LEHIGH ENERGY UPDATE

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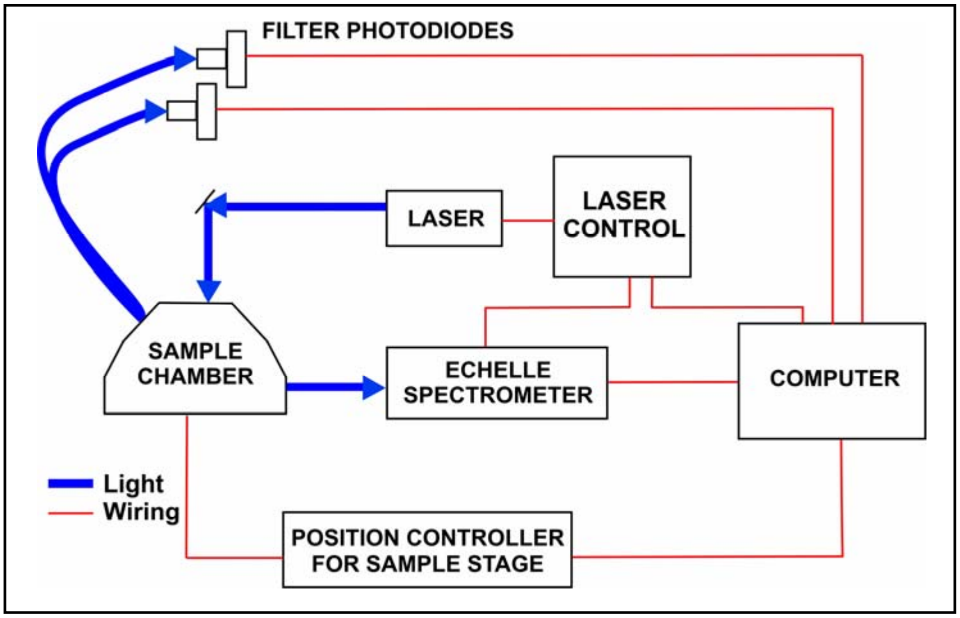

Schematic of LIBS System Used for Coal Mineral Composition Analysis

LASER MEASUREMENT OF COAL ASH COMPOSITION DEMONSTRATED AT POWER PLANT

The Brayton Point power plant in southeastern Massachusetts fires a range of coals, including bituminous coals from the eastern U.S. and South American coals from Colombia and Venezuela. Some of these coals have mineral compositions which are susceptible to high temperature slagging, and the resulting variability in coal feedstock causes difficulties for the station, sometimes forcing it to take remedial actions on a retroactive basis to mitigate the impacts of coal ash slagging. Carlos Romero of Lehigh's Energy Research Center is collaborating on a project to develop a laser-based measurement system, which promises to become a valuable tool for predicting the onset of slagging conditions in coal-fired boilers. The research project team includes Romero, Ricardo Moreno and Zheng Yao from the Energy Research Center and investigators from the Energy Research Company of Staten Island, New York, led by Robert DeSaro.

Romero explains, "We are using a measurement technology referred to as Laser Induced Breakdown Spectroscopy (LIBS) along with neural network techniques to determine the composition of the coal ash and relate the composition measurements to ash slagging potential. The LIBS System consists of a pulsating laser, sample chamber, optical spectrometer and photodiodes, amplifier unit and a processing computer. The laser vaporizes a small portion of the coal sample, and the resulting measured emission spectrum provides an indication of the wavelengths of the elements which

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PREDICTING THE REMAINING LIFE OF HIGH TEMPERATURE STEEL PIPING

As the fleet of U.S. coal-fired power plants continues to age, one of the many decisions power generation companies will need to make is when to replace high temperature and pressure steam piping connecting the boiler and turbine. Waiting too long before replacing a creep-damaged steam pipe can lead to catastrophic pipe rupture and replacing a pipe prematurely would be an unnecessary expense. A research team at the Energy Research Center led by Professor Terry Delph has developed an analysis method which provides more realistic estimates of remaining useful life than has been possible up to now.

Delph explains, "Steel components used for high temperature and pressure applications undergo a degradation process referred to as creep damage, which weakens the steel and will eventually lead to mechanical failure by pipe rupture. The years of life which remain in a steam pipe depends on the years of service, operating temperature and stress level, and original creep properties of the material. There are well-defined ASME procedures which can be used for making remaining life predictions, and these require availability of creep and creep rupture test data obtained from material similar to the material used to make the steam pipe. The difficulty with this approach is that there is always relatively large scatter in creep and creep rupture test data, possibly due to differences in properties of steel from one batch to another and to random errors in creep test data. Large uncertainties in the creep and creep-rupture data can result in unacceptably large uncertainties in predictions of remaining life."

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("LIBS" Continued from P. 1)

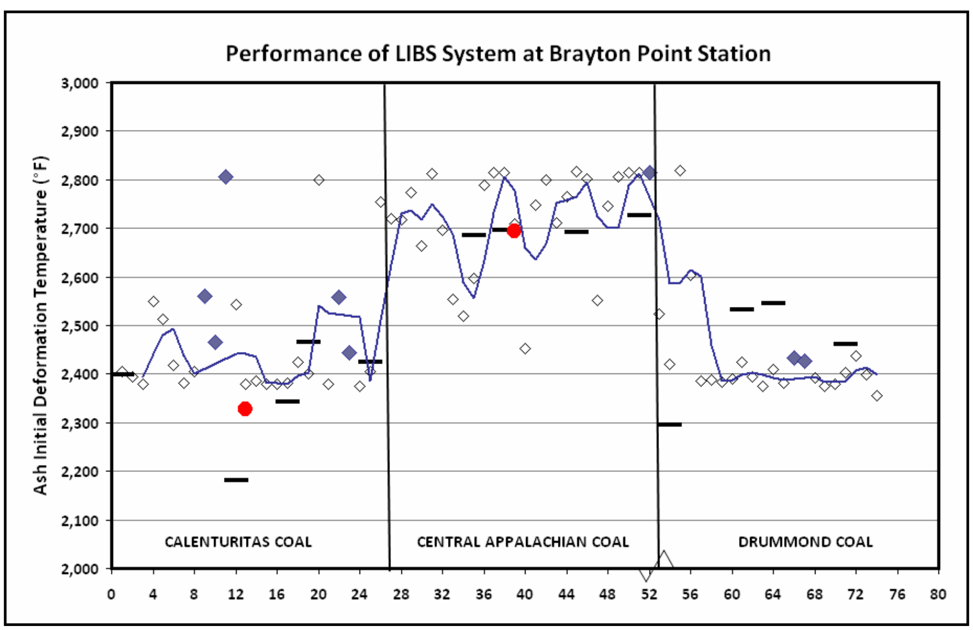
were present in the coal sample. The measured wavelengths are then used to identify the elements and their relative concentrations. The following elements can be measured with the type of spectrometer used in the system: Al, Ca, Mg, Na, Fe, Si, and Ti. The LIBS measurement system is extremely fast, with data from a coal sample collected in a matter of seconds. The project team performed laboratory tests on a set of 16 coals assembled from coal-fired power plants and having a range of slagging issues. These samples were also analyzed independently for ash minerals and ash fusion temperatures using standard ASTM methods. Calibration curves were developed to relate LIBS signal output to the amount of each element present as determined by the ASTM tests.

We then used neural network models to relate the mineral composition measured by LIBS to the initial ash deformation temperatures obtained from the ASTM tests. Initial ash deformation temperature is often used as an indicator of the onset of slagging, and we expect the LIBS system to provide us with a signal which, when compared to the gas temperatures at the furnace exit, will indicate whether the coal being burned will cause slagging problems on the waterwalls or on heat exchangers at the high temperature end of the boiler."

Tests were performed at Brayton Point Station in which coal samples were collected manually from the pulverizers and coal pipes and analyzed in the LIBS system. These tests were performed using three different coals from the U.S. and South America. The resulting neural network predictions of ash deformation temperatures were within close agreement with deformation temperatures measured by the ASTM tests. The graph shows a comparison of the LIBS acquired temperatures with those obtained from the ASTM analyses and with fusion temperatures provided by the coal delivery certificates. These results demonstrated that LIBS coal analyses performed on an hourly basis would be capable of providing feedback on ash deformation temperatures with sufficient resolution to alert the station personnel to changes in as-fired coal quality. By having a timely warning that the slagging potential of the coal ash has changed, the boiler operators would be in a position to take actions to adjust the furnace exit gas temperature or initiate a more aggressive waterwall or leading edge superheater sootblowing. Depending on the boiler, these adjustments might involve parameters such as fuel air ratio, burner tilt angle, air register setting, and mill loading patterns.

Romero continues, "We are now working on automating the LIBS measurement system by combining the instrument with an automatic coal sampling system. We also plan to develop intelligent computer software which would provide advice to the Station personnel on the actions they might take to adjust the boiler control settings to compensate for a measured change in coal ash fusion temperature. We are also interested in performing additional power plant field trials of LIBS with manual coal sampling to verify that it can measure initial ash deformation temperature for a much wider range of coal properties."

This project was supported by the U.S. Department of Energy's State Technologies Advancement Collaborative (STAC) program and managed by the New York State Energy Research and Development Authority (NYSERDA) and by a SBIR Phase I project. ■

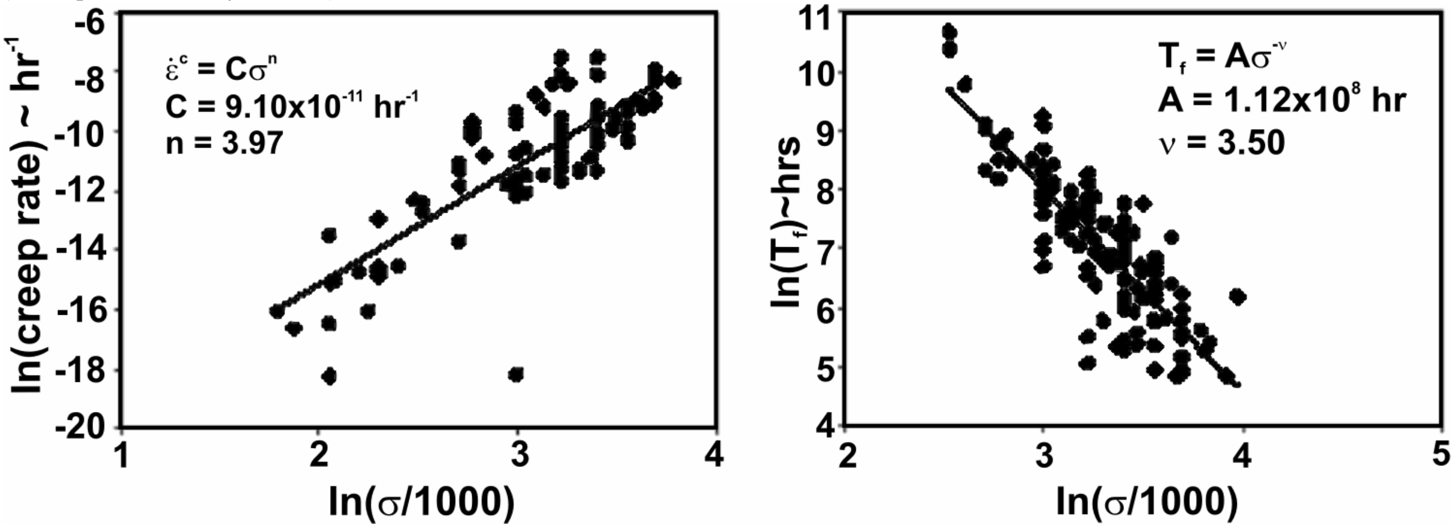


Predicted and Measured Initial Deformation Temperatures – Brayton Point Tests [◊ LIBS (Conveyor Belt Samples); ♦ LIBS (Coal Pipe Samples); ▬ ASTM Analysis; ● Coal Certificate (ASTM); —— Moving Average]

RESEARCHERS' PROFILES

- ***Carlos Romero*** is an Associate Director of the Energy Research Center with a Ph.D. in Mechanical Engineering. He is a specialist in combustion kinetics and emissions control.
- ***Zheng Yao*** is a Research Scientist at the Energy Research Center and he has a MS degree from Lehigh University in Mechanical Engineering.
- ***Ricardo Moreno*** is studying for an MS degree in Mechanical Engineering at Lehigh University.
- ***D. Gary Harlow*** is Professor of Mechanical Engineering and Mechanics (MEM) and Chair of the MEM Department. His research interests encompass stochastic modeling and fracture mechanics, addressing topics such as the modeling of failure processes in aluminum alloys, steels, and composites, and mechanical and system reliability.
- ***Terry Delph*** is Professor of Mechanical Engineering and Mechanics. He is a specialist in high temperature creep phenomena in structural steels.
- ***Murat Ozturk*** is a Research Engineer in Mechanical Engineering and Mechanics with a Ph.D. in Mechanical Engineering. His research interests are in computational mechanics involving elastic and plastic deformations and stresses.

(“Creep” Continued from P. 1)



These two figures show creep data and creep-rupture data for A-335 steel. Plotted on log-log scales, the data exhibit extremely large scatter, which results in unacceptably large uncertainty in calculations for remaining life of high temperature steam pipes.

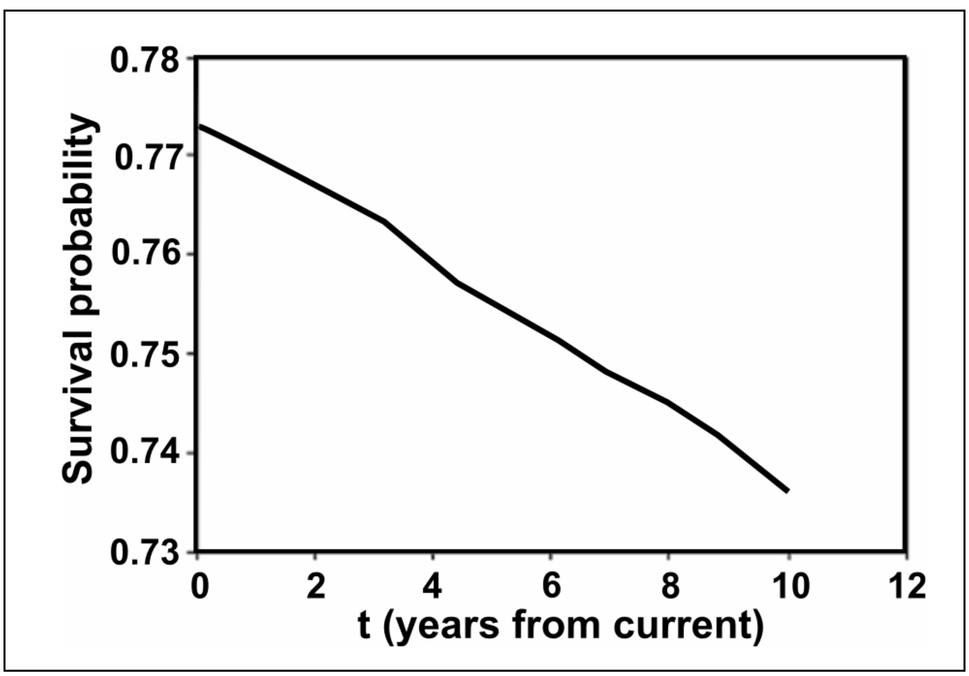
To solve the data uncertainty problem, the Lehigh team (Terry Delph, Gary Harlow and Murat Ozturk) turned to Monte Carlo simulations for obtaining predictions of remaining life. The Monte Carlo method is a numerical technique developed for making probabilistic predictions for a wide range of complex physical phenomena. In this case, the application of Monte Carlo to the steam piping problem gives the probability of failure of a steam pipe at the present time or at a certain number of years in the future.

Professor Harlow continues, “We used the Monte Carlo approach to predict the remaining life for three steam pipes in a coal-fired power plant which had close to over 40 years of operation. The predictions for the main steam line, which operates at a steam temperature and pressure of 1000°F and 2400 psia, indicate a failure probability ranging from 13% to 48%, depending on the stress model used to compute the stresses. The hot reheat line, which operates at 1000°F and 600 psia, had a probability of failure of approximately 10%, and a low temperature and pressure steam extraction line (735°F and 200 psia steam) had a negligibly small probability of failure. The results for these three conditions show expected trends with steam temperature and pressure.

The model we’ve developed can also be used to estimate how the probability of failure changes with time. In one calculation, we saw the probability of failure increase from a value today of 23% to 26% ten years into the future.”

Delph adds, “The decision as to what represents an unacceptably high failure probability is, of course, a management decision. However, we believe that the methodology we’ve developed provides a more rational basis for run/replace decisions than the commonly used deterministic lifetime assessment approach, which is unable to cope with the very large scatter in material creep and creep-failure data.”

The Lehigh team is now planning to expand the capabilities of the analysis. There will be some situations in which creep and fatigue damage will combine to increase the probability of failure, and modifications to the analysis methodology are needed to make it possible to determine the magnitude of combined creep and fatigue effects. In addition, girth welds are often made in many locations of the plant. Since the creep resistance of the weld heat affected zone is typically inferior to that of the base metal, this is an important topic that requires more attention. Research is needed to determine the range of data currently available for welds and then apply the Monte Carlo technique to the weld data. It is also likely that creep data for welds may also need to be developed, since data for welds are typically not readily available for many new and existing steels. ■



As the power plant continues to operate, the survival probability of the main steam line decreases.

LEHIGH ENERGY UPDATE is a publication of the Energy Research Center at Lehigh University. Subscriptions upon request. Address inquiries to Edward K. Levy, Director, Energy Research Center, Lehigh University, Bethlehem, PA 18015 or by visiting our homepage at www.lehigh.edu/energy. Ursla Levy, editor.

SHORT COURSE ANNOUNCEMENT

"FIRESIDE PERFORMANCE OPTIMIZATION AND EMISSIONS CONTROL WITH COAL-FIRED BOILERS"

December 3-4, 2008 at Lehigh University

COURSE DESCRIPTION

This intensive two-day course focuses on fireside performance monitoring and optimization with emphasis on the latest developments in techniques, software, equipment and instrumentation. This course addresses both theory and practice, stressing "how to" perform reliable field tests, accurately measure key parameters, and analyze data. The instructors will share their first-hand experience through their case studies which span decades of projects dedicated to performance optimization and emissions control with coal-fired boilers. Each participant will receive a comprehensive set of course notes.

COURSE INSTRUCTORS

The course instructors include Dr. Edward K. Levy who is Director of Lehigh University's Energy Research Center and Drs. Nenad Sarunac, Carlos Romero, and Harun Bilirgen who are Research Scientists in the Center. Between the four instructors, the course team has over 75 years of research and field experience with the thermal aspects of power generation and energy conversion, with an emphasis on emissions control and performance optimization of coal-fired power plants.

WHO SHOULD ATTEND

This course is designed for generating company engineers and engineering managers who need to make decisions about:

- Heat Rate Improvement Options
- Emissions Control
- Equipment Maintenance
- Equipment Design Upgrades

COST

- $1,025
- $895 for employees of Energy Liaison Program Member Companies

FOR MORE INFORMATION OR TO PRE-REGISTER, CONTACT:

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COURSE PROGRAM

Introduction
- Heat Rate Definitions
- Design and Physical Phenomena Affecting Performance and Emissions

Factors Affecting Unit Performance
- Boiler and Auxiliaries
- Turbine Cycle
- Utility Experience

Heat Rate Measurement Methods
- Description of Methods
- Measurement Accuracy

Pulverizers, Coal Pipes and Burners
- Pulverizer Performance
- Coal Pipe Imbalances
- Combustion Problems

Slagging and Fouling
- Effects of Fuel Properties on Slagging and Fouling
- Effects of Boiler Control Settings
- Sootblowing Optimization

Air Preheaters and Cold End Optimization
- Principles of Operation
- Cold End Fouling

Electrostatic Precipitators: Fireside Effects
- Principles of Operation
- Opacity Control

NO_x Formation and Control
- Formation Mechanisms
- Control Techniques

SO_2, SO_3, CO_2 and Mercury
- Control Techniques

Combustion Optimization
- Case Studies

CEU'S

- 1.5 CEU's will be awarded for course attendance.

Course Brochures will be mailed in early September and will also be available at www.lehigh.edu/energy

Please notify Jodie Johnson at **jlk4@lehigh.edu**
with any name and address changes.

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