Automated Loss-on-Ignition (LOI) Sensor for Improved Coal Power Plant Efficiency

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Overview

Draper Laboratory is developing an automated system that will take inline loss-on-ignition (LOI) measurements to improve the efficiency of coal power plants. The system automatically acquires fly ash samples via a sample probe inserted into the flue gas stream near the economizer and delivers them to an integrated Thermo-Gravimetric-Analyzer (TGA) to perform near real-time analysis that is fully compliant with the ASTM C311 standard. The first prototype was installed at a 750 MW plant in February 2009 and was able to successfully acquire ash samples and deliver the results via a wireless connection to the control room. Future versions will incorporate other integrated sensors (e.g. O_2 , CO, etc…) to fully evaluate the combustion process and enable optimized real-time feedback control of the power plant.

Background

Approximately 500 coal based power plants generate 50% of the electricity consumed in the United States each year. Although renewable generation is the ultimate goal, it will take decades before enough capacity is added to have a significant impact. In comparison, improving the efficiency of US coal plants by 10% (e.g. 30% → 33%) provide efficiency gains equivalent to more than doubling all of the renewable resources that have been deployed over the past four decades.

Draper and its partners have been developing systems that will address this fundamental need in the power generation sector. Loss on Ignition (LOI) is a key indicator of combustion and process efficiency. It is currently monitored by sending manually acquired ash samples back to an offsite lab where days may pass before the results can be used to optimize the combustion process. However, an equivalent sensor that provides real-time feedback control will guarantee that the plant is always operating at its optimum level as it responds to demand fluctuations, coal and weather variations, and equipment malfunctions by allowing parameters such as air/fuel ratio to be balanced under all conditions. In addition to pure efficiency gains, it also ensures that a plant's emission control equipment is operating at its ideal point and the ash output has the appropriate carbon content so it may be sold as a concrete product rather than dumped as landfill waste.

Prototype System

The system operates by automatically acquiring ash samples from the flue gas stream by a probe inserted into a standard Oxygen sensor access port near the economizer where temperatures have dropped to ~700^{o}F. A pneumatically actuated vacuum generator induces flow through a cyclone which separates ash particles from the mean flow. The main flow is exhausted back into the duct while ash particles are dispensed to the TGA for LOI sample analysis. Additional sensors (e.g. O_2) can be included in the exhaust line near port P-1 where the majority of the abrasive ash has already been removed.

During the dispense cycle, the ash passes through a two level valve system which provides pressure isolation between the flue gas stream and the ambient environment where the TGA operates. Samples are gravity fed, though a pneumatically actuated vibrator assists sample handling. Access ports are available to clear any clogs with high pressure flow, though this was never necessary during initial testing at the pilot plant.

The samples were delivered to cups which were used by the TGA for analysis. After processing, they were automatically cleaned to enable immediate re-use. The LOI calculation was completed by measuring the percent mass change of the sample during a controlled burn in the TGA's oven using a standard thermal profile. Data results were interpreted and returned as a digitized value to any internet capable computer or handheld via an EVDO based web interface.

Advantages

A fully integrated sensor suite offering near real-time data provides the following benefits:

- Improved efficiency
  - Energy out / coal in
  - Decreased slagging
    - Improved heat transfer
- Reduced emissions and waste
  - Mercury reduction
  - NO_x reduction
  - CO_2 reduction
  - Standards compliant ash disposal (for concrete use)
- Increased reliability
  - Decreased corrosion
  - Extended lifetime of support hardware

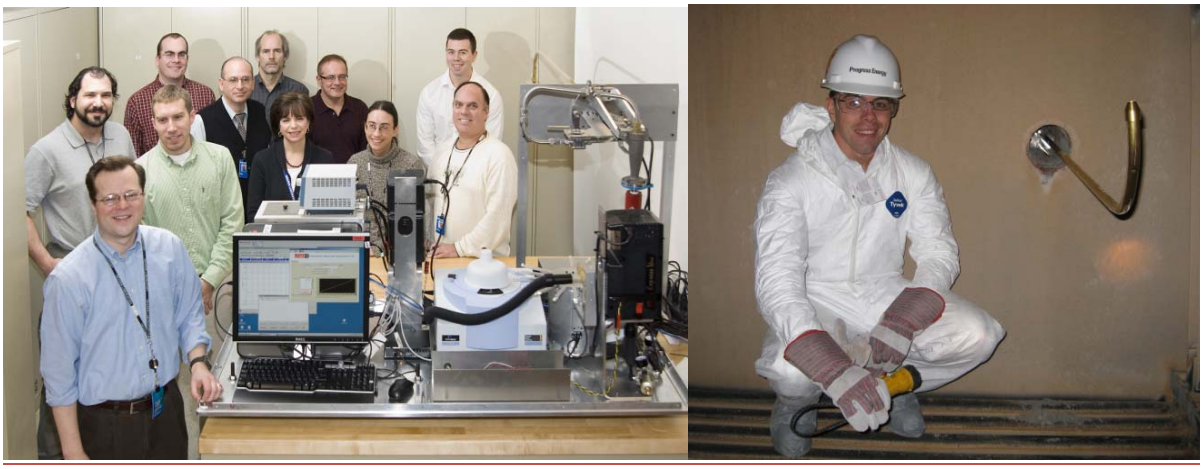

FIGURE 1 – A) TEAM AROUND THE ALPHA PROTOTYPE IN THE LAB AND B) INSIDE VIEW OF THE SAMPLE PROBE AFTER INSTALLATION