Reducing Unburned Carbon using Coal Flow Distribution Analysis

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Summary

Careful control of coal distribution and air flow can reduce unburned carbon and minimize excess air requirements, resulting in improved overall boiler efficiency and less adverse impacts on downstream emissions control equipment. Thus maintaining fuel and air flow at optimal levels becomes a major concern if one wishes to achieve minimum unburned carbon and low NO_x emissions while maintaining optimum boiler performance throughout the unit's load range.

Pulverized coal is transported by primary air in a two phase flow regime making it difficult, if not impossible, in the past to measure coal mass flow on a continuous basis. Typically, coal flow and fineness have been measured only at steady-state conditions and only intermittently using extractive sampling techniques. This papers serves to introduce a real-time "flow measuring system" for pulverized coal based on the use of microwave technology.

Measuring Innovations Consulting (***MIC***) was established in April of 2001 for the purpose of developing and providing power plant operators with instrumentation and hardware to help optimize the coal combustion process. The first device developed by ***MIC*** is a real-time coal-flow measurement system. The system uses high frequency microwave energy transmitted perpendicular to the flow of pulverized coal in the coal pipe between the pulverizer and the burner. Microwave energy is reflected by the moving pulverized coal particles and based on the amount of reflected energy the system determines the relative coal flow in each of the pipes of that pulverizer. *MIC* has developed both a portable system that can be used to diagnose combustion problems and a permanently installed system for continuous combustion process optimization. Future developments will look at real-time particle size distribution measurement and air flow measurement techniques along with development of devices for balancing coal flow.

The measurement technique is based on the latest high frequency microwave technology available. The system uses either two (2) or three (3) sensors per coal pipe. The sensor tip is mounted flush with the inside of the coal pipe therefore; there is no intrusion of any part of the sensor into the coal flow. The sensor does not require any kind of wear protection and does not interfere with or disturb the coal flow. As holders for the sensors *MIC* uses either a dedicated sensor fitting or a dustless fitting which attaches to a standard coal sampling port. The microwave guide tube is used to plug the opening. This allows for maintenance and replacement of the sensor electronics, should this become necessary, while preventing any coal from escaping through the fitting. The customer is asked to take responsibility for drilling and tapping the ½" NPT threaded holes for the dedicated fittings.

When using electromagnetic waves to measure mass flow it is normally required to obtain both particle concentration (density) and particle speed (velocity). Concentration is obtained using attenuation or the phase shift of the wave. Velocity is measured using either the Doppler Effect or the electrostatic charge transfer technique. Combining or multiplying density by velocity by the area gives the desired mass flow measurement. Thus the measurement has to rely on measuring multiple variables, which can change rapidly and affect the accuracy and repeatability of the measurement technique. For example, all temperature variations need to be measured and compensated for since these will affect both density and velocity.

Velocity can be very difficult to measure because each coal particle has a different size and shape and will slip in the primary air at different relative velocities. The more variables one has to measure, the greater the potential for inaccuracies.
Taking these points into consideration *MIC* concluded that there was a simpler and more accurate way to determine coal-flow. Simply stated the system counts the number of particles (concentration) passing through the microwave beam and based on analysis of the number and the intensity of the signal returns (larger particles return more energy than smaller particles) the system determines the relative flow in each of the coal pipes. If one also knows the total mass of coal entering a pulverizer (typical measured at the coal feeder), one can determine the mass flow in any given coal pipe of that pulverizer. Even with large variations in the coal characteristics, day to day or hour to hour the system can accurately determine the coal distribution in each pipe. The system does not use temperature as part of the mass flow calculation and therefore does not require any temperature measurement or correction.

Moisture in the coal is transparent to microwave energy and thus flow measurement it is not affected by changes in moisture. A reading is taken every second and from that reading one generates a new value every 10 seconds, thus the cycle time between measurements is 10 seconds. Due to the measuring technique which recognizes only moving particles, it is of no concern in which orientation the sensors will be installed. *MIC* has installed our sensors in both vertical as well as in horizontal runs of coal pipes.

To date *MIC* has permanent systems in operation at a German power plant and has conducted tests on numerous plants in Germany and the United States. The results obtained using the *MIC* mobile system have correlated well with results obtained using extractive techniques and can identify the source of high unburned carbon or other combustion related problems.

Today various extractive sampling methods are used for pulverized coal-flow measurement. Systems like the “Rotorprobe”, SMG10, ASME-probe, AKOMA and others are commonly used. All these systems have in common that they only provide “snapshot” type of information about coal-flow. They require much manpower to use, especially if one wishes to measure several pipes at the same time. Extractive coal-flow measurement remains a difficult and dirty job. The extractive methods also require steady state conditions during the sampling phase, meaning that the pulverizer being measured is placed in manual control precluding gaining knowledge of what is happening to coal flow during load changes.

Considering this it is our conclusion that the need exists for a device that can determine pipe-to-pipe coal flow distribution. The system should be easy to operate, provide accurate and repeatable information without being effected by changing coal and plant operating conditions. There are many benefits associated with balanced coal/air flow in pulverized coal burners. These include lower unburned carbon and NO_x emissions, improved safety and more efficient operation. The value of these benefits are much greater than the cost of the measurement device describe in this paper. This technology will continue to evolve and over time the technology will become capable of measuring other parameters, such as velocity and coal fineness.