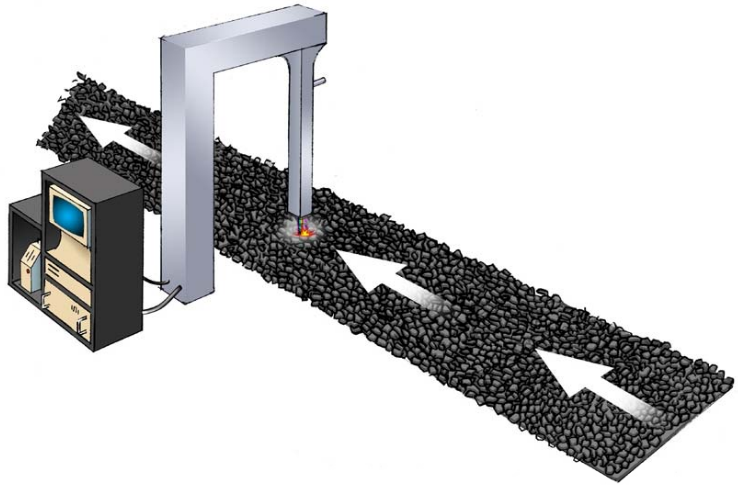
Real-Time Monitoring of Coal Properties and Ash Fusion Temperature



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THE CONCEPT

The Energy Research Company (ERCo) and the Lehigh University Energy Research Center (ERC) team have developed a system for on-line, in-situ, real-time measurement of coal properties. The system includes artificial intelligence (AI) models to accurately predict the slagging propensity of coal and coal blends as they are fed into power plant boilers, and advisory software for heavy-slagging prevention. This allows plant engineers and boiler operators to take a number of actions to mitigate or possibly eliminate slagging problems. This will improve boiler efficiency, increase unit power output, reduce greenhouse gas emissions, improve unit availability through decreased slagging-related boiler outages, and reduce consumer electric rates.

The concept starts with an in-situ, real-time laser measurement of the coal using Laser Induced Breakdown Spectroscopy (LIBS). The laser measurement concept is shown in the figure above. A laser beam is directed onto the raw coal moving on the belt prior to going to the pulverizers. The laser vaporizes and ionizes micrograms of the coal. The resulting emitted radiation is collected by a spectrometer which records the wavelength and the intensity of the radiation. The wavelengths uniquely identify each element and the intensities are proportional to their concentrations. Measuring at this point provides enough lead time for plant engineers to make feedstock adjustments, in terms of blending coals and directing a particular fuel to more slagging-tolerant unit(s) to prevent heavy-slagging situations.

LIBS measurements are made continuously and simultaneously. The raw spectra from the LIBS measurement are fed into a previously trained Artificial Neural Network (ANN) that accurately predicts ash fusion temperature.

Together with the LIBS-based fusion temperature prediction, pertinent boiler data (including furnace exit gas temperature (FEGT) indication) are used by an expert system-based software to provide advice to boiler operators on operational actions that can be taken to anticipate and mitigate heavy slagging. ERCo and the ERC have extensive experience in this type of measurement and data analysis.

OPERATOR ACTIONS

With this information, the power plant operators can take the following steps to prevent or mitigate heavy slagging:

- Optimize the sootblowing schedule – Blowing too infrequently allows slag deposits to take hold and runaway buildup follows. On the other hand, too much sootblowing will result in tube damage causing outages and lost revenue.
- Modify boiler control settings, such as excess O_2, burner tilt, biasing of coal flow to individual mills and burners, biasing rotating classifier speed, and load reduction.

LABORATORY RESULTS

In each laboratory test, a series of three samples was shot 100 times each using the experimental LIBS system. The LIBS data were then fed into a previously trained ANN to generate fusion temperatures. To achieve these results, the ANN model was previously calibrated with 16 different pulverized coal samples of bituminous and low-rank coals

The predicted fusion temperatures from the trained set cluster linearly along a diagonal line which represents a perfect match. The as-received coals, not part of the training set, fell close to the diagonal. More importantly, compared to the ASTM fusion temperature method, the three predicted temperatures were within ±151°F, which is the established tolerance for the ASTM methods. These results proved the feasibility of predicting fusion temperature on-line and in real-time with as-received coal.

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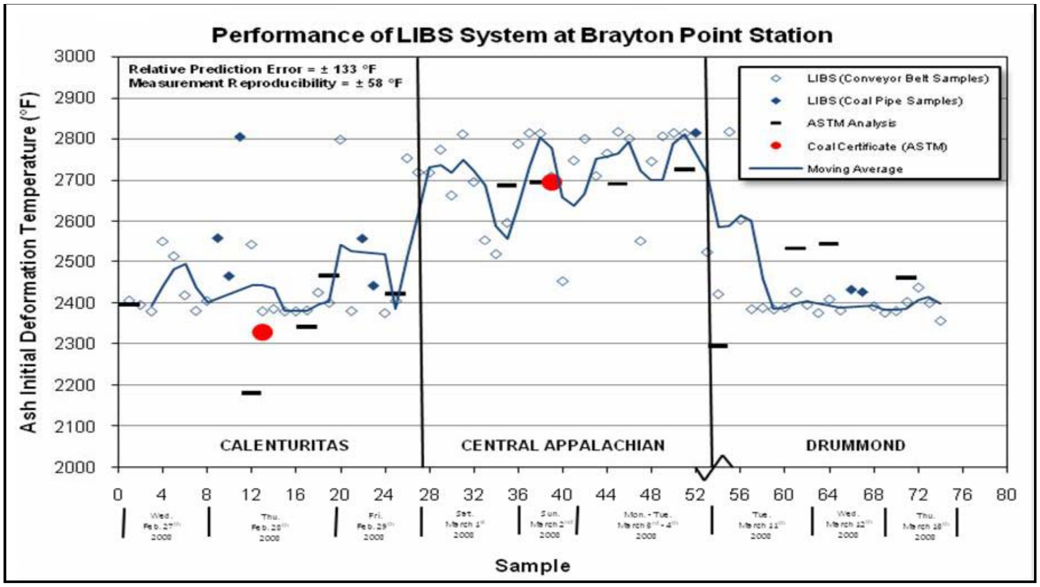
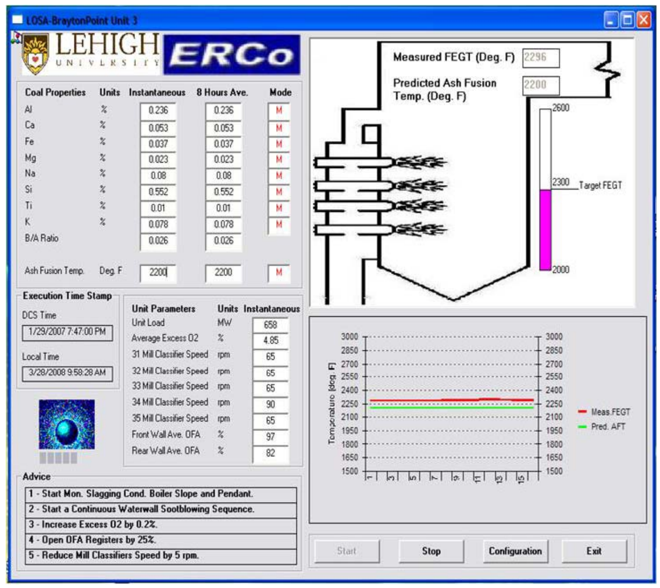


FIELD RESULTS

Off-line tests were conducted at Dominion Energy's New England Brayton Point Station and the results are shown in the figure above. The field results indicate an average LIBS-based prediction for Calenturitas coal fusion temperature of 2,434˚F ±133˚F versus 2,302˚F for the ASTM tests. The corresponding average LIBS-based prediction for Central Appalachia and Drummond coal was 2,722˚F ±133˚F and 2,432˚F ±133˚F, respectively. This was compared to the average value obtained from the ASTM tests for Central Appalachia and Drummond coal that was of 2,700˚F and 2,459˚F, respectively. The average relative fusion temperature prediction error for all three coals tested at Brayton Point was ± 133˚F. The average precision for the LIBS measurements for all three coals is ± 58˚F, which was well within the measurement tolerance for repeatability and reproducibility of the ASTM methods for ash fusion temperatures.

The figure to the right shows the on-line advisory software based on the LIBS technology. When the ash fusion temperature deviates from a target boiler FEGT level, the software provides expert textual advice to the boiler operators on recommended measurements to monitor or actions to take to compensate for potential ash deposition problems.



ECONOMIC BENEFITS

A review of North American Electric Reliability Council (NERC) data shows that the average 600 MW power plant has about 400 hours per year in forced outages. One generating company had a catastrophic slagging event that resulted in a one week forced outage during peak winter generation. The lost generation opportunity for the five day (120 hours) forced outage is estimated to have cost the generating company $3.6 million.

A second 650 MW generating unit experienced a major slagging accident that cost approximately $12 million to repair. The generating company also lost three months of electricity generation opportunity, which had a significant impact on the company's revenue.

Better furnace and convective-pass temperature control and lower steam consumption due to optimal boiler control settings and sootblowing strategy will also reduce unit heat rate. The electricity generating industry has seen heat rate improvement ranging from 50 to 100 Btu/kWhr. Assuming a fuel cost of $1.40 per MMBtu, this could save a generating company from $300,000 to over $600,000 per year per unit in fuel costs. This translates into an energy savings of about 357 MMBtu/year for each power plant.

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