Healy Clean Coal Project

Project completed

Participant

Alaska Industrial Development and Export Authority

Additional Team Members

Golden Valley Electric Association, Inc.—host and operator

Stone and Webster Engineering Corp.—engineer

TRW, Inc., Space & Technology Division—combustor technology supplier

The Babcock & Wilcox Company (B&W)—spray dryer absorber technology supplier

Usibelli Coal Mine, Inc.—coal supplier

Steigers Corporation—environmental and permitting support

Location

Healy, Denali Borough, AK (adjacent to Healy Unit No. 1)

Technology

TRW's Clean Coal Combustion System; Babcock & Wilcox's spray dryer absorber (SDA) with sorbent recycle

Plant Capacity/Production

50 MWe (nominal)

Coal

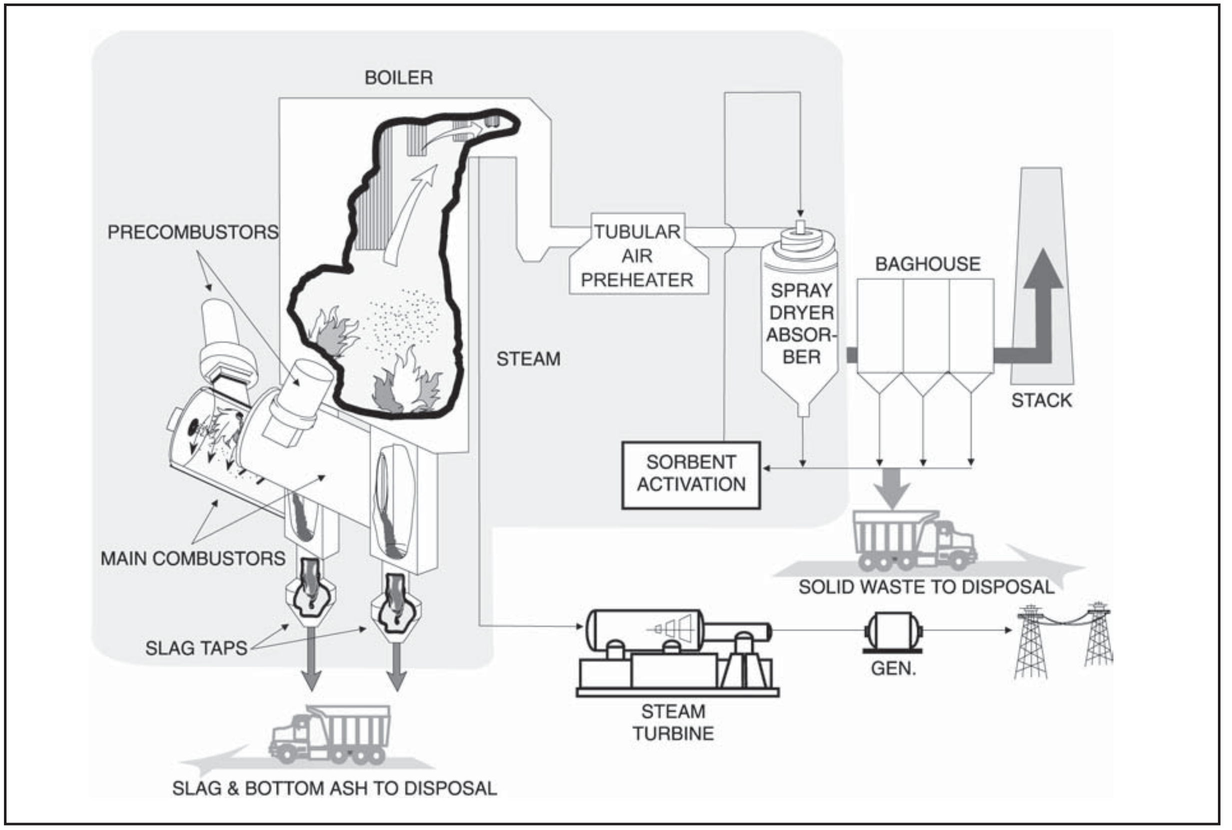
Usibelli subbituminous 50% run-of-mine (ROM) coal and 50% waste coal

Project Funding

Total	$242,058,000	100%
DOE	117,327,000	48
Participant	124,731,000	52

Project Objective

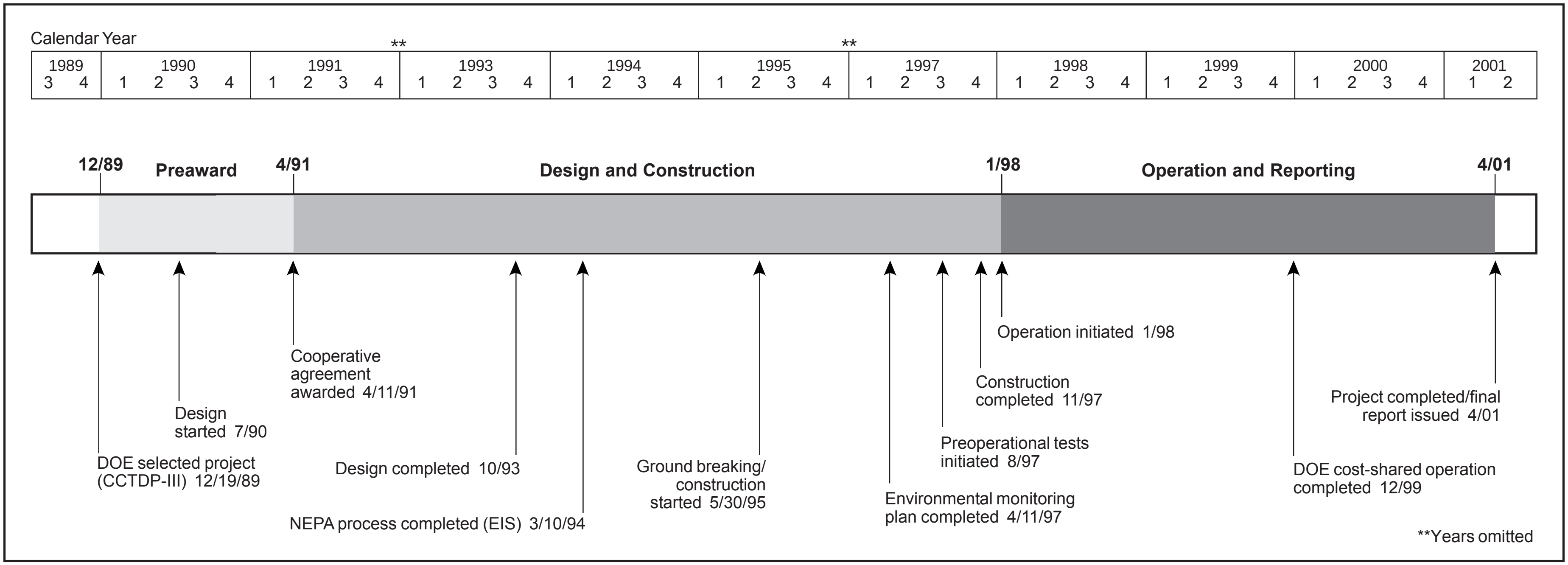
To demonstrate an innovative new power plant design featuring integration of an advanced combustor coupled with both high- and low-temperature emissions control processes.



Technology/Project Description

Emissions are controlled using TRW's clean coal combustion system, an advanced entrained/slagging combustors through staged fuel and air injection for NO_x control and limestone injection for SO_2 control. Additional SO_2 is removed using B&W's activated recycle SDA.

A coal-fired precombustor increases the air inlet temperature for optimum slagging performance. The slagging combustors are bottom mounted, injecting the combustion products into the boiler. The main slagging combustor consists of a water-cooled cylinder that slopes toward a slag opening. The precombustor burns 25–40% of the total coal input. The remaining coal is injected axially into the combustor, rapidly entrained by the swirling precombustor gases and additional air flow, and burned under substoichiometric conditions for NO_x control. The ash forms molten slag, which flows along the water-cooled walls and is driven by aerodynamic and gravitational forces through a slot into the slag recovery section. About 70–80% of the ash is removed as molten slag. The hot gas is then ducted to the furnace where, to ensure complete combustion, additional air is supplied from a tertiary air windbox to NO_x ports and to final overfire air ports. Pulverized limestone ($CaCO_3$) for SO_2 control is fed into the combustors where it is flash calcined (converting $CaCO_3$ to lime (CaO). The mixture of this CaO and ash that was not removed in the combustor, called flash-calcined material, is removed in the fabric filter system. Most of the flash-calcined material is used to form a 45% solids slurry, which is injected into the spray dryer. The SO_2 in the flue gas reacts with the slurry droplets as water is simultaneously evaporated. The SO_2 is further removed from the flue gas by reacting with the dry flash-calcined-material on the baghouse filter bags.



Results Summary

Environmental

- NO_x emissions ranged from 0.208–0.278 lb/10^6 Btu, with typical emissions of 0.245 lb/10^6 Btu on a 30-day rolling average, which is well below the permit limit of 0.350 lb/10^6 Btu on a rolling day average.
- SO_2 emissions were consistently less than 0.09 lb/10^6 Btu, with typical emissions of 0.038 lb/10^6 Btu, which are below the permit limit of 0.10 lb/10^6 Btu (3-hour average).
- High SO_2 removal efficiencies in excess of 90% were achieved with low-sulfur coal and Ca/S molar ratios of 1.4–1.8.
- Particulate matter (PM) emissions were 0.0047 lb/10^6 Btu, which is well below the permit limit of 0.02 lb/10^6 Btu.
- CO emissions were less than 130 ppm at 3.0% O_2, with typical emissions of 20–50 ppm at 3.0% O_2, which is well below the permit limit of 202 ppm at 3.0% O_2.
- Tests showed that the SDA system SO_2 emissions, PM emissions, and opacity were well within guarantees of the technology supplier.

Operational

- Carbon burnout goals for the technology supplier were achieved—greater than 99% carbon burnout at 100% maximum continuous rating (MCR) for the ROM, 50/50 blend of ROM/waste coal, and 55/45 blend. The carbon burnout was typically 99.7%.
- The contract goal of the technology supplier for slag recovery greater than 70% at 100% MCR for all coals was also achieved. Slag recovery ranged from 78–87%, with a typical recovery of 83%.
- During a 90-day test in the second half of 1999, the plant availability was 97% at a capacity factor of 95%.
- The SDA pressure drops and power consumption were well below guarantee levels of the technology supplier.
- The system required less limestone and produced less solid waste by-product than anticipated.

Economic

- The capital costs of a 50-MWe and 300-MWe plant using this system are $90.6 million ($1,812/kW) and $450.7 million ($1,502/kW) (1993$), respectively.
- The variable operating costs for the 300-MWe system is $7.2 million/yr (1993$) for the fixed cost and $28.4 million/yr (1993$) for the variable costs (based on 90% capacity factor).
- The levelized cost of power is 36.5 mills/kWh (constant 1993$) for the 300-MWe plant (based on 90% capacity factor).
- The levelized cost per ton of SO_2/NO_x removed is $6,499/ton (constant 1993$) for the 300-MWe plant (based on 90% capacity factor).

Project Summary

The Healy Clean Coal Project is the first utility-scale demonstration of the TRW clean coal combustion system. The project site is adjacent to the existing Healy Unit No. 1 near Healy, Alaska and the Usibelli coal mine. Power is supplied to the Golden Valley Electric Association (GVEA).

Environmental Performance

The entrained/slagging combustor is designed to minimize NO_x emissions, achieve high carbon burnout, and remove the majority of fly ash from the flue gas prior to the boiler. The slagging combustor is also the first step of a three-step process for controlling SO_2 by first converting limestone to flash-calcined lime. Second, the flash calcined-lime absorbs SO_2 within the boiler. Third, the majority of the SO_2 is removed with B&W's SDA system, which uses the flash-calcined lime and fly ash captured in the baghouse. Because most of the coal ash is removed by the slagging combustors, the recycled material is rich enough in calcium content that the SDA can be operated solely on the recycled solids, eliminating the need to purchase or manufacture lime for the back end scrubbing system.

During a cumulative six-month combustion system characterization test, a series of tests were performed to establish baseline performance of the combustion system while burning ROM and ROM/waste coal blends, to map combustor performance characteristics over a broad range of operating conditions and hardware configurations, and to determine the best configuration and operating conditions for long-term operation. During the 24-month demonstration test period, the NO_x, SO_2, PM, opacity, and CO emission goals were met with the exception of short-term SO_2 and opacity exceed-ances during start-up and repairs. The emissions, as well as permit and NSPS requirements, are presented in Exhibit 3-47.

Performance testing of the SDA system conducted in June 1999 showed that the technology performed well. Measurements of the SDA inlet, SDA outlet, stack, limestone feed, coal feed, air preheater hopper ash, surge bin ash, electrical power consumption, and stack opacity, as well as normal plant data from the plant distributed control system, showed that the technology exceeds the guarantees. The results of the tests and the performance guarantees are shown in Exhibit 3-48. It should be noted that environmental performance was not fully optimized.

Exhibit 3-47
Healy Performance Goals and Demonstration Test Program Results
(January 1998–December 1999)

Parameter	NSPS	Permit	Goal	Actual Range	Actual Typical
NO_x	0.5 lb/10^6 Btu (new plant after 7/97)	0.350 lb/10^6 Btu (30-day rolling avg) 1,010 tons/yr (full load)	0.20–0.35 lb/10^6 Btu (30-day rolling avg)	0.208–0.278 lb/10^6 Btu (30-day rolling avg)	0.245 lb/10^6 Btu (30-day rolling avg)
SO_2	70% removal with emissions <0.60 lb/10^6 Btu	0.086 lb/10^6 Btu (annual avg) 0.10 lb/10^6 Btu (3-hour avg) 65.8 lb/hr max (3-hour avg) 248 tons/yr (full load)	70% removal (minimum) 79.6 lb/hr max (3-hour avg)	~90% removal <0.09 lb/10^6 Btu (30-minute avg corrected to 3% O_2)	0.038 lb/10^6 Btu (30-minute avg corrected to 3% O_2)
PM	0.03 lb/10^6 Btu 99% reduction	0.020 lb/10^6 Btu (hourly avg) 13.2 lb/hr (hourly avg) 58 tons/yr (full load)	0.015 lb/10^6 Btu (hourly avg)	NA	0.0047 lb/10^6 Btu[b]
Opacity	20% Opacity (6-minute avg)	20% Opacity (3-minute avg) 27% Opacity (one 6-minute period per hour)	20% Opacity (3-minute avg)	2–6% Opacity (30-minute avg)	3.9% Opacity[a] (30-minute avg)
CO	Dependent on ambient CO levels in the local region	0.20 lb/10^6 Btu (hourly avg) 202 ppm (corrected to 3% O_2) 132 lb/hr, 577 tons/yr (full load)	206 ppm (corrected to 3.0% O_2) 200 ppm (corrected to 3.5% O_2)	20–50 ppm (30-minute avg corrected to 3% O_2)	25.9 ppm (30-minute avg corrected to 3% O_2)

[a] Measured 2.3% after correction of problems with premature filter bag failures in the baghouse.

[b] Not measured during demonstration test program. Data are from source test in March 1999.

Operational Performance

The slagging stage of the combustor performed extremely well and continuously demonstrated the capability to burn both ROM and ROM/waste coal blends over a broad range of operating conditions. The precombustor performed very well with ROM coal, but exhibited more variable performance, in terms of slagging behavior, during the initial tests with ROM/waste coal blends.

Localized slag freezing was observed in the precombustor during early testing. A combination of hardware configuration and operational configuration changes were made that minimized slag freezing. These changes included relocating the secondary air from the precombustor mix annulus to the head end of the slagging stage and completely transferring the precombustor mill air to the boiler NO_x ports following boiler warmup. These changes eliminated the mixing of excess air downstream of the precombustor chamber to minimize local slag freezing and increased the precombustor operating temperature to provide additional temperature margin. The mill air change had the added benefit of simplifying combustor operation by eliminating the need to monitor and control coal-laden mill air flow to the precombustor mill air ports during steady-state operation.

Testing of the slagging combustor also showed that the contract goals were achieved, which included greater than 99% carbon burnout at 100% maximum continuous rating (MCR) for the performance, ROM, 50/50 blend of ROM/waste coal, and 55/45 blend; and greater than 98% carbon burnout at 100% MCR for waste coal. The carbon burnout was typically 99.7%. Slag recovery ranged from 78–87%, with a typical reading of 83%, easily meeting the contract goal for slag recovery of greater than 70% at 100% MCR for all coals.

The SDA system also performed well. During performance testing in June 1999, system pressure drops were well below the 13 inches water gage (in. w.g.) guarantee. The range was 9.6–10.0 in. w.g. as can be seen in Exhibit 3-48. Power consumption was approximately 38–41% less than the guaranteed level. Based on these results, Stone & Webster concluded that the SDA system met all performance guarantees.

Economic Performance

Capital and operating cost estimates were prepared by an independent consultant to the participant for new plants in the "lower 48" that incorporate the technology demonstrated at Healy. The capital costs for a 50-MWe and 300-MWe plant are $90.6 million (1,812 $/kW) and $450.7 million (1,502 $/kW) (1993$), respectively. The variable operating cost for the 300-MWe plant is estimated at $7.2 million per year and the fixed operating costs are estimated at $28.4 million per year based on a 90 percent capacity factor (1993$). The levelized cost of power would then be 36.5 mills/kWh (constant 1993$). The levelized cost per ton of SO_2 and NO_x removed is $6,499/ton (constant 1993$) for the 300-MWe plant.

Exhibit 3-48
Healy SDA Performance Test Results and Performance Guarantees

Operating Parameter	Guarantee	Range of Parameter Values
SO_2	79.6 lb/hr (max)	<2.15
PM	0.015 lb/10^6 Btu	0.0014-0.0052
Opacity	20% Opacity (3-minute avg) 27% Opacity for 3 minutes per hour	1.0-2.0
System Pressure Drop	13 in. w.g.	9.6-10.0
System Power Consumption	550.5 kW	324-340

Commercial Applications

This technology is appropriate for any size utility or industrial boiler in new or retrofit uses. It can be used in coal-fired boilers as well as in oil- and gas-fired boilers because of its high ash-removal capability. However, cyclone boilers may be the most amenable type to retrofit with the entrained/slagging combustor because of the limited supply of high-Btu, low-sulfur, low-ash-fusion-temperature coal that cyclone boilers require. The commercial availability of cost-effective and reliable systems for SO_2, NO_x, and particulate control is important to potential users planning new capacity, repowering, or retrofits to existing capacity in order to comply with CAAA requirements.

Contacts

Arthur E. Copoulos, Project Manager, (907) 269-3029
Alaska Industrial Development and Export Authority
813 West Northern Lights Blvd
Anchorage, AK 99503
(907) 269-3044 (fax)
acopoulos@aidea.org

Victor K. Der, DOE/HQ, (301) 903-2700
victor.der@hq.doe.gov

Robert M. Kornosky, NETL, (412) 386-4521
robert.kornosky@netl.doe.gov

References

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Spray Dryer Absorber System Performance Test Report: June 7-11, 1999. Stone & Webster Engineering Corporation. February 2000.