 250°F to 150°F.

The heated gas and inert gas will be drawn into two heating sections of the stabilization reactor through the stabilization recirculation fan. The process heating gas will pass through the stabilization heat exchanger to raise the recirculation gas temperature to 300°F prior to entering the stabilization fluid bed reactor. SynCoal® will enter and exit the stabilization fluid bed reactor through double dump valves.

Rehydration is the process by which water is added to the SynCoal® to provide additional stabilization and dust suppression. Rehydration consists of controlled quenching with water addition that provides additional cooling and serves as a heat sink, so that additional oxidation can occur but at a reduced rate. The rehydration system would be comprised of an enclosed belt conveyor receiving 150°F oxidized SynCoal® from the stabilization fluid bed reactor, wherein water is added for additional stabilization and dust suppression.

The stabilization fluid bed reactor would discharge oxidized SynCoal® through a double dump valve and a material spreader directly to the enclosed rehydration belt conveyor. The spreader limits conveyor SynCoal® bed depth to 12 inches at maximum throughput. The conveyor is equipped with water spray stations mounted to the conveyor enclosure to provide a fan shaped spray to fully cover the width of the belt. The rehydration conveyor is sized to provide sufficient residence time and water to rehydrate the SynCoal® to a maximum of 8% moisture by weight and lower the bulk temperature to 100°F.

Cleaning is the process by which a portion of the ash and sulfur containing fraction is removed from the SynCoal®. The cleaning system is comprised of a cleaning screen, coarse and fine fraction stoners, and a coarse fraction separator (gravity table). The cleaning system would provide separation of high specific gravity waste fractions, consisting primarily of pyrites and rocks, from the product stream.

The SynCoal® would discharge to a single deck cleaning screen either from the reactor, stabilizer, or rehydrator. Material size separation would be effected on the vibrating screen deck, segregating the discharge product streams into coarse and fine fractions. The differentiation between coarse and fine fractions at Colstrip has been shown to be approximately 10-mesh, but would need to be based upon actual feedstock testing.

The coarse fraction from the screen would discharge to a coarse fraction stoner, wherein separation of a high specific gravity fraction from the product would be effected through vibration and fluidization. During separation, the high specific gravity solids remain in contact with the inclined deck, migrating up toward the waste discharge. The lighter product fraction would be partially fluidized and move down the deck toward the product discharge. The high specific gravity solids discharged from the coarse fraction stoner would be introduced to the coarse fraction separator. The gravity table operates on a principle similar to the stoner, but provides greater cleaning and separation efficiency. Moveable side-mounted baffles allow for manual adjustment of waste/product fraction separation, discharging both streams from the same side of the unit.

The fine fraction from the screen discharges to a new fine fraction stoner, wherein separation of higher specific gravity fractions from the product would be effected in a similar manner to that of the coarse fraction stoner. The product SynCoal® fractions from the coarse fraction stoner and gravity table and the fine fraction stoner discharge into product storage or load-out facilities.

5.3 Capital Costs

A capital cost estimate for the RPD was developed using vendor quotations for major process equipment and engineering factors for other direct costs. This estimate is presented in Table 9. It was found that the equipment cost for process heating was similar regardless of the method of heating. Therefore, the design cost developed for the M.R. Young Station should be similar, even if a different heating system is used. Since this cost estimate was developed for a specific site (M.R. Young Station), it should only be used as a guideline for the cost of a facility at another location.

Table 9. Reference Plant Design Capital Cost Estimate (1997 Dollars)

Description	Cost
Engineering and Permits	$875,000

Site Work	$286,300
Concrete	$738,400
Masonry	$155,700
Metals	$1,722,300
Moisture/Thermal Protection	$721,300
Doors and Windows	$9,100
Process Equipment	$12,584,600
Mechanical Work	$5,419,700
Electrical Work	$2,957,650
Direct Cost	$25,470,050
Indirect Cost	$6,867,600
Contingency	$2,263,636
Profit	$1,730,064
Startup	$623,721
Project Owners Cost	$2,128,101
Total Project	$39,083,172

5.4 Operating Costs

Operating costs are a function of site specific factors and can vary considerably from one location to another. Therefore, rather than providing specific operating costs, the following relationships define the requirements for feedstock, utilities, and manpower. These can be converted into costs for a particular location by using site specific values.

Variable Costs (per ton of product)

product yield (fraction) = product (tons)/feed (tons)
feedstock (cost) = price ($ per ton)/product yield
water removed (tons) = water in feed (tons/ton)/product yield – water in product (tons/ton)
fuel cost ($/ton) = cost ($/10^6 Btu) x 2.2 x water removed/heat transfer efficiency
power cost ($/ton) = cost ($/kWh) x 36/product yield
cooling water cost ($/ton) = cost ($/1,000 gal) x 0.25

Fixed Costs (per year)

labor cost = average annual wage x number of operators
administration cost = labor cost x 0.17
maintenance cost = initial capital x 0.06
supplies = maintenance cost x 0.15
insurance cost = asset value x 0.01
property taxes = asset value x 0.01

These costs are for example purposes only and can vary widely with location. They do not include local income or ad valorem taxes or special costs.

6.0 COMMERCIALIZATION

Western SynCoal LLC is continuing to pursue commercialization opportunities focused on next generation projects, both internationally and domestically with unique niche markets that can benefit from SynCoal® in the short term. These efforts have generated a number of prospects, but have not resulted in any definitive new projects yet.

Since the Westmoreland acquisition of Western Energy Company/Western SynCoal LLC, the suspension of operation at the ACCP was the only viable business decision, since the new consolidated tax return would not allow utilization of the Section 29 credits and the associated net operating losses to partially offset operating costs. At that time, Westmoreland could not economically continue to operate the ACCP.

7.0 CONCLUSIONS

After problems typical of plant startups were overcome, the ACCP ran essentially as designed; that is, it was able to operate at design capacity and produce SynCoal® product with the expected moisture and sulfur contents. The product was tested in a variety of applications, both industrial and utility, and proved to have benefits for both applications. Its uniform properties and low moisture content provided superior performance.

Unfortunately, SynCoal® proved to be dust prone and would also spontaneously combust if left exposed to the atmosphere in a pile larger than about one to two tons. These tendencies presented serious handling problems and made the untreated SynCoal® unsuitable for shipment in open hopper cars. Thus, SynCoal® needs to be used almost immediately after production or else stored in airtight containers.

Considerable effort was expended to study the spontaneous combustion problem in an attempt to find a solution. Although this effort was partially successful, no fully satisfactory passivation procedure was developed. One approach which extended storage life but did not fully overcome the problem of spontaneous combustion was rehydrating the coal. However, this lowers the coal's heating value and defeats part of the benefit of drying the coal.

In spite of the problems, the SynCoal® demonstration plant was able to establish several long-term industrial and specialty customers on a commercial basis, and there is potential for a SynCoal® facility sited at a power plant so that the product could be burned as soon as produced with only temporary storage in an inert gas blanketed silo. If waste heat from the power plant could be used to provide at least part of the energy for the SynCoal® plant, this could prove to be a particularly attractive arrangement. Process improvements, such as using an Aeroglide tower in place of the vibrating fluidized bed reactors, could also lead to cost reductions that would improve process economics.

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APPENDIX A

Significant Accomplishments from Concept Inception until Shutdown of the Demonstration Plant (1981-2001)

SIGNIFICANT ACCOMPLISHMENTS SINCE CONCEPT INCEPTION

1981	**September**	• Western Energy contracted Mountain States Energy to review a low rank coal upgrading concept called the Greene process.
1982	**June**	• Mountain States Energy built and tested a small batch processor in Butte, Montana.
1984	**November**	• Initial operation of a 150 lb/hr continuous pilot plant at Montana Tech's Mineral Research Center in Butte, Montana, testing the Greene drying process.
	December	• Patent application filed for the Greene process.
1985	**November**	• Product cooling and cleaning capability added to the pilot plant.
1986	**January**	• Initiated process engineering for a demonstration-size Advanced Coal Conversion Process (ACCP) facility.
	October	• Completed six-month (over 3,000 operating hours) continuous pilot plant test producing approximately 200 tons of SynCoal®.
		• Western Energy submitted a Clean Coal I proposal to DOE for the ACCP Demonstration Project in Colstrip, Montana.
	December	• Western Energy's Clean Coal proposal was identified as an alternate selection by DOE.
1987	**November 6**	• The Internal Revenue Service issued a private letter ruling designating the ACCP product as a "qualified fuel" under Section 29 of the IRS code.
1988	**February 16**	• U.S. Patent No. 4,725,337 issued.
	May	• Western Energy submitted an updated proposal to DOE in response to the Clean Coal II solicitation.
	December	• Western Energy was selected by DOE to negotiate a Cooperative Agreement under the Clean Coal I solicitation.
1989	**March 7**	• U.S. Patent No. 4,810,258 issued.

1990	**June 13**	• Reached a negotiated agreement with DOE on the Cooperative Agreement.
	September 13	• Signed Cooperative Agreement, after Congressional approval.
	September 17	• Contracted project engineering with Stone & Webster Engineering Corporation.
	December 5	• Formed Rosebud SynCoal® Partnership.
		• Started construction at the Colstrip site.
1991	**March 25**	• Novated the Cooperative Agreement to the Rosebud SynCoal® Partnership.
	March 28	• Formal ground breaking ceremony at Colstrip, Montana.
	December	• Initiated commissioning of the ACCP Demonstration Facility.
1992	**April**	• Completed construction of the ACCP Demonstration Facility and entered Phase III, Demonstration Operation.
	June 25	• Formal dedication ceremony for the ACCP Demonstration Project in Colstrip, Montana.
	August	• Successfully tested product handling by shipping 40 tons of SynCoal® by truck to Montana Power Company's Unit No. 3.
	October 2	• Completed an 81 hour continuous coal run.
	November	• Converted to single process train operation.
	December	• Produced a passivated product with a two-week storage life.
1993	**January**	• Produced 200 tons of passivated product that was stable for 13 days in an open storage pile.
	February 15	• Completed 45 day operating period with a 62% availability.
	March	• Identified an environmentally compatible dust suppressant that inhibits fugitive dust from the SynCoal® product. Completed annual Mine Safety and Health Administration safety training.

SIGNIFICANT ACCOMPLISHMENTS SINCE CONCEPT INCEPTION (cont'd.)

1993	**June**	• Initiated deliveries of SynCoal® under long-term contracts with industrial customer.
	July	• Identified a conditioning method that inhibits spontaneous combustion and dust formation.
	August	• State evaluated emissions and determined that the ACCP process was in compliance with the air quality permit.
	August 10	• ACCP demonstration facility went commercial.
	September	• Tested nearly 700 tons of BNI lignite as a potential process feedstock, achieving approximately an 11,000 Btu/lb heating value product with substantially reduced sulfur.
		• Tested over 500 tons of BNI lignite.
		• Stored approximately 9,000 tons of SynCoal® in inerted product silos and stabilized 2,000 to 3,000 tons in a managed open stockpile.
		• Operated at an 84% operating availability and a 62% capacity factor for the month.
	October	• Processed more coal since resuming operation in August following the summer's maintenance outage than during the entire time from initial startup (approximately 15 months).
		• Tested North Dakota lignite as a potential process feedstock, achieving a product with a heating value of nearly 11,000 Btu/lb and substantially reduced sulfur content.
	November	• Operated at an 88% operating availability and a 74% capacity factor for the month.
	December	• Shipped 16,951 tons of SynCoal® to various customers.

SIGNIFICANT ACCOMPLISHMENTS SINCE CONCEPT INCEPTION (cont'd.)

1994 January
- Shipped 18,754 tons of SynCoal® to various customers.
- Completed 48 tons/hr SynCoal® stabilization process design.
- Completed stability reactor testing.

February
- Plant operated with a 67% availability.
- Completed 8 tons/hr SynCoal® stabilization process design.

March
- Completed a 50/50 coal/SynCoal® blend test burn at Montana Power Company's J.E. Corette plant.

April
- Completed a 25/75 Coal/SynCoal® blend followup test burn at Montana Power Company's J.E. Corette plant.

May
- Began regular shipments of SynCoal® fines to industrial customers.
- Exceeded pro forma average monthly sales levels for the first time since startup.

June
- Concluded 30 day, 1,000 mile, covered hopper rail car test shipment.
- Increased industrial sales to 39% of total (7,350 tons out of a total of 18,633 tons).

July
- Supported an additional 30-day test burn at Montana Power Company's J.E. Corette plant.
- Continued preparing for annual maintenance and facility improvement outage to begin August 19.

August
- Began the annual maintenance and facility improvement outage.
- Completed a conceptual design incorporating SynCoal® processing at MPC's J.E. Corette plant.

September 11
- Completed the annual maintenance and facility improvement outage.

September 20
- Held an open house and tour to raise public and market awareness of SynCoal®.

SIGNIFICANT ACCOMPLISHMENTS SINCE CONCEPT INCEPTION (cont'd.)

1994	**September**	• Completed conceptual design for an ACCP plant expansion, incorporating a process stability step.
	October	• Scheduled test burns with two industrial users for November.
		• Tentatively scheduled two small additional test burns during December.
	November	• Conducted test burns with two industrial users.
		• Scheduled an additional test burn during December.
		• Scheduled to reestablish deliveries to Continental Lime in Townsend, Montana.
	December	• Conducted test burns with one additional user.
		• Tentatively scheduled two additional test burns during January.
		• Rescheduled to reestablish deliveries to Continental Lime in Townsend, Montana.
1995	**January**	• Conducted test burns with an additional industrial user.
		• Tentatively scheduled two additional test burns during February.
	February	• Continued test burn with an industrial user.
		• Supplied a short test at a small utility plant.
		• Tentatively scheduled two additional test burns during March.
	March	• Supported a test burn with an industrial user.
		• Supplied a short test at a small heat plant.
		• Record monthly sales volume of 28,548 tons, or 118% of original design capacity.

SIGNIFICANT ACCOMPLISHMENTS SINCE CONCEPT INCEPTION (cont'd.)

1995 **April**

- Set monthly availability (94%) and capacity (129%) records for the third consecutive month.
- Recorded monthly sales volume of 30,827 tons (123% of original design capacity).

May

- Second best monthly availability and capacity factors.
- Monthly sales volume of 28,705 tons (115% of original design capacity).

June

- Completed annual maintenance and modification outage.

July

- Set new production record of 127% design capacity and 92% availability.
- Initiated process waste test with Colstrip Energy Limited Partners.
- Started construction of granular SynCoal® truck loadout.
- Received DOE approval to extend the Cooperative Agreement.

August

- Set new production record of 128% design capacity and 93% availability
- Finished process waste test with Colstrip Energy Limited Partners.
- Continued construction of granular SynCoal® truck loadout.
- Conducted full train test at Corette with a blend of Dust Stabilized Enhancement (DSE) conditioned granular/fines mix and raw Rosebud coal.

September

- Wyoming Lime became the newest industrial customer.

October

- SynCoal® truck loadout completed.

November

- Continued deslagging tests at Milton R. Young station.

December

- Reached millionth ton processed mark.

SIGNIFICANT ACCOMPLISHMENTS SINCE CONCEPT INCEPTION (cont'd.)

1996	**February**	• The Reference Plant Design draft report was submitted.
	April	• The plant, which had shut down, was forced to limit production to supply only current industrial customers.
	June	• A sales agreement was reached with Units 1 and 2 for purchase of SynCoal®. The plant resumed full production.
	July	• Received Department of Energy bid for 25 tons of 14 x 60 mesh high sulfur SynCoal® for gasifier testing at METC.
	August	• Set new monthly availability record of 95.7%.
	October	• Delivered 25 tons of high sulfur SynCoal® to the Department of Energy-METC
	November	• Over 800,000 tons of SynCoal® product has been sold.
		• ACCP Facility employees honored for working 475,000 hours without a lost time accident.
1997	**March**	• Conducted ash yield tests for Globe Metallurgical.
		• Completed pneumatic unloading test at Montana Power's Units 1 & 2.
		• T-96 silo gate modifications completed.
	April	• The SynCoal facility produced its one millionth ton of SynCoal®.
	May	• Conducted a coke/SynCoal® blend test.
	July	• The entire inventory of SynCoal® fines sold.
	August	• All customers have been trained on the "SynCoal® Safe Handling Review" presentation.
	September	• Testing completed to determine feasibility of delivery of DSE SynCoal® fines/blend to Colstrip Units 1 and 2.
	October	• Completed Annual Maintenance Outage.
	November	• "Normal Operating Procedures" established for the ACCP Plant.

SIGNIFICANT ACCOMPLISHMENTS SINCE CONCEPT INCEPTION (cont'd.)

	December	• A "Best Practices" operating procedure was completed for the inert gas system..
1998	**February**	• A former customer, Continental Lime, resumed taking SynCoal® shipements.
	March	• A letter agreement was signed to begin construction of a pneumatic SynCoal® delivery system to Colstrip Unit 2.
	May	• A "creep drive test" was conducted to determine if a blend could be effectively handled in the existing rail loadout. • All ACCP employees received confined space training • Unit 2 Pneumatic SynCoal® Fuel Project construction was begun.
	June	• The ACCP operations group has worked over 750,000 hours without a lost time accident.
	July	• A blended SynCoal® product has been successfully delivered and received by our customers.
	August	• All major equipment has been purchased and delivered for the Unit 2 Pneumatic SynCoal® Fuel Project.
	September	• Construction on the Unit 2 Pneumatic SynCoal® Fuel project is approximately 65% complete.
	November	• All customers are taking blended SynCoal® product.
	December	• An agreement was signed with a Japanese engineering firm to conduct tests at the SynCoal® plant.
1999	**January**	• Startup of the Unit 2 Pneumatic Syncoal® Fuel Project.
	February	• Unit 2 Pneumatic SynCoal® system was turned over to operations and regular deliveries commenced. • ACCP Plant has processed over 2 million tons of raw coal.
	March	• Completed a SynCoal® test burn with Holnam, Inc., with favorable results. • SynCoal® sales were at a near record high (the highest sales were in November 1995).

SIGNIFICANT ACCOMPLISHMENTS SINCE CONCEPT INCEPTION (cont'd.)

1999	**April**	• Regular deliveries to the Unit 2 Pneumatic SynCoal® Fuel Project were made for the entire month.
	May	• Holnam, Inc., of Trident, Montana, signed a SynCoal® Sales Agreement.
	June	• Automation of the T-85 sampler was completed.
	July	• Dust collection hoods have improved fugitive dust emissions significantly. • Installed water line to replace city water with water reclaimed from Mine Area A-2.
	August	• Feed total was 47,470 tons for the month, which is as high as it has been since December, 1995.
	December	• A proposal was submitted to a gold company in Nevada to assess using SynCoal® as a fuel supplement in their ore roasting process.
2000	**January**	• New CO_2 system is fully functional.
	March	• The ACCP facility operated 40 consecutive days, which is the longest consecutive run on record.
	June	• The Aeroglide Test Reactor is substantially complete.
	July	• Newly designed critical explosion vent panels have all been replaced.
	September	• Telemetry system for monitoring CO_2 installed.
	December	• The ACCP employees have worked 9 years without a lost-time accident.
2001	**March**	• Increased capacity from 68 tons/hr to approximately 80 tons/hr tested.
	June	• Plant shut down and mothballing completed.