ON-LINE FLAME MEASUREMENTS FOR IMPROVED COMBUSTION

Burner imbalances in coal, oil, and gas-fired combustors can result in low combustion efficiency, elevated emissions of nitrogen oxides (NOx) and carbon monoxide (CO), localized reducing conditions and promotion of slagging. Differences from one burner to the next in combustion conditions are due to factors such as imbalances in fuel to air ratio, differences in burner settings, and maintenance problems at individual burners. Being able to sense combustion conditions at the burner level would be very helpful in eliminating imbalances; however, the instrument options available for making direct measurements of flame characteristics at the burner level are extremely limited.

Research being carried out by Dr. Carlos Romero of the Energy Research Center on a new generation of on-line flame sensors will one day make it possible to achieve much better burner balance than is presently possible. According to Romero, “Conventional combustion control systems for multi-burner boilers rely on monitoring parameters such as average excess oxygen (O2), CO level in the flue gas, and flow rates of fuel and air. These measurements are not adequate for providing tight control of the combustion stoichiometry at the burner level. Oxygen analyzers, usually located at the economizer gas outlet, are subject to calibration and drift problems and have difficulty handling O2 stratifications across the sampling duct and air-in-leakage. In coal-fired boilers, measurements of fuel and air are performed globally, on a per-pulverizer basis and for the total secondary air stream to all burners in a common windbox. Experience has proven that a single burner with poor combustion can result in elevated emissions for a multi-burner boiler. It is recognized that improved air fuel balancing between individual burners will result in lower emissions levels and better combustion efficiency.”

Romero’s research, which is funded by DOE and is being carried out in collaboration with investigators at the University of Missouri, deals with the use of a non-intrusive spectrometer-based system to make real-time measurements of flame temperature and chemical composition. The radiation spectrum from a flame extends over a wide range of wavelengths, with local peaks in radiation intensity signifying the presence of specific chemical species and reactions within the flame. In addition, the underlying blackbody variation of radiation intensity with wavelength can be used to determine flame temperature. The objective of the research so far has been to demonstrate the ability to make local measurements of flame temperature and composition, and then to show that these measurements are directly related to combustion parameters such as air/fuel ratio and NOx emissions.
The first phase of this research has focused on flame measurements in natural gas-fired industrial furnaces of the type used to make glass and aluminum products. The measurement system consists of commercially-available off-the-shelf spectrometers, a special collimating lens, fiber optic cable, electronics, and data collection software. After initial development and testing in the laboratory, separate sets of experiments were conducted at three industrial furnaces, firing natural gas/air and oxygen enriched fuel. Measurements were also made on a 2 MBtu/hr single-burner research boiler. Different installations have been tried: the optical arrangement has been mounted perpendicular to the flame, at an angle, and focused on a burner directly opposite the observation window. Simultaneously, independent measurements were made of fuel and oxygen (or air) feed rates, NOx and CO emissions at the stack or in the vicinity of the pertinent burner, and flame temperature.

The results show that the hydroxyl flame radical (OH) emission band in the flame is a strong function of oxygen (or air) to fuel ratio and that use of this parameter can be utilized to determine NOx emissions from a particular burner. The ability of the spectrometer to accurately correlate flame temperature with respect to burner operating conditions was also confirmed by the field data. Because high flame temperature is a cause of thermal NOx and also affects slagging in coal-fired boilers, the ability to sense flame temperature on-line would be of practical importance.

As part of the testing, Romero collected data to determine the dynamic response of the OH spectral signal to abrupt changes to oxygen (or air) to fuel ratio. The measurements showed excellent dynamic response and very good repeatability.

Romero adds, “Our experiments show the potential for using spectroscopy to obtain real-time data on local flame conditions, and then using these data for burner tuning and boiler combustion optimization. There are potential applications of this technology to gas-fired combustors, both for industrial furnaces and utility boilers. However, based on our experience with pulverized coal boilers, we also feel that this same approach will work in a coal-fired environment.

Coal-fired utility boilers pose a challenge for on-line flame monitoring systems due to the complicated near-burner flow field, optical interference and flame dynamic conditions. But we believe those problems can be solved.”