PRACTICAL PRB COAL EXPERIENCES

ABSTRACT

Converting to, or test burning Powder River Basin (PRB) coals can often be a stressful experience as utilities attempt to balance sensible capital expenditures with responsible personnel and equipment safety precautions. The authors have compiled multiple PRB coal project experiences into one concise discussion on PRB-firing realities. Practical alternative solutions are offered to cope with the more significant PRB coal offenses, such as reflective ash, pozzolanic ash, ash resistivity, furnace fouling, dust control, and inerting.

1.0 INTRODUCTION

This discussion relates experiences of nine PRB-fired units. One of the units is a pulverized coal (PC) fired unit originally designed for PRB coal. Four other PC units were converted from bituminous to PRB coal. The discussion includes four cyclone units converted from bituminous to PRB coal. The nine example units include eight drum units and on supercritical unit. Six of the units have boilers manufactured by B&W, while the other three are manufactured by Foster Wheeler Corporation.

All nine of the units have employed a wide variety of techniques to cope with the PRB coal, and experienced an equally wide variety of successes and failures. Even the one unit originally designed for PRB coal is not without PRB-related problems. Each unit name, unit number, and utility identity have been kept anonymous because of today's competitive market environment. We have subsequently selected the most prominent successes as a focal point for one general set of practical solutions to the most common PRB-firing problems.

2.0 UNIT DESCRIPTIONS

The following general descriptions relate the more significant features of each of the nine example units. Table No. 1 summarizes these and other parameters about each unit.

2.1 Unit No. 1

Unit No. 1 is a B&W opposed-fired PC drum unit, originally designed to burn PRB coal. The unit has a steaming rate of 4,700 kpph at 2,400 psi. Furnace volume is 592,000 cu ft. Steam temperature control is accomplished by a combination of firing rate, selection of pulverizers in service, and superheat and reheat sprays. The unit employs a dry ash removal system and was originally built with no waterlances.

This unit operated for many years burning PRB coal without suffering a derate. However, superheat spray flow was often as high as twice the originally predicted flow rate. The unit was eventually retrofit with waterlances to help back-end gas temperatures and reduce spray flow.

2.2 Unit No. 2

Unit No. 2 is a Foster Wheeler opposed-fired PC drum unit, converted from bituminous to PRB coal. This unit was originally designed for a steaming rate of 2,200 kpph at a pressure of 2,400 psi. The furnace volume is 160,000 cu ft. Steam temperature control is accomplished through a combination of backpass dampers and superheat and reheat sprays. The unit suffered no derate as a result of the conversion to PRB coal. No waterlances were originally installed on this unit.

2.3 Unit No. 3

The description for Unit No. 3 is identical to that of Unit No. 2, except for a steaming rate of 3,800 kpph at 2,400 psi. The conversion to PRB coal caused a unit derate of 400 kpph. The limitation was caused by high furnace exit gas temperature. No waterlances were originally installed on this unit.

2.4 Unit No. 4

Unit No. 4 is a B&W cyclone unit, with a steaming rate of 1,300 kpph. The furnace volume is 116,000 cu ft. Steam temperature control is accomplished through a combination of firing rate and superheat and reheat sprays. The unit did not suffer a derate as a result of converting to PRB coal.

2.5 Unit No. 5

The description for Unit No. 5 is the same as for Unit No.. 4, except that the furnace volume is 131,000 cu ft. The installation of five waterlances aided in the prevention of a derate on this unit.

2.6 Unit No. 6

Unit No.. 6 is a B&W opposed-fired PC drum unit. The unit has a steaming rate of 4,900 pph at 2,400 psi. Furnace volume is 620,000 cu ft. Steam temperature control is accomplished by a combination of firing rate, selection of pulverizers in service, and superheat and reheat sprays. The unit employs a dry ash removal system and was originally built with No. waterlances.

2.7 Unit No. 7

Unit No.. 7 is a B&W cyclone unit, with a steaming rate of 4,400 kpph. The furnace volume is 262,000 cu ft. Steam temperature control is accomplished through a combination of firing rate and superheat and reheat sprays. The unit did not suffer a derate as a result of converting to PRB coal.

2.8 Unit No. 8

Unit No.. 8 is a B&W cyclone unit, with a steaming rate of 4,400 kpph. The furnace volume is 262,000 cu ft. Steam temperature control is accomplished through a combination of firing rate and superheat and reheat sprays. The unit did not suffer a derate as a result of converting to PRB coal.

2.9 Unit No. 9

Unit No.. 9 is a Foster Wheeler opposed-fired PC supercritical unit with a steaming rate of 4,600 kpph. Furnace volume is 380,000 cu ft. The unit was originally designed for bituminous coal and subsequently converted to burn PRB coal. No. derate resulted from the conversion. The success of this conversion was a result of liberal use of waterlances, installation of a flue gas conditioning system, and the implementation of various techniques to mitigate the effect of the pozzolanic ash.

3.0 PRB CONVERSION PROBLEMS

The following is a brief discussion of the specific PRB coal-firing problems encountered by the nine example units. These problems are representative of those experienced by the rest of the power industry. This is not intended to be a complete technical discussion on each subject, but rather a brief explanation of the nature of each problem.

3.1 Reflective Ash

While the industry often refers to this property as reflective ash, Diamond Power will refer to the same property as emissivity. The commonly used term “reflective ash” refers to deposits of sodium and/or magnesium compounds on the furnace water walls which exhibit the property of low emissivity. These deposits are reflective, especially in the wave length range of primary radiation heat transfer within the furnace.

It should be noted that the majority of the heat transfer within the furnace is by radiation. Thus, coating the eater wall surface with such a reflective substance significantly retards radiation heat transfer, which results in higher furnace exit gas temperature. An increase in furnace exit gas temperature correspondingly increases superheat and reheat sprays, and air heater gas exit temperatures, both of which reduce boiler efficiency. A very large increase in furnace exit gas temperature will initiate fouling, as the vaporized sodium in the flue gas (which normally condenses onto ash particles and exits the furnace relatively harmless) begins to condense onto the relatively cold superheat and reheat tubing.

3.2 Dust Hazard

PRB coal is more friable and, thus, more dusty than other coals. This tendency toward "dustiness" presents a new level of dust management and control. The dust hazard extends from the rail car unloader to the various coal handling conveyor belts and components, coal pile dozers, and into the plant to the bunkers and pulverizer area. Every aspect of coal handling suffers from PRB coal's friability.

3.3 Mill Explosions

In addition to the increased dust level, PRB coal is more volatile. Volatility manifests itself most often in the form of mill explosions, usually occurring during mill start-up or mill shutdown.

3.4 Pozzolanic Ash

PRB coal ash has a significant amount of calcium oxide, a key ingredient in cement. Fly ash with calcium oxide content in excess of 10 to 15 percent quickly solidifies when hydrated. This may not affect some PRB blends, but it is a problem with nearly all units firing 100 percent PRB.

3.5 Increased Ash Resistivity

PRB coal ash increases the fly ash resistivity, which deteriorates electrostatic precipitator performance. The primary factor is the reduction electrostatic precipitator performance. The primary factor is the reduction in sulfur content. However, sodium and iron also have noticeable effects.

3.6 Reduced HHV

PRB coal has more moisture and less carbon than bituminous coals, resulting I a significantly lower heating value. The lower heating value results in an increase in coal flow to support a comparable heat release. Thus, the unit and its auxiliaries will realize an increased duty on all coal handling system equipment, an increased duty on all coal pulverization equipment and transportation equipment, and an increase in auxiliary power consumption.

3.7 Reduced Boiler Efficiency

Firing PRB coal will reduce boiler efficiency. Even if furnace cleaning is accomplished adequately and furnace exit gas temperature remains low, boiler efficiency will drop because of the significant increase in fuel moisture resident in the PRB coal. Having nearly three times the amount of moisture as bituminous coals, a PRB coal fire must evaporate nearly three times as much moisture and raise the vapor temperature to equal the air heater gas outlet temperature.

3.8 Air Heater Surface Ratios

There will be an increased need for hot primary air flow when firing PRB coal, brought about by two factors. The reduced HHV and the lower boiler efficiency both increase the required coal flow rate and the corresponding primary air flow rate. Also, the increase in moisture requires a higher primary air-to-fuel ratio for transportation and drying. Total unit air flow, however, will remain approximately the same (except for an increase due to the decrease in boiler efficiency). This, a need arises for significantly greater primary air heater surface and significantly less secondary air heater surface. This problem is real, but apparently modern air heater sizing practices are forgiving. None of the four PC units converted from bituminous to PRB coal required a redistribution of heat transfer surfaces.

4.0 SOLUTIONS

the following discussion summarizes the various methods the nine example units used to address the conversion problems referenced above.

4.1 Reflective Ash Solutions

The solution most often initially employed during a PRB coal conversion is to increase the use (frequency) of the existing air or steam soot blowers. This was the initial step on most of the example units. Even the unit originally designed for PRB coal had No. waterlances initially. This solution proved unacceptable in all nine cases. Simply stated, soot blowers are not effective at removing the reflective ash deposits on furnace water walls.

Waterlances are an alternative to furnace water wall cleaning. In every case, waterlances were installed to improve cleaning, reducing furnace exit gas temperature. One of the Foster Wheeler units had a fin tube economizer, which was prevented from plugging primarily because of the effectiveness of the furnace waterlances.

The nine sample units varied from using a continuous end-to-end cycle of waterlance insertions to occasional use, triggered by visual observation. We on a continuous end-to-end cycle probably indicates inadequate waterwall coverage. Using a visual observation to determine waterlance usage is likely to be ineffective because the reflective ash is nearly undetectable visually. An objective means of measuring the need for furnace cleaning is much preferred over subjectivity.

4.2 Dust Hazard Solutions

Solutions to the dust hazard problem vary widely. Most units included additional dust collectors at some point in the system. Some units supplemented dust collection with an application of surfactant. One unit applied surfactant to the train as it left the mine, to the coal as it was unloaded, and to the coal as it was conveyed into the powerhouse. Permanent conversions to PRB coal may also require designs for dust explosion control, such as explosion blowoff doors. This solution was frequently discussed but not employed on any of the nine sample units.

At the opposite end of the capital cost spectrum in dust hazard solutions, some units adequately controlled dust with minimal dust collection and a significant increase in area housekeeping. This approach seemed to work well in combination with personnel traffic control. In some instances, traffic was rerouted so that the pulverizer aisle or the dust collector vicinity were No. longer routine passageways. Some areas were cordoned off with warning signs and directions for rerouting. Enhanced personnel training focusing on the characteristics and hazards of PRB coal dust was also employed.

Even the coal yard dozers require special dusty-environment equipment and explosion-proof equipment to operate safely and reliably.

4.3 Mill Explosion Solutions

Mill inerting was employed in all five of the PC-fired units. One unit employed a hybrid mill-inerting/mill-fogging system which appeared to work quite well. The mill fogging approach was developed and subsequently patented by another utility, with usage rights purchased by the example utility. The utility which originally developed the fogging concept has subsequently removed its inerting system, with No. further mil explosions. The example utility (Unit No.. 9) uses a sequence which initially fogs the pulverizer in an attempt to drop all dust out of suspension and wet down any coal dust lying on horizontal surfaces. After approximately one minute of fogging, the fogging continues and a CO_2 inerting system initiates. Apparently, CO_2 inerting, which eventually does inert the mill interior, can initially create a hazard by increasing the amount of dry airborne coal dust. Fogging apparently minimizes the amount of dust in that environment.

The tendency toward mill explosions and mill fires was further reduced by lowering the set point for mill exit temperature. In most cases the new set point was about 135 degrees F.

4.4 Pozzolanic Ash Solutions

One solution to the pozzolanic ash problem is to convert the entire fly ash removal system to a dry ash removal system. This remedy is expensive and carries No. guarantee of success. Even though the system is dry, introduction of moisture in any manner, such as condensation, will tend to solidify at least a portion of the ash in the system.

In an effort to address an existing wet fly ash removal system, one unit combined three somewhat innovative approaches to result in successful ash removal. The three approaches consisted of scouring the system occasionally with bottom ash, excessively diluting the ash sluice line with water, and installing a Teflon boot within the hydrovactor. The bottom ash scouring was accomplished through an existing crossover line in a redundant ash sluice system. Excessive ash dilution was also effective, but required an increase in ash sluice pump capability and ash sluice water usage, which may be impractical for some units. Both solutions are inexpensive. The Teflon boot liner also was effective and cost approximately $15,000 each. One problem encountered with the Teflon boot liner was an occasional collection of fly ash between the boot and the hydrovactor. This required dismantling the system for cleanout.

4.5 High Ash Resistivity Solutions

One solution for improving precipitator performance with low sulfur coal is to replace the precipitator with a much larger one. This, of course, is expensive, time consuming, and requires an extended outage. An effective alternative is to install a flue gas conditioning system. The flue gas conditioning system injects small amounts of ammonia and SO_3, which reduces ash resistivity and improves precipitator collection efficiency. This is an annual expense, but the chemicals are very inexpensive.

Once again, properly cleaning the furnace to keep the furnace exit gas temperature down also will keep precipitator gas temperature down and thus improve precipitator performance.

4.6 Reduced HHV Solutions

There were No. surprise or innovative approaches to this problem. Most utilities either operated more equipment (i.e., fewer spares) or they operated their equipment longer or faster (i.e., less downtime for maintenance). Equipment replacement could be required if No. spare capacity remains. However, this was not the case at any of the five PC units.

4.7 Reduced Boiler Efficiency Solutions

The largest heat losses are moisture and dry gas loss. Dry gas loss can be addressed through proper furnace cleaning as previously discussed. There is No. practical solution to the increase in efficiency loss due to fuel moisture. Off-site predrying is a possibility, but none of the nine sample units employed this technique. A minor improvement in efficiency may be realized by improving pulverizer product fineness to help reduce efficiency loss due to carbon in the fly ash. This too is a challenge with PRB coal because of the reduced HHV, which demands a higher throughput from each mill.

4.8 Air Heater Surface Ratio Solutions

None of the nine sample units required air heater alterations. If required, repartitioning a trisector or adding an additional separate primary air heater could be solutions. The four cyclone units required hotter rather than more primary air to keep the slag tap flowing. This was accomplished by rerouting the primary air source to a location at the top of the air heater plenum where temperatures were as much as 80 degrees higher.

5.0 SELECTED PRACTICAL SOLUTIONS

A critical look at this nine-unit experience identifies at least one "first principle" and five other practical ways to support a successful conversion to PRB coal:

a. Principle-Proper Furnace Cleaning
b. Flue Gas Conditioning
c. Bottom Ash Scouring
d. Ash Sluice Dilution
e. Hydrovactor Teflon Boot
f. Improved Housekeeping and Traffic

5.1 Waterlances

The referenced first principle addresses proper furnace cleaning. Many of the negative performance and maintenance aspects of PRB coal can be mitigated by doing a superb job of furnace cleaning. The preferred approach is to achieve good combustion and superior cleaning within the furnace so that the furnace exit gas temperature remains low and the change in fuel remains transparent to the rest of the boiler. This is the best money spent in a PRB conversion. Proper furnace cleaning solves many secondary problems such as high furnace exit gas temperature, fouling, excessive superheat or reheat sprays, and actually improves boiler efficiency and precipitator performance.

5.2 Flue Gas Conditioning

Fine gas conditioning significantly improves precipitator performance at a modest capital expense and low annual expense. Flue gas conditioning is an effective method of removing precipitator performance from the list of PRB performance constraints.

5.3 Bottom Ash Scouring

Bottom ash scouring costs nothing if a redundant ash line crossover exists. Bottom ash scouring simply uses abrasive bottom ash to scour the insides of the fly ash sluice lines. Bottom ash scouring will not unplug a line but it will reduce the rate of buildup on the inside of ash sluice lines.

5.4 Ash Sluice Dilution

Ash sluice dilution is also inexpensive and effective. A dilute ash sluice line uses more water and more auxiliary horsepower, but also makes it much more difficult for the ash to set up while still in the ash sluice lines.

5.5 Hydrovactor Teflon Boot

The hydrovactor is the most restrictive part of the entire ash sluice system. Pluggages will usually occur at this point. The Teflon boot is effective at a cost of around $15,000 each.

5.6 Improve Housekeeping and Restrict Access

The utility can avoid a portion of the added dust collection costs by simply improving their housekeeping practices and restricting access to those areas where increased dust is a problem. Each utility must evaluate the safety aspect of this approach for each individual application. It should be noted that from a safety standpoint, the National Fire Protection Association (NFPA) does not address PRB coal any differently than other coals. Thus, the utility is on its own to develop enhanced safety precautions.

6.0 CONCLUSION

PRB coal can be safely fired in many units without pending a fortune in capital improvements. The few steps offered here may provide the plant staff with some insight as they choose their own solutions to the challenges of PRB-coal firing. Personnel safety is always top priority, whatever solution is employed.

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COMPARISON OF NINE PRB COAL CONVERSION UNITS

	UNIT	NO. 1	NO. 2	NO. 3	NO. 4	NO. 5	NO. 6	NO. 7	NO. 8	NO. 9
Before PRB Conversion	Commercial Date	1979	1972	1975	1966	1969	1982	1972	1977	1978
	Design Capacity (kpph)	4,700	2,300	3,800	1,300	2,000	4,900	4,400	4,400	4,600
	Furnace Volume (ft^3)	592,000	160,000	345,600	116,000	131,000	620,000	262,000	262,000	380,000
	Cap/Vol Ratio (pph/ft^3)	7.94	14.38	11.00	11.21	15.27	7.90	16.79	16.79	12.11
	Boiler Mfgr	B&W	FFWEC	FWEC	B&W	B&W	B&W	B&W	B&W	FWEC
	Type of Firing	PC-Opposed	PC-Opposed	PC-Opposed	Cyclone	Cyclone	PC-Opposed	Cyclone	Cyclone	PC-Opposed
	Design Coal	PRB	Bituminous	Bituminous	Bituminous	Bituminous	Bituminous	Bituminous	Bituminous	Bituminous
	Ash Conveying Type	Dry	Dry	Dry	Dry	Dry	Dry	Wet	Wet	Wet
	Qty. Of Waterlances	0	0	0	0	0	0	0	0	0
After PRB Conversion	Derate (kpph)	0	0	400	0	0	0	0	0	0
	Derate Cause	N/A	N/A	FEGT	N/A	N/A	N/A	N/A	N/A	N/A
	Ash Conveying Type	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Wet
	Qty. Of Waterlances	0	0	0	6	5	30	16	16	27