Western Coals Push East

Many factors must be evaluated when considering a switch or blend of Western coals, including materials handling, mill impacts, low- and high-temperature fouling tendencies, flame stability and emissions impacts.

Western coals have become a significant force in the U.S. electric utility industry, impacting both power plant competitive operating strategies and emissions control strategies. Growing from negligible production levels in the early 1970s, Western coals now account for almost half of all coal mined in the United States, nearly all of which is used for power generation. More telling than these sheer numbers, however, is the impact that Western coals, particularly Powder River Basin (PRB) subbituminous coals, have had on the fuels market and on utility operating strategies around the country. This is summed up best in the following statement by Dick Rinehart, senior consultant for Black & Veatch: "Powder River Basin coal, either directly or indirectly, sets the pricing of coal across the entire United States."

PRB coals are rapidly spreading eastward. Despite their higher moisture contents compared with bituminous coals, resulting in significantly lower heat contents, subbituminous coals are commonly the low-cost fuel to Eastern and Midwestern plants, and the complete replacement of bituminous fuels is often only precluded by a smaller furnace that cannot achieve required heat release rates. Furthermore, with the lower price comes another bonus: a lower sulfur content that aids in meeting Clean Air Act SO\textsubscript{2} emission requirements. Blending PRB coals with bituminous coals can eliminate the need for a scrubber, reduce its required size or minimize the number of SO\textsubscript{2} credits that have to be purchased. As compared to Illinois Basin and...
Eastern coals, the PRB coals also generally have lower NO\textsubscript{x} emissions potential, which also enhances their appeal as future coal sources.

**The PRB Rush**

PRB coals move east through five main transportation corridors, according to Rinehart. In each, PRB coals are pushing farther and farther east to be blended with other fuels. In the northern corridor, rail-to-ship across Lake Superior, PRB coals are now being used by Detroit Edison and Consumers Power as far east as the western edge of Lake Erie. PRB coal delivered through the rail corridor into Chicago reaches Commonwealth Edison and NIPSCO coal-fired plants across Illinois and Indiana, and has extended as far as Toledo Edison in Ohio. Barge-traffic on the Ohio River now carries PRB coal to several TVA coal-fired plants, into Kentucky, Tennessee and Alabama. Rail traffic to the southeast through Memphis transports PRB coal to Mississippi Power's Watson and Daniel plants, and as far east as Georgia Power's Plant Scherer. Finally, through the Mississippi River to the Gulf of Mexico, PRB is delivered all the way to Tampa Electric's Big Bend Station, where 1 million tons are fired annually out of 6.5 million tons.

The fact that PRB coal can be delivered so far east at a competitive price is testament to the extremely high coal mining productivity achieved in the Powder River Basin. Stripping ratios (ratio of coal thickness to overburden thickness) have been declining, but technology advancements such as larger draglines and higher-capacity haul trucks have maintained productivity and kept prices relatively constant. At Plant Scherer, which fires about 6.1 million tons of PRB coal annually out of a total burn of 10.6 million tons, the total delivered cost of PRB coal is $1.50/MMBtu, compared to $1.55-$1.76/MMBtu for Appalachian coals, according to Rinehart. In addition to the mining economics noted above, this situation reflects the low costs of efficient large-scale and competitive rail transport furnished by the Western railroads as compared to the Eastern carriers transporting from their traditional sourcing regions.

**Rise and Fall of the Illinois Basin**

Illinois Basin coals are taking the brunt of the Western coal onslaught. Plagued by high sulfur contents and comparatively higher mining costs, Illinois Basin coals are struggling to remain a viable option in a utility fuels market that not only demands low cost, but now demands lower sulfur contents as Phase II of the Clean Air Act comes into effect.

Illinois Power is switching to PRB coals at its Hennepin and Baldwin power stations by the end of 1999 because it is the low-cost Phase II compliance option. Purchasing allowances, which Illinois Power had done for Phase I, or installing scrubbers, would have been more expensive than the coal switch, even though the plants are in the heart of the Illinois coal basin.

Hennepin recently completed a 30-day test burn of PRB coal to identify operational...
challenges and gauge the switchover’s effect on plant performance. The plant experienced a 10 to 15 percent derate with the PRB coal, according to plant manager Dan Thompson, and the test burn revealed many areas where physical and/or operational changes must be made, but there were no potential showstoppers to a complete replacement of the Illinois Basin coal.

To compensate for the PRB coal’s higher moisture contents, operation of Hennepin’s coal mills will be modified to raise the mill inlet temperature. This will be achieved with better heat recovery and a bigger exhauster fan. To limit fouling tendencies in the boiler's backpass, the furnace exit gas temperature (FEGT) is being maintained at least 100°F below the ash softening temperature of the PRB coal. "As with all fuels, there is a tradeoff between FEGT and fouling potential," said Jim Cumbow, director of operations at Hennepin. "In the short term with our approach, we can fire 100 percent PRB coal and still use the existing sootblower system as necessary. For the long term, however, we will be installing additional IK sootblowers and water cannons to maintain heat transfer capabilities."

For materials handling and dust control, Illinois Power is installing additional dust suppression and dust collection equipment at critical transfer points from barge to plant. Hennepin will also now require an SO₃ flue gas treatment system to maintain effective particulate control in the unit’s electrostatic precipitators.

Illinois Power will retain the ability to fire non-PRB coals at Hennepin and Baldwin, but does not expect any significant price spike in the foreseeable future. Even if prices do spike, the Illinois reserves aren’t going anywhere, and there will always be someone in the Illinois Basin willing to mine coal if a seller's market develops. Such a hedge is important to Eastern utility managers. Sustained production from the Eastern and Midwestern coal fields, together with an active spot market, act to dampen any prospective price spikes in the west.

**My New Kentucky Home**

The Tennessee Valley Authority provides a good gauge of Western coal progression. After extensive fuel evaluation efforts, TVA now fires Western coals, straight or in blends, at six of its plants (Allen, Shawnee, Paradise, Gallatin, Widows Creek and Colbert) and has test-burned Western coals at most of its other unscrubbed coal units. For 1999, TVA expects to burn approximately 42 million tons of coal, about 12 million tons of which will be from west of the Mississippi River.

Economics are the driving factor. "Simply put, at least for the western portion of TVA’s system, the cheapest Btu I can deliver is a Western coal," said Richard Rea, TVA’s manager of fuel acquisition and supply. The Shawnee plant in West Paducah, Kentucky bears this out. Operating under a local SO₂ emissions limit of 1.2 lb/MMBtu since the late 1970s, which forced the used of low-sulfur Appalachian coals for many years, the Shawnee fuel now consists of a 70/30 blend of low-sulfur Colorado and PRB coals.

PRB coals are currently blended at percentages ranging from 15 percent to 50 percent of heat input at TVA’s plants, with plans to bump this as high as 80 percent at Gallatin and Paradise Unit 3 to meet Phase II SO₂ limits. TVA’s fuel switching philosophy is to utilize PRB coals to the maximum extent that derates are prevented, according to Denton Eady, TVA project engineer - combustion; existing plant equipment remains in use, with minor plant modifications to accommodate the Western coals’ unique characteristics:

- Dust suppression and fire protection systems have been upgraded at key materials handling locations. The break-even point is around a 20 percent PRB blend, according to Rea. Where PRB is blended at more than 20 percent, TVA has had to invest in foam spraying equipment to provide sufficient dust suppression.
- Inerting systems have been installed on the pulverizers, using water fog, steam or CO₂.
Excess pulverizing capacity at TVA’s plants burning Western coals has been eliminated. Mill outlet temperatures have fallen from the 165-170 F range to the 135-150 F range, depending on the amount of PRB coal being fired, but with no detrimental impacts related to agglomeration or condensation.

- Temperature monitors have been installed in the upper regions of the boilers to provide a more frequent indication of furnace exit gas temperature, which can then be used to gauge fouling potential and regulate sootblowing schedules.

Although TVA’s fuel switching strategy is designed to avoid derates, market conditions may dictate otherwise. Plant managers have the flexibility to intentionally derate in order to take advantage of favorable fuel and electricity market conditions, according to Eady. At Shawnee, for example, PRB use is typically capped at 30 percent; however, if PRB fuel costs are low and the plant is not being dispatched at full load, PRB content can be increased to 60 percent, which results in a nominal derate but reduces operating costs and increases profitability.

Western coals may have downstream impacts on power plant wastewater streams, particularly as ammonia-based post-combustion NOx systems come on-line in the next several years. TVA and EPRI are working on a tailored collaboration project that will examine the combined effects of ammonia and fly ash on wastewater discharge characteristics. Wastewater pH is expected to increase because of ammonia slip from selective catalytic reduction systems and because of the more alkaline PRB fly ash. Higher pH favors the formation of ammonia nitrogen, which is the more toxic form of ammonia to aquatic life. Furthermore, a higher pH could result in different dissolved trace metal concentrations, thereby altering wastewater toxicity.

Wild Cards

As Western coals surge eastward, it is easy to gloss over the barriers that may stunt further growth. While these barriers may not be insurmountable or even likely, they must be acknowledged. Transportation capacity is the biggest wild card. As demonstrated by the supply disruptions that plagued the Union Pacific railroad in 1997, coal movement around the United States can be significantly hampered by insufficient infrastructure and inadequate carrier coordination. Union Pacific and Burlington Northern Sante Fe, the two main rail carriers from the Western coal fields, have pledged to make the investments necessary to accommodate additional growth, but only time will tell. Perhaps more significantly, the proposed Dakota Minnesota and Eastern railroad, which would carry up to 100 million tons of coal out of the PRB each year to Eastern markets through Chicago and the Great Lakes, could greatly increase competition and may even promote the sharing of trackage rights among the major railroads.
Mining costs and mining industry consolidation represent a second wild card. There are some concerns that the widespread switchover to PRB coals may result in a price spike in Midwestern and Eastern markets. The Western coal fields are now operated by only a handful of large mining companies. If these companies are able to lock up the majority of the reserves in the PRB, the market dynamics would change. Black & Veatch's Rinehart does not expect a price spike, however, because, except for the large capital outlays required for new PRB mine development, mining companies can still enter the market relatively easily. A bigger uncertainty rests with the federal government. Since the reserves in the Powder River Basin are on federal lands, if additional land leasing is denied or restricted in the future, PRB coal pricing could change considerably. Though plausible, these scenarios are unlikely, as they would deter competition and invite federal intervention.

A third wild card concerns the Clean Air Act Amendments (CAAA) of 1990. With the recent appeals court rulings threatening to block or delay EPA's proposed national ambient air quality standards for particulate matter and the SIP Call provisions for NOx, there are rumblings that the CAAA, including the SO2 stipulations, could be rescinded. Such a rescission would have serious repercussions for Western coals, as some of their inherent value would be discounted. It is very difficult to imagine Congress walking anywhere near the quagmire that would develop around a reconsideration of the CAAA, but the appeals court rulings indicate that environmental regulations are no longer sacrosanct.

Whatever obstacles exist—now or in the future—Western coals are indisputably thriving in today's power generation market, and all indications point to steady growth.

Cognizant of the penetration of Western coals into Eastern utility markets, EPRI commissioned a number of studies to gauge the impacts that PRB coals and coal blends have on power plant operation and performance (EPRI TR-105748, TR-106340 and TR-111756). TR-105748 describes the experience of a number of utilities burning or having tested PRB coals/blends. TR-106340 describes a systematic test program undertaken by a utility in burning an increasing proportion of PRB blend with their baseline bituminous coal and provides guidelines for other utilities planning to do the same. This sidebar describes TR-111756, a more recent and detailed study on the characterization of PRB blends in a pilot scale combustion facility, conducted under a joint sponsorship program with the Department of Energy, the Energy & Environmental Research Center of the University of North Dakota, Consolidation Coal Company and Northwest Research Inc.
A series of combustion tests was designed to evaluate and compare the combustion characteristics of several Powder River Basin (PRB) subbituminous coals and various Eastern and Midwestern bituminous coals individually and together. Among the areas evaluated were boiler tube ash-fouling potential in the high- and low-temperature regions typical of the convective pass of a bituminous-designed boiler, furnace wall slagging, carbon conversion, flame stability, ESP performance, and SO2, NOx and particulate emissions. Mill performance was also analyzed.

**Mill Impacts**

The pulverizer is usually the first area impacted by a switch to a subbituminous coal or a blend containing subbituminous coal. The high moisture content of the subbituminous coal contributes to a decreased mill outlet temperature as the moisture evaporates in the mill. Attempts to maintain the design outlet temperature by closing tempering air dampers results in a limitation to achieving rated load as the proportion of subbituminous coal increases. Allowing the mill exit temperature to decrease provides some room to achieve rated load at higher blend ratios. However, some minimum temperature exists that is required to maintain adequate velocity for coal pipe transport and prevent condensation and agglomeration as the gas temperature approaches the dew point. When this limit has been reached, attempts to achieve higher blend ratios of subbituminous coal results in boiler derate.

The mill performance tests indicated that at design pulverizer conditions, relative to pulverization of bituminous coal, the decreased thermal input of the subbituminous coals resulted in mill derates of up to 55 percent of the maximum thermal input of the bituminous coals (see figure). By raising the mill inlet temperature by 200 to 300 F, thermal throughput for the subbituminous coals could be increased by 10 to 20 percent. Increasing the air/fuel ratio also tended to increase thermal throughput, but at the expense of a coarser product. At the maximum thermal throughput for the subbituminous coals and the highest air/fuel ratio, product fineness decreased by up to 15 percentage points, from 85 percent to 70 percent passing 200 mesh. Interestingly, the lowest-heat-content subbituminous coal exhibited the lowest thermal derate of the two PRB coals tested, but required much higher mill energy input.

**High-Temperature Fouling**

It is unclear to what extent the ash-forming species in a subbituminous coal will interact with those from a bituminous coal to form deposits in a utility boiler. Experience has suggested that these interactions are not readily applicable to all fuel blends; therefore, no hard-and-fast estimate of fouling tendencies may be provided by simply proportioning the results of ASTM ash analyses at the desired blend ratios. For this reason, a single bituminous coal (Pittsburgh seam, Bailey mine) was blended with two PRB subbituminous coals (Black Thunder and Antelope mines) to determine their fouling tendencies at two load levels.

The results indicate higher fouling rates for each of the subbituminous coals compared with the bituminous coals, with the blends exhibiting a lower ash-fouling rate at the full-load conditions (FEGT of 2,200 F). The lower fouling rate of the blends was attributed to interactions between the two ash types. In each case, however, the strength of the deposit increased irrespective of the fouling rate as the percentage of subbituminous coal in the blend increased. The highest sodium-content subbituminous coal exhibited the strongest deposits than its lower-sodium counterpart.

**Low-Temperature Fouling**

A nonstandard 12-hour combustion test investigated the ash-fouling tendencies of seven coals/coal blends on low-temperature heat-exchange surfaces. A set of four steam-cooled probes were inserted into the flue gas duct at temperatures around 1,550 F to collect ash-fouling deposits simulating reheat/economizer boiler tubes.

The tests indicated that similar deposition rates could be expected for each of the fuels tested, with a slight increase in rate noted as the percentage of subbituminous coal in the blend was increased. The results also showed the blends to have greater sintering strengths.
than the parent coals. It was expected that as the percentage of subbituminous coal in the test fuels increased, with corresponding increases in ash calcium concentrations, the resulting low-temperature deposits would develop increasingly greater sintering strengths because of the increased calcium sulfation.

**Flame Stability**
To assess flame stability behavior, the EPRI team tested various fuel blends in two operating modes simulating full load and turndown conditions at two-thirds load. Overall, flame stability test results indicated that, relative to the Bailey bituminous coal, the blends of Bailey with the subbituminous coals would not dramatically impact the ignitability and stability of the combustion flame. Each of the fuels tested provided stable combustion flames over a wide range of secondary air swirl settings. Carbon-in-ash evaluations indicated a trend toward lower ash carbon levels as the proportion of subbituminous coal in the blend was increased. This may tend to offset some of the limits to grinding efficiency when considering mill performance.

**Emissions**
As expected, SO₂ emissions were dramatically reduced as the percentage of PRB coal was increased in a given blend. Interestingly, there was evidence of increased sulfur capture in the ash as the percentage of subbituminous coal in the blend increased, an effect that was more pronounced at lower furnace exit gas temperatures. NOₓ emissions also decreased as the fraction of PRB coal increased; NOₓ emissions from parent subbituminous coals were roughly one-half those of the parent bituminous coals. Particulate emissions testing indicated similar results for all fuels tested under similar conditions. There was no apparent trend toward decreased electrostatic precipitator collector efficiency for either of the blends, although one of the blend sets indicated a slight reduction in collection efficiency as the percentage of subbituminous coal in the blend increased.

At Ontario Power Generation's Nanticoke Generating Station, a coal blending facility permits on-site blending of PRB coals with Eastern coals in proportions that still permit normal plant operation to be maintained. Pressures to further reduce production costs, however, demanded that a greater amount of PRB coal be incorporated into the fuel blend.

This required modifications to the fuel preparation system.

The primary issue at Nanticoke is that there is an insufficient quantity of drying capacity in the incoming primary air to the pulverizers to permit adequate heating and drying of the high-moisture PRB coals. To address this shortcoming, Nanticoke decided to investigate the feasibility of installing natural gas-fired burners directly into the existing primary air ducts, between the Ljungstrom air heaters and the pulverizers. While unorthodox, this approach has proven to be a safe, effective and economical means of retrofitting the primary air system to accommodate the consumption of fuel blends containing up to 50 percent PRB coal.

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