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WESTERN SYNCOAL LLC

ADVANCED COAL CONVERSION PROCESS DEMONSTRATION

PROJECT PERFORMANCE SUMMARY
CLEAN COAL TECHNOLOGY DEMONSTRATION PROGRAM

MARCH 2006

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COAL PROCESSING FOR CLEAN FUELS

Advanced Coal Conversion Process Demonstration

This project successfully demonstrated the ACCP technology that converts "low-rank" Western coals to a high value, low moisture, reduced sulfur product known as SynCoal®.

Overview

This project is part of the U.S. Department of Energy's (DOE) Clean Coal Technology Demonstration Program (CCTDP). This program addresses energy and environmental concerns related to coal use through cost-shared partnerships with industry. These partnerships are designed to accelerate commercialization of the most promising advanced coal-based power generation and pollution control technologies. By law, DOE's contribution cannot exceed 50 percent of the total cost of any project. However, industry has stepped forward and cost-shared over 65 percent of the total CCTDP project funding. The project presented here was selected in Round 1 of the CCTDP.

The demonstration project summarized in this document is the Western SynCoal LLC Advanced Coal Conversion Process (ACCP), which is designed to upgrade low-cost, "low-rank" Western coal, such as that from the Powder River Basin, to a high quality fuel. This Western coal inherently has low sulfur content that provides an environmental advantage over the medium and high sulfur content coal mined in other parts of the country, because when burned it produces relatively lower sulfur dioxide (SO_2) emissions. Some Western coal has a countervailing disadvantage and the label "low-rank" because it has high moisture and ash content. High moisture and ash content lower the heating value of coal and raise its transportation cost due to the resulting higher volume required on an equivalent heat content basis.

While conventional drying processes can raise the heating value of low-rank coals, drying alone has certain disadvantages. When dried, coal can reabsorb moisture; drying coal can cause the formation of dust and fines; and drying, without further treatment, can make coal susceptible to spontaneous combustion. Upgrading also involves the removal of some ash, which further improves the heating value of the coal product.

The ACCP converts low-rank Western coal to a high-quality boiler fuel by means of a process that involves two stages of thermal upgrading with hot combustion gas, followed by a cooling stage and finally physical cleaning to separate ash. The technology is registered as the SynCoal® process. The process was demonstrated at a 45-ton-per-hour test facility adjacent to Western Energy Company's Rosebud Mine near Colstrip, Montana. In terms of throughput, the test facility is about one-tenth the projected size of a commercial facility.

The ACCP was demonstrated to successfully produce the high quality SynCoal® product. The SynCoal® product was found to have some potential dust and spontaneous combustion issues that created shipping and storage concerns. Spontaneous combustion could occur if the SynCoal® product was piled or shipped in quantities larger than about two tons. These concerns somewhat limited large-scale broad commercial application. The ACCP designers have identified long-term industrial, utility and specialty customers that benefit from generation and use of SynCoal® onsite at their facilities. Onsite generation and use of SynCoal® minimizes the dust and spontaneous combustion concerns.

The Project

The ACCP concept of thermally processing low-rank coal with low pressure, superheated, recycled gas was first tested at the Montana College of Mineral Science and Technology who constructed and operated a 150 lb/hr continuous pilot plant. The plant was constructed in 1984 and operated through 1992. Twelve different coals were tested in the pilot plant. Over its life the pilot plant processed 300 tons of coal during 4,000 operating hours. These tests successfully demonstrated that the ACCP had reduced the moisture content, lowered ash slagging potential, reduced abrasiveness, and lowered the sulfur content of the fuel.

Since the technology required further development to prove its commercial potential, the next step after the successful pilot project was to construct a demonstration plant. DOE approved funding for an ACCP plant and awarded a Cooperative Agreement in 1990 to Western Energy Company. Thereafter, private financing was obtained from Northern States Power Company. This resulted in the formation of a general partnership, known as the Rosebud SynCoal Partnership, with the partners being Western SynCoal Company, a wholly owned subsidiary of Western Energy, and Scoria, Inc., a wholly owned subsidiary of NRG, Inc., which itself was a wholly owned subsidiary of Northern States Power Company.

By agreement, Rosebud SynCoal Partnership assumed Western Energy's obligations under the Cooperative Agreement with DOE. Western SynCoal Company, a subsidiary of Montana Power Company, was the managing general partner of Rosebud SynCoal Partnership. The Rosebud Partnership proceeded to construct the ACCP plant at Colstrip, Montana. Construction was complete in March of 1992. In 2000, Westmoreland Coal Company acquired Western SynCoal LLC. On December 4, 2001, Western SynCoal LLC was assigned U.S. Patent 6,325,001, "Process to improve boiler operations by supplemental firing with thermally beneficiated low-rank coal." The SynCoal® plant was closed in 2001. EnPro, LLC of Wyoming purchased Western SynCoal and three associated DOE contracts from Westmoreland on January 3, 2003.

During the life of the ACCP project, nearly 2 million tons of SynCoal® products, including regular, fines, blend, dust and stability enhanced (DSE), and special high-sulfur SynCoal® were shipped to various customers. Before the demonstration ended, the ACCP plant supplied more than a dozen commercial customers with SynCoal®.

Project Sponsor
Western SynCoal LLC (EnPro, LLC of Wyoming purchased Western SynCoal and three associated DOE contracts on January 3, 2003)

Additional Team Members
None

Location
Colstrip, Rosebud County, Montana, adjacent to Western Energy Company's Rosebud Mine

Technology
Western SynCoal, LLC's ACCP for upgrading low-rank sub-bituminous and lignite coals

Test Plant Capacity/Production
45 tons/hr of SynCoal® product

Coal
Powder River Basin sub-bituminous (0.5–1.5% sulfur) and lignite

Demonstration Duration (actual test operations)
June 1992–May 2001

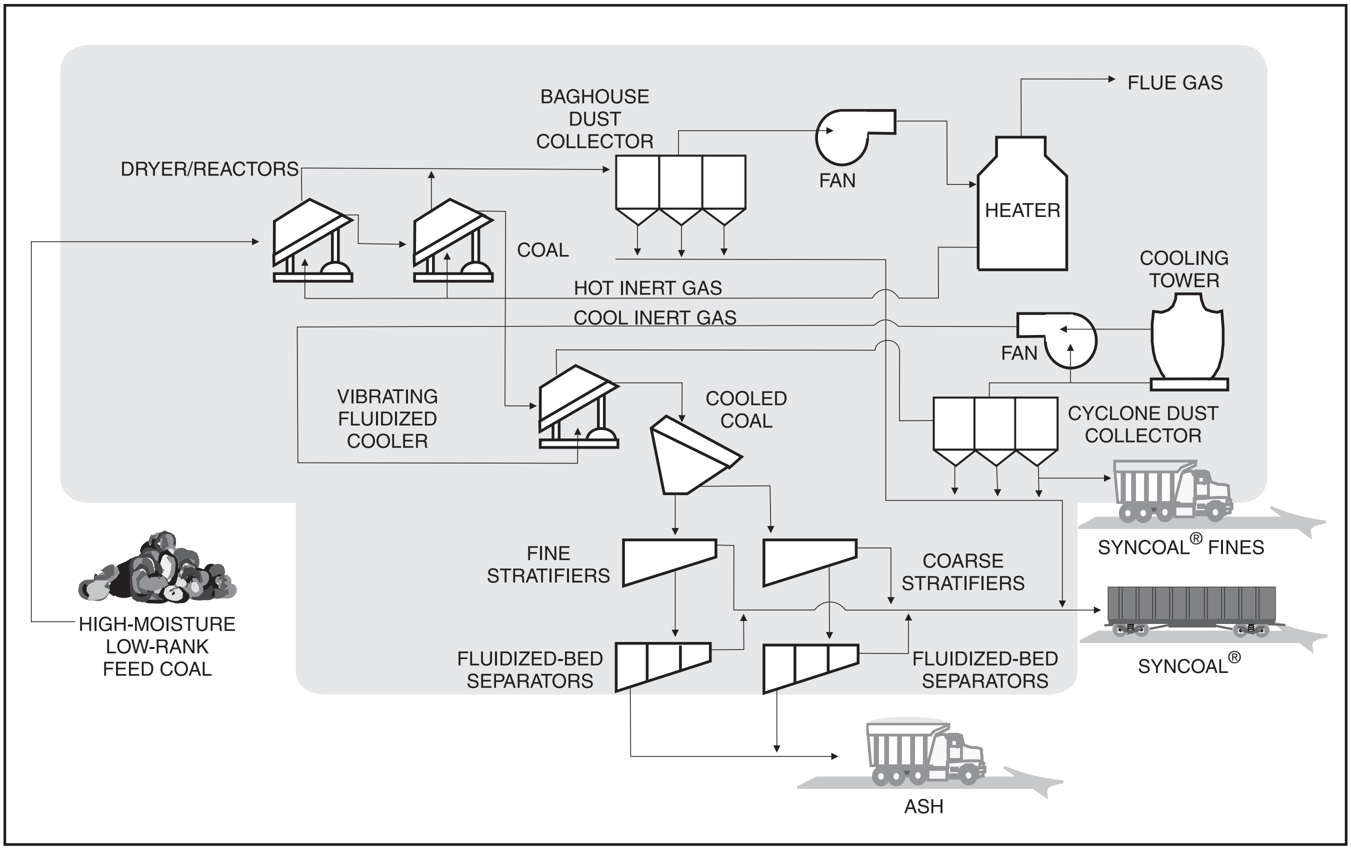
Project Funding

Total	$105,700,000	100%
DOE	43,125,000	41
Participant	62,575,000	59

Project Objective
To demonstrate Western SynCoal LLC's ACCP to produce a high quality fuel from low-rank low-sulfur Western coal.

SynCoal is a registered trademark

The Technology



In essence, thermal upgrading of coal processed at the ACCP demonstration plant is accomplished in three stages (two heating stages followed by a cooling stage) of vibrating fluidized-bed reactors that remove water, carboxyl groups, and volatile sulfur compounds. To complete production of the final SynCoal® product, the coal is then subjected to a deep-bed stratifier cleaning process to separate pyrite-rich ash from the coal. Data analyzed after the demonstration period supports the general conclusion that the ACCP is capable of converting Western coals with a moisture content of 25–55 percent, a sulfur content of 0.5–1.5 percent, and a heating value of 5,500–9,000 Btu/lb, to a high-quality low-sulfur fuel with a moisture content as low as 1 percent, sulfur content as low as 0.3 percent, and heating value of up to 12,000 Btu/lb. The enhanced properties of the product provide ample evidence that low-rank Western coal can be altered to produce high-quality fuel for industrial and electric utility use. A simplified process flow diagram of the original ACCP plant is depicted in the figure above.

Original Design

In the initial step of the ACCP process, the raw low-rank feed coal is screened to the desired size. Rejected coal is conveyed back to the active stockpile. Properly sized coal is conveyed to the 1,000-ton raw coal storage bin that feeds the process facility. Coal conversion is then performed in two parallel processing trains. Each train consists of two 5-foot by 30-foot vibratory fluidized thermal reactors in series, followed by a water spray section and a 5-foot by 25-foot long vibratory cooler. Each processing train is fed up to 1,139 lb/min (34.17 tons/hr) of 1.5-inch by 1.5-inch coal. After being heated by combustion gas, coal exits the fluidized-bed reactor at a temperature slightly higher than required to evaporate water and flows to a second vibratory reactor where the coal is heated to nearly 600 °F. This temperature serves to remove chemically bound water, carboxyl groups, and volatile sulfur compounds. In this second stage, water trapped in the pore structure of the coal is removed. Particle shrinkage that occurs in the second stage liberates ash minerals and imparts a unique cleaning characteristic to the coal.

The coal that exits the second-stage thermal reactors 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(s). 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 °F and enters the coal cleaning system. The gas leaving the vibratory coolers is sent to a twin cyclone for dust removal and cooled by water sprays in a direct contact cooler before being circulated to the vibratory cooler. Particulate is removed from the first-stage process gas by a pair of baghouses operating in parallel. The second-stage process gas is treated by a quad cyclone arrangement, and the cooling 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.

The cooled coal is sized and fed to deep-bed stratifiers where air pressure and vibration separate mineral matter, including much of the pyrite, thereby reducing the sulfur content of the product. The low specific gravity fractions are sent to a product conveyer while heavier fractions go to fluidized-bed separators for additional ash removal. Each fluidized-bed separator, using air and vibration to effect gravity separation, again splits this coal into light and heavy fractions or streams. The light stream is considered product, and the heavy stream is sent to a 300-ton storage bin to await transport to an off-site user or to a disposal site.

The converted, cooled and cleaned SynCoal® product enters the product handling system. The product handling system consists of the equipment necessary to convey the clean, granular SynCoal® product into two 6,000-ton concrete silos, and allows train loading with the existing load-out system. In addition, the SynCoal® fines collected in the various particulate collection systems are combined and transferred to a 50-ton surge bin that feeds the fines to a briquetting system for reintroduction with the granular SynCoal® or to a diverter leading to a ground level truck.

The heat required to process the coal is provided by a natural gas-fired process furnace, which uses process gas from the second-stage coal conversion reactor as supplemental fuel (refer to the process diagram on page 4). The 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. 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, allow for vapor release at an elevation great enough to maximize dissipation of the gases.

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 ACCP 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.

Improvements and Modifications

As with any first-of-a-kind plant, efforts were made during initial operations toward improving process efficiencies and reducing overall costs. Accordingly, the ACCP facility was modified as necessary during startup and operation. Equipment was improved, additional equipment installed, and new systems designed, installed, and operated. Considerable attention was paid to dust and spontaneous combustion issues identified during startup.

The originally designed two train, fines tubular-drag conveying system wore out rapidly effecting the system capability to keep up with fines production. To operate closer to design conditions for the thermal coal reactors and coolers, obtain tighter control over operating conditions, and to minimize product dust, the ACCP plant was converted to single train operation to reduce overall fines loading prior to modifying the fines handling system during a 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.

Demonstration facility at the Rosebud mine with reclamation area in the background

The main rotary air locks were required to shear the pyrite and rock interspersed throughout the coal. As originally designed, the rotary air locks were insufficient to break this non-coal material and tripped the entire process each time one of the eight rotary air locks jammed. Consequently, the drive motors were retrofitted from 2- to 5-horsepower for all eight process rotary air locks. Also, an electrical current sensing circuit that reverses the rotary airlock rotation was designed, tested, and applied to the rotary air locks. 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).

During the life of the project, work continued on testing and evaluating technologies to enhance product stability and reduce fugitive dust. In 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. Positive results led to the permanent installation of a less costly additional system that provided inert gas by cooling and drying a portion of the combustion gas from the exhaust stack.

A commercial anionic polymer applied in a dilute concentration with water was found to provide effective dust control. A companion product was identified that can be used as a rail car topping agent to reduce wind losses. The application of the dilute water-based suppressant, known as dust and stability enhanced (DSE), also provided a temporary heat sink useful for short term shipments and stockpile storage.

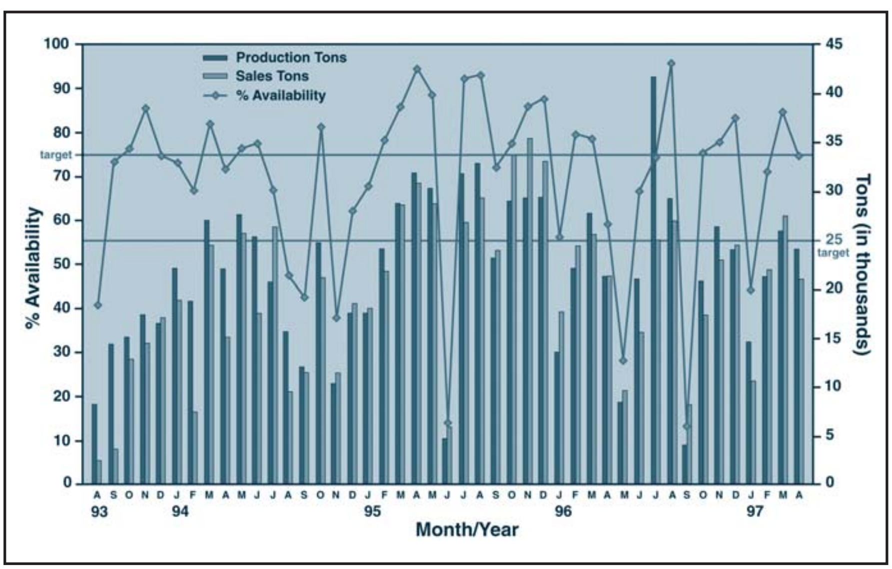


Figure 1. SynCoal® Production and Sales History

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

In October 1999, a Research Development Agreement and a Services Agreement were signed between SGI International and Western SynCoal LLC. SGI was interested in gaining information on the field performance of an Aeroglide Tower Reactor test unit for coal drying and finishing. The demonstration project participants were interested in determining if this approach would modify the characteristics of the final SynCoal® product thereby permitting traditional transportation techniques to be employed. When the project demonstration ended, development efforts were focused on the Aeroglide method.

To meet its objective, the Aeroglide technology allows process gases to contact the solids in a mechanically "gentle" environment (*i.e.*, solids are fed to the unit and flow downward, assisted only by gravity, through a system of baffles that gradually 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 migrate to adjacent baffles and exit the process bed of solids. The Aeroglide reactor was configured to partially rehydrate processed SynCoal®, remove the heat of reaction, and partially oxidize the product in an effort to promote product stability. The results were promising, but the testing was not of sufficient duration to permit an absolute conclusion.

Results Summary

Operational

- More than 2.8 million tons of raw coal were processed to produce almost 1.9 million tons of SynCoal® products over the life of the project.
- The product was close to the design basis product from a chemical standpoint, but was unacceptable because of instability (spontaneous combustion) and dustiness.

Environmental

- Particulate matter emissions from the process stack were 0.0259 gr/dscf (2.563 lb/hr).
- Nitrogen oxide (NO_x) emissions were 4.50 lbs/hr (54.5 parts per million (ppm)).
- Carbon monoxide (CO) emissions were 9.61 lbs/hr (191.5 ppm).
- Sulfur dioxide (SO_2) emissions were 0.227 lbs/hr (2.0 ppm).
- Total hydrocarbons (HC) as propane (less methane and ethane) were 2.93 lb/hr (37.1 ppm).
- Hydrogen sulfide emissions were 0.007 lb/hr (0.12 ppm).

The project met all environmental permit requirements. From an environmental standpoint the primary issue was the inherent dustiness of the SynCoal® product.

Economic

- Data accumulated during the demonstration period along with engineering and market studies were used to prepare a Reference Plant Design (RPD) to illustrate the integration of 100-ton/hr SynCoal® modules into Units 1 and 2 of the M. R. Young generating plant at Center, North Dakota.
- The contrasting purposes between the test facility and the commercial RPD led to numerous cost differences between the two. The RPD, for example, eliminated the need for an independent heat source because heat requirements could come from the plant itself. Similarly, an independent cleaning process was deemed unnecessary for the RPD.
- Using 1997 dollars, the direct capital cost for the RPD was estimated to be $25,470,050. Total project cost was estimated to be $39,083,172, taking into account profit, startup, contingency, and other indirect costs.

The economics for SynCoal® production appear to indicate that tax credits or some other subsidy would be required to make SynCoal® economically attractive to the broad commercial market. SynCoal® has been found to be attractive for some niche market applications.

Operational Performance

Plant operations commenced in 1992 with equipment shakedown and process trials. 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. Production and sales of SynCoal® continued through 1998 but were limited by product storage capacity. Numerous issues that arose during the demonstration were related to the objectives planned at the outset and pursued consistently during the life of the project. These demonstration objectives were as follows:

- 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 help ended. To support this, some items analyzed 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.

An agreement in 1998 with the Colstrip Unit 2 generating 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 percent, very close to the target availability.

Figure 2 (page 8) shows production rate as a function of design capacity. Averaged over the life of the project, the ACCP facility operated at 71.2 percent of rated capacity.

A typical material and energy balance around the ACCP is shown in Figure 3 (page 8), based on testing conducted in May 1994. The results are for the Rosebud coal that was normally processed through the ACCP Demonstration Facility.

Although it was originally assumed that SO_2 emissions would have to be controlled by injecting chemical sorbent into the duct work, operating data indicated that injection of sorbent would not be necessary to meet SO_2 permit emissions levels under normal operating conditions. A mass spectrometer was installed to monitor emissions and process chemistry, but the injection system was left in place in case a change should occur that required SO_2 emissions to be reduced.

The elimination of several bottlenecks that were identified during operations required some capital investment, including supplemental coal firing for process heat, removal of the 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 have the potential to boost commercial production to more than 500,000 tons/yr of product with minimal plant down time.

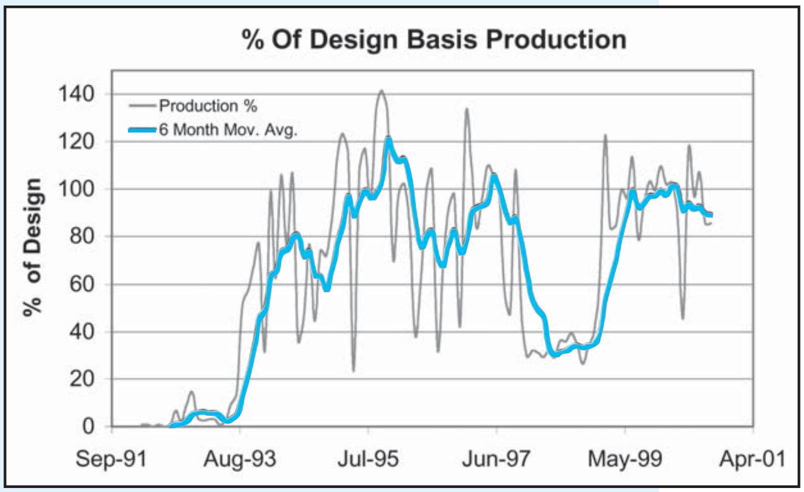


Figure 2. Production as Function of Design Capacity

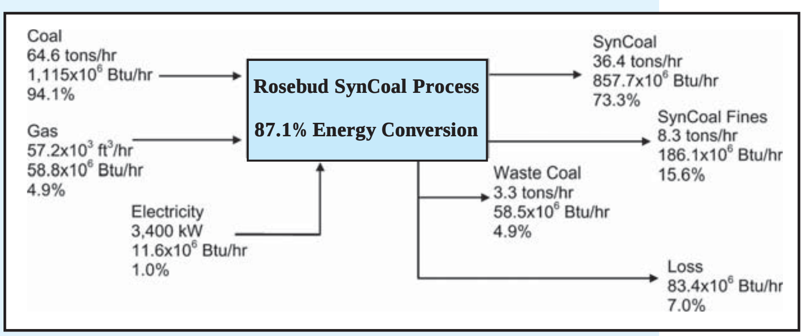


Figure 3. General Material and Energy Balance

During the course of operations, a series of test burns were performed at a number of utility and industrial installations. As a result of the 1998 contract to supply Colstrip Unit No. 2, more data was accumulated for that particular facility than for the others. The data collected for Colstrip Unit No. 2 also afforded an opportunity for the performance comparisons discussed below since Unit No. 1 is at the same location and had comparable capacity.

In the Spring of 1999, Colstrip Unit No. 1 was overhauled, resulting in an increase in its average output of 7 MWe (net). With this increase in output, the overhauled Unit No. 1 would have produced 5.4 MWe more than Unit No. 2. For the days SynCoal® was used, however, Unit No. 2 out-produced the overhauled Unit No. 1 by an average of 7.3 MWe — 285.7 MWe (net) compared to 278.4 MWe (net) — with 15.0 percent of the total heat input coming from SynCoal®. SynCoal® also was responsible in 1999 for actual SO_2 emissions reductions for Unit No. 2 of approximately 430 tons, or an 8 percent reduction, and a NO_x emission reduction of about 826 tons, a 19 percent reduction, when compared with Unit No. 1 emissions.

Environmental Performance

In the ACCP's coal cleaning area, fugitive dust was controlled by placing hoods with exhaust fans over the fugitive dust sources conveying the dust-laden air to baghouses. The baghouses effectively removed coal dust from the air before discharge. The Montana Department of Health and Environmental Sciences completed stack tests on the east and west bag house outlet ducts and the first-stage drying gas bag house stack in 1993. The project met all environmental permit requirements.

Another stack emissions survey was conducted in May 1994. The survey determined the emissions of particulates, SO_2, NO_x, CO, total hydrocarbons, and hydrogen sulfide from the process stack. The resulting average emission levels and related limits for these pollutants were:

- Particulate matter: 0.0259 gr/dscf (2.563 lb/hr) (limit: 0.031 gr/dscf).
- Nitrogen oxides: 4.50 lb/hr (54.5 ppm) (limit: 7.95 lb/hr estimated controlled emissions, and 11.55 lb/hr estimated uncontrolled emissions based on vendor information).
- CO: 9.61 lb/hr (191.5 ppm) (limit: 6.46 lb/hr estimated controlled emissions, and 27.19 lb/hr estimated uncontrolled emissions based on vendor information).
- Total hydrocarbons: 2.93 lb/hr (37.1 ppm) (as propane less methane and ethane).
- Sulfur oxides: 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).
- Hydrogen sulfide: 0.007 lb/hr (0.12 ppm).

Economic Performance

To complete an analysis of the commercial potential of the ACCP, data accumulated during the demonstration period along with engineering and market studies were used to prepare a Reference Plant Design (RPD) to illustrate the integration of 100-ton/hr SynCoal® modules into Units 1 and 2 of the M. R. Young generating plant at Center, North Dakota. The contrasting purposes between the test facility and the commercial RPD led to numerous differences between the two.

For example, the demonstration plant was designed to be a stand-alone facility requiring an independent heat source. Additionally, it was important to produce a cleaned product since more potential SynCoal® applications were thereby created. The RPD plant on the other hand was designed to be constructed at the site of a coal-fired power plant. Therefore, the heat requirements for the RPD could come from the power plant itself. Also, it was determined that the ash produced from firing uncleaned SynCoal® could be handled by the existing furnace and related auxiliaries. This determination made the cleaning process unnecessary for the RPD. Some of the engineering assumptions listed below, made in developing the RPD for the M. R. Young Power Station, also are indicative of differences in design between the demonstration project and the RPD:

- Design availability at 80 percent.
- Plant would be constructed adjacent to an existing power station that would provide 2,400 psig, 1,000 °F steam, with condensate returned to the boiler feed water system.
- Other utilities also would 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 percent 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.

It was decided not to include SynCoal® stabilization in the RPD because there was no need for long-term storage in this plant arrangement. 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. Even though stabilization, re-hydration, 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 alternate site.

Capital Cost Estimate

An RPD capital cost estimate was developed using vendor quotations for major process equipment, and engineering factors for other direct costs. This estimate is presented in the RPD Capital Cost Estimate Table 1 below. It was found that the equipment cost for process heating was similar regardless of the method of heating. In general, however, since the cost estimate was developed for a specific site (M. R. Young Power Plant), it should only be used as a guideline for the cost of a facility at another location.

Table 1. RPD 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 (subtotal)	$25,470,050
Indirect Cost	6,867,700
Contingency	2,263,636
Profit	1,730,064
Startup	623,721
Project Owners Cost	2,128,101
Total Project	**$39,083,172**

Operating Costs and Economic Analysis

Economics for the technology were estimated using the above capital cost and the estimated operating costs provided in Table 2.

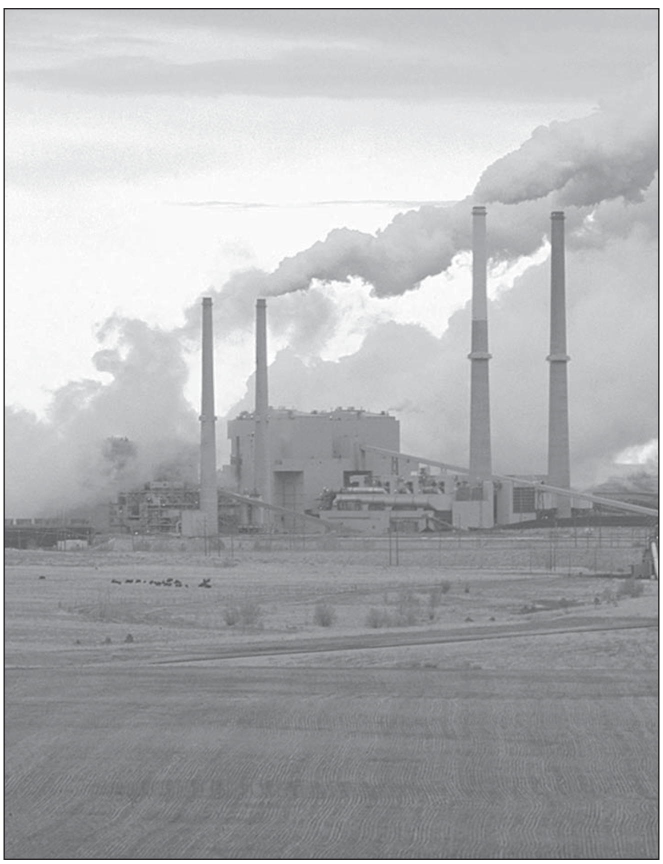
SynCoal® demonstration project site near Colstrip, Montana

Table 2. Operating and Maintenance Costs for Economics

Cost Element	Cost per Year
Variable Operating Costs	$8,000,000
Fixed Operating Costs	
Operating labor	$665,600
Administration	$113,150
Maintenance labor	$2,346,000
Maintenance materials	$351,900
Total O&M costs	**$11,476,650**

This analysis assumes that the feed is typical Rosebud Mine coal with a product yield of 69.2 percent (*i.e*., both SynCoal® and fines are sold as product), providing an annual production rate for the plant of 515,265 tons of SynCoal®. Based on these values, the cost of SynCoal® is in the range of about $30–$40/ton ($1.25–$1.70/million Btu, based on a product higher heating value of 11,675 Btu/lb), depending on whether current or constant dollars are used. Since the estimate is for a SynCoal® unit located next to a power plant, no passivation or transportation costs are included. If either of these is needed, costs would be higher.

This economic analysis indicates that the cost of SynCoal® is likely in the range where tax credits or some other subsidy would be required to make it economically competitive in a broad commercial market, in spite of the technical advantage of being clean burning with a high heating value. Further development may reduce capital and operating costs and improve process competitiveness for the broad market. There has been some success for SynCoal® in niche applications for the technology as described in the next section on "Commercial Applications."



Montana Power Company's Colstrip Power Plant that agreed to purchase and use SynCoal® fuel

Commercial Applications

The ACCP operated essentially as designed, producing a high quality SynCoal® product with expected low moisture and reduced sulfur content. This product also proved, however, to be dust prone with a tendency to spontaneously combust if left exposed to the atmosphere in a pile larger than one or two tons. Serious handling problems resulted, making untreated SynCoal® unsuitable for shipment in open hopper cars. The product must therefore either be used almost immediately after production or stored in airtight containers.

In spite of the volatility of SynCoal®, its designers were able to identify a valuable utility market use for a SynCoal® facility. Their conclusion was that as long as the facility is located at a power plant or trucked to a facility within 200 to 300 miles, thereby permitting the product to be burned soon after its production with only temporary storage in an inert gas blanketed silo, a potentially successful design can result. This approach is outlined in the above-described Reference Plant Design for the ACCP. This design incorporates several economic features that aid the ACCP potential profitability. Additional process improvements also exist, such as using an Aeroglide Tower in place of the vibrating fluidized-bed reactors to further reduce costs.

During the ACCP demonstration several long-term industrial and speciality customers were established, indicating additional commercial potential for the SynCoal® product. This industrial market segment is much more amenable to special handling since these customers normally receive much smaller quantities of fuel, and are very receptive to high quality fuel sources. For example, SynCoal® has been found to provide superior performance in direct-fired applications, particularly as a blend with petroleum coke. It provides good ignition and stable flame characteristics, while the petroleum coke is a low-cost product that gives a longer burning time and therefore provides an expanded processing zone.

Contacts

Ray W. Sheldon, (406) 855-5008
ENPRO
P.O. Box 22745
Billings, MT 59103
(406) 245-3232 (fax)

Thomas A. Sarkus, NETL, (412) 386-5981
thomas.sarkus@netl.doe.gov

Joseph B. Renk III, NETL, (412) 386-6406
joseph.renk@netl.doe.gov

Douglas B. Archer, DOE FE HQ, (301) 903-9443

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U.S. Department of Energy

Assistant Secretary for Fossil Energy

Washington, DC 20585

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