Improving heat rate by input/loss monitoring

The old proverb "You get what you inspect, not what you expect" has once again been proven true at the Boardman Coal Plant in Oregon. Recently, as part of an upgrade of the plant's control system and instrumentation, engineers found that the boiler was operating with 20% air in-leakage because the 14 O_2 probes in its exit flue couldn't "see" burners on the boiler's back wall. Moving those probes, and adding another 12, solved the problem.

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Commissioned in 1982, the 585-MW Boardman Coal Plant (Figure 1) is jointly owned by Portland General Electric Co. (65%), San Diego Gas & Electric (15%), Idaho Power Co. (10%), and Pacific Northwest Generating Co. (10%). Its boiler from Foster-Wheeler generates 3.8 million lbs/hr of steam at 1,005F by burning several blends of Powder River Basin and Utah coals with significantly different chemistries and heating values ranging from 8,100 Btu/lb to over 12,500 Btu/lb.

Like the staff at many power stations, Boardman's engineers and operators traditionally paid closest attention to the plant's two key "controllable parameters": fuel flow in and megawatt-hours out. The boiler's heat rate—a measure of its efficiency—was calculated only once a month from measurements of cumulative coal flow and random samples for heating value. Realizing that low-cost generation would have an edge in the coming competitive era, Boardman's owners decided that it was time to improve the plant's efficiency.

A prerequisite for the success of any initiative to raise a plant's efficiency is the ability to monitor as many of its operating variables as often as possible. Accordingly, the first move Boardman's owners made was to upgrade the plant's old, analog control system to a modern, digital one comprising a WDPF distributed control system (DCS) from Westinghouse Corp. and Input/Loss Method (ILM) software from Exergetic Systems Inc. (San Rafael, Calif.). Among its other functions, the ILM system calculates real-time boiler efficiency and heat rate. Every 2 minutes, it feeds those numbers (as well as 15-minute running averages of other relevant plant data) to the DCS so operators can act on them. The DCS communicates with the ILM system via an interface from Real Time eXecutives Inc. (RTX), Wrentham, Mass. Outputs of the ILM system are made available both through the RTX interface and via a Modbus protocol provided by Kepware Inc. (Yarmouth, Maine).

The performance monitor retrofit required upgrading plant instrumentation to enable calculations of major systems' heat balance. Temperature and pressure instruments were added at both low-pressure turbine crossover pipes, thermocouples were added to existing wells at the main and reheat steam turbine inlets, and new steam flow orifices were added in the steam lines feeding the auxiliary turbines (which at Boardman drive both boiler feed pumps and boiler feed booster pumps).

The ILM system is more than a computational engine. It combines results from its sophisticated boiler simulator, fuel samples, and continuous emissions monitoring instruments with data from the plant historian. Once in the DCS, this information lets operators know how efficiently fuel is being used, what the boiler's fuel and effluent flows are, the chemical makeup and heating value of the coal being burned, and trends in the variables—all based on the second law of thermodynamics.

Air leaks suck

Having put the DCS and the ILM system in service, Boardman's engineers began using them to identify areas where Btus and percentage points in efficiency were being lost. It didn't take long to pinpoint the first problem spot. In the process of modeling the plant to prepare it for on-line monitoring, a preliminary boiler analysis by the ILM indicated over 20% of air in-leakage. Testing on May 5, 2000, indicated a boiler efficiency of 83.21%—much lower than expected. As part of the testing program,

1. Boardman Coal Plant. The 656-ft stack of the Boardman Coal Plant is one of Oregon's tallest man-made structures and stands out against the flat plains of the state's northeast corner. *Courtesy: Portland General Electric* detailed oxygen and CO_2 profiles at the boiler's exit were then obtained.

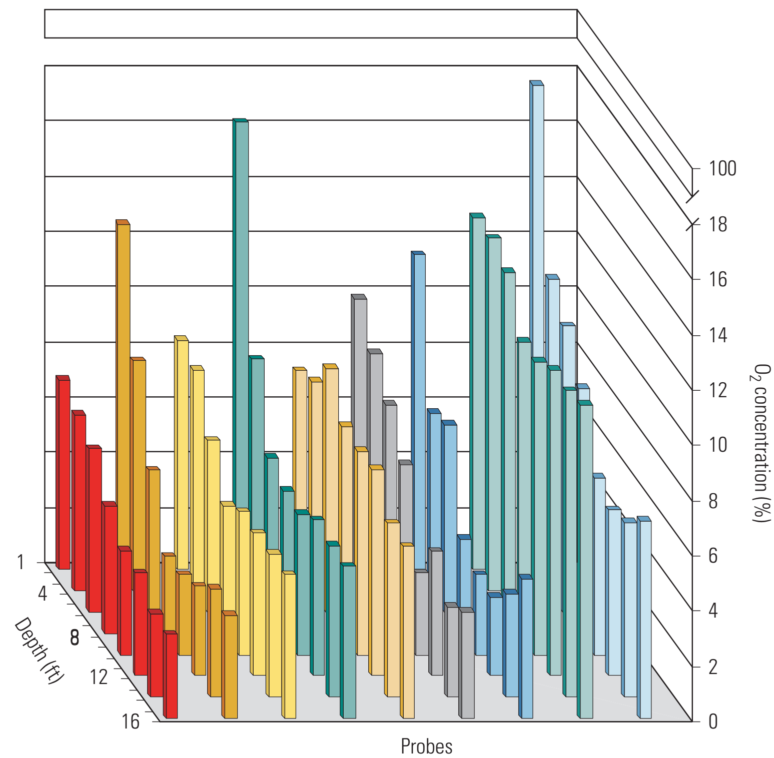
Although initial follow-up inspections revealed several places where air was leaking, the leaks were not large enough to account for the shortfall in boiler efficiency calculated by the ILM. Further inspections uncovered leaks in another two areas that had never been noted. One was air in-leakage through pulverizers that had been taken out of service. Leaks in the other area were attributed to the unreliable operation of burner sleeve dampers. The design of Boardman's boiler calls for using the outer air registers of burners to adjust and isolate them, but the latter appeared not to be happening. Additional analysis confirmed the diagnosis and indicated that the impact on plant performance was significant. That, of course, begged the question: If this much "extra" air was being added, why wasn't this phenomenon noted by O_2 probes in the boiler exit flue?

An independent lab was hired to create a top-to-bottom, side-to-side O_2 profile of the boiler exit flue. Results of these measurements are shown in Figure 2. Boardman's stack has two ducts, and testing consisted of measuring O_2 on two 40-point traverses of the entire exit flue. The results showed significant stratification and many higher-than-expected O_2 readings—although the 14 O_2 probes in the ducts continued to indicate that O_2 concentrations were averaging just 2.8%.

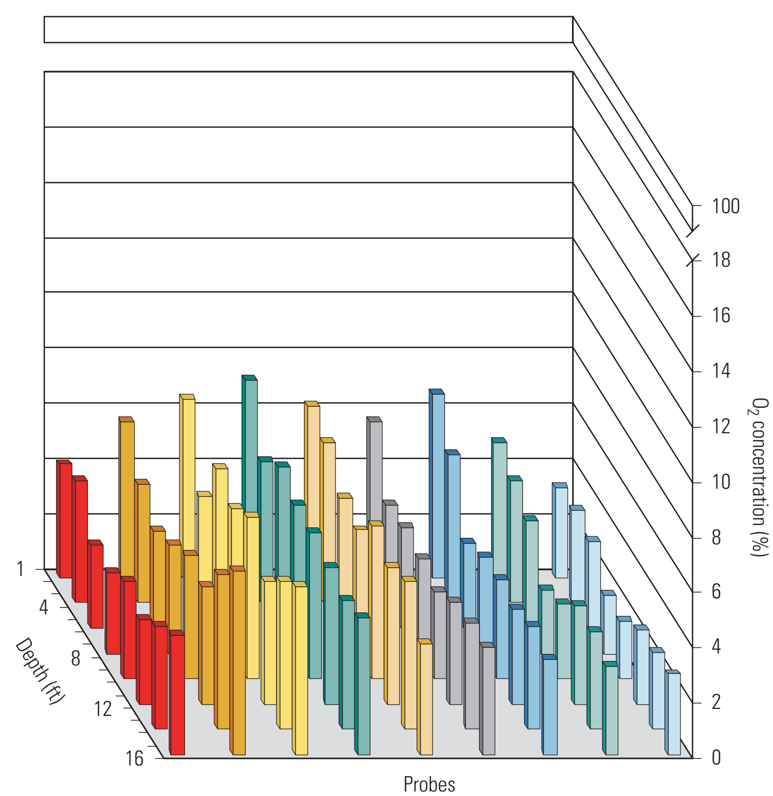
What could be responsible for the discrepancy? A poor design, as it turned out. Within the boiler's exit flue, seven of the O_2 probes were mounted at the 6-foot level; the other seven were at the 12-foot level, in a 22-foot-deep duct. The locations of the O_2 probes tended to bias average readings in favor of the front burners. Due to the stratification of the gas flow and the fact that there were no O_2 probes in the bottom of the duct, burners on the back wall of the boiler were not "seen," so the amount of excess air they were releasing was not being measured. Inadequately isolated out-of-service burners only exacerbated the problem.

With the information from the traverse of the exit flue and the performance-testing results, the plant elected to modify all 32 sleeve dampers (to enable them to be completely isolated) and move the 14 existing O_2 probes. Plant engineers determined that to adequately monitor exit flue O_2 it would be necessary to place the probes to monitor at the centroids of equal areas in the duct. Doing that would require installation of 12 additional O_2 probes. Not knowing what the results would be, the plant decided to move the existing O_2 probes to monitor at the centroids of equal areas in the upper half of the

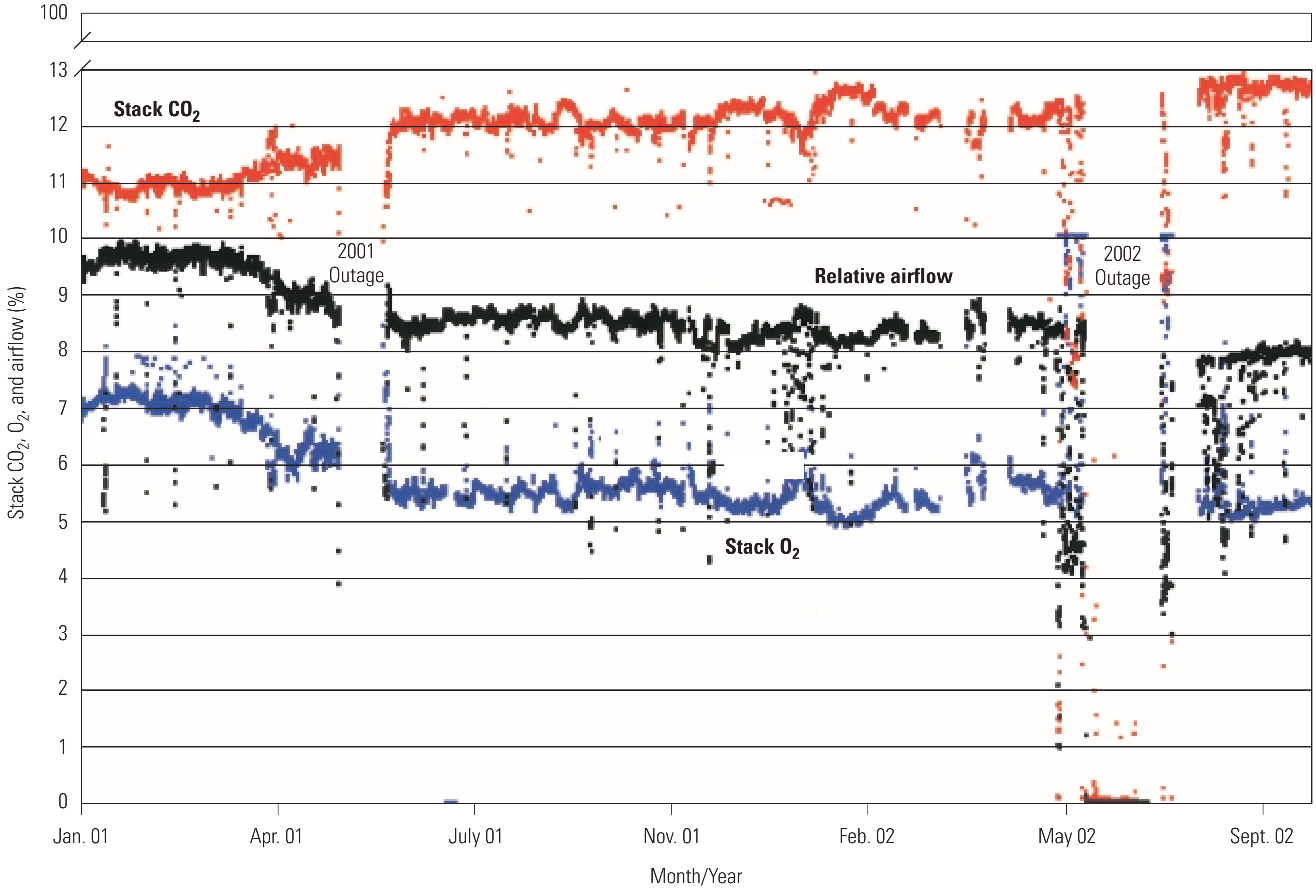
2. Before. The O_2 profile of the boiler exit flue prior to instrumentation and hardware modifications showed significant stratification and many higher-than-expected O_2 readings. *Source: Portland General Electric*



3. After. Post-modification measurements of exit flue O_2 show significantly lower levels. *Source: Portland General Electric*



4. Reduced in-leakage. Enhanced air-leakage management and hardware upgrades demonstrate considerable improvement in boiler performance over time. CO_2 readings taken across Boardman's air preheaters indicate that air in-leakage was reduced from 20% to 5%. *Source: Portland General Electric*



duct and make duct modifications to support future installations if deemed necessary. After additional testing, the following year, 12 new O_2 probes were added in the lower half of the boiler exhaust at the centroids of equal areas of the lower half of the flue.

5. Slag dent. Randy Curtis, one of Boardman's plant engineers, holds a dented tube from the lower slope of the boiler. The dent was caused by a large mass of falling slag. *Courtesy: Portland General Electric*

The results of this modification were dramatic. Boiler efficiency rose from just over 83% to between 85% and 85.6% with the same fuel. Another traverse of the flue was completed (after the modifications) while controlling to an O_2 setpoint of 2.5% (Figure 3, page 39). Of course, these readings did not reflect a simple setpoint change but improved air leakage and improved controls. As further confirmation, CO_2 readings taken across the air preheaters indicated a component leakage of approximately 5%, versus the original system leakage of 20%.

6. Dirty job. PRB coal has a greater tendency to slag than eastern coal, which increases the frequency and difficulty of boiler cleaning. Boardman Plant Manager Loren Mayer inspects the reheater section. *Courtesy: Portland General Electric*

Since the modifications, boiler efficiency has further improved by 0.5%, as shown in Figure 4. More than one year's worth of data shows the value of the instrumentation improvements made during the outages of 2001 and 2002. These are measured, "noncalculated" parameters that directly reflect plant performance.

Another important point worth mentioning is that following the two retrofits, stack CO levels could be maintained at less than 10 ppm. When CO readings greater than 10 ppm were encountered, burners were adjusted to reduce the reading. The fully instrumented boiler stack greatly aided these adjustments. Boardman plant operators can now pinpoint improperly adjusted burners by analyzing the stack O_2 profile. An expected side benefit is reduced boiler slagging, which is currently a big maintenance burden (Figures 5 and 6).

Not content with their recent successes, Boardman engineers are now in the process of installing a neural network to optimize boiler efficiency in real time. The system will use a performance monitor from Exergetic Systems. ■