

LEHIGH ENERGY UPDATE



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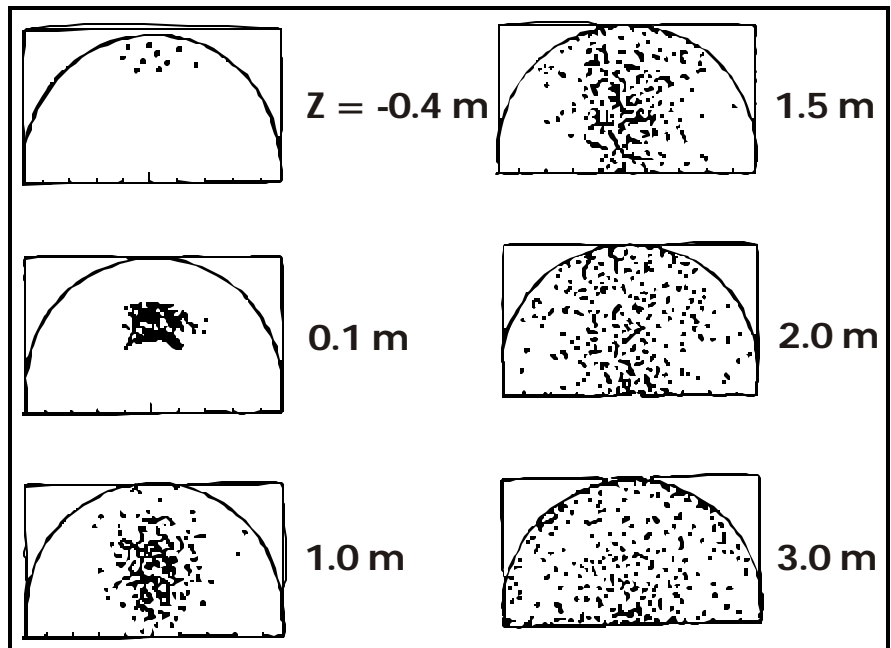
LABORATORY EXPERIMENTS AND COMPUTERS PROVIDING ANSWERS TO COAL FLOW MEASUREMENT QUESTIONS

Being able to perform accurate measurements of the flow rates of pulverized coal and air in the pipes which carry coal from the pulverizers to the burners has been a long-standing problem for utilities with pulverized coal boilers. Without the means of obtaining accurate measurements, it is difficult to achieve a closely balanced flow distribution. Poorly balanced coal pipes can lead to maintenance problems, increased levels of unburned carbon and higher rates of NO_x emissions. Investigators at the Energy Research Center are using a newly built test facility, special fiber optic probes and advanced computer software in a search for answers to the coal pipe measurement problem.

Consequences of Flow Maldistributions

The need for accurate coal pipe measurements and the reasons for the difficulties in obtaining them are related to the complicated flow geometries used in power plants. A large tangential pulverized coal-fired utility boiler is usually equipped with five or more pulverizers, each of which provides coal to anywhere from four to eight burners. In one commonly used design, the coal flows from each pulverizer through a single pipe. This flow is split into two or more branches, which, in turn, are split into additional flows.

When a mixture of air and fine coal particles flows through a piping system, regions of highly concentrated coal flow, referred to



Computer predictions showing rate of dispersion of a coal rope due to an orifice plate located at $Z=0.0$. The dots indicate location in cross section of pipe with heavy concentration of coal. For this case, the flow was fully mixed within 2 to 3 m from orifice.

as ropes, are formed. Poor distribution of coal over the cross section of a pipe entering a splitter can result in an unbalanced situation, leading to differences in coal flow rate from one pipe to the next. Maldistribution of coal between coal pipes caused by roping leads to uncontrolled differences in the fuel to air ratio between burners. This results in localized regions in the furnace which are fuel-rich, where not enough air is present to permit complete coal combustion. Other zones in the furnace are fuel-lean, forming high local concentrations of

NO_x due to high local concentrations of O_2 .

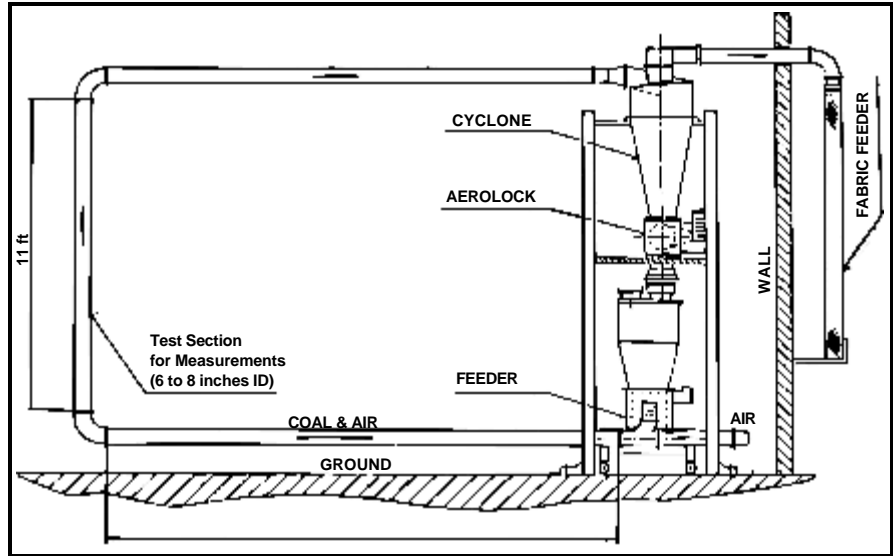
Elevated levels of unburned carbon due to coal maldistribution result in a loss in boiler efficiency and, because of the potential for fires, they can result in unsafe boiler operating conditions. High fly ash carbon content results in reduced fly ash resistivity; and in units with electrostatic precipitators, this can result in increased particulate emissions. Increases in unburned carbon levels can also limit the ability to utilize fly ash because of the adverse impact of unburned carbon on fly ash properties.

As already noted, flow maldistribution problems caused by roping and coal settling also lead to measurement difficulties. Because of the highly nonuniform nature of the coal flow over the pipe cross section, collected coal samples typically do not contain a representative particle size distribution nor do they provide sufficiently accurate information on the total solids flow rate through the pipe. This limits the ability to balance burners and fine-tune boiler operations to achieve low levels of NO_x and efficient combustion.

In addition to their impact on performance and emissions, coal flow maldistributions can also lead to boiler maintenance problems. Coal pipe ropes have been linked to settling of pulverized coal particles in horizontal sections of coal pipes and coal pipe plugging. If allowed to go unattended, a plugged coal pipe can lead to fires in both the coal pipe and windbox, resulting in expensive repairs and a lengthy outage.

New Laboratory Flow Loop Facility

The approach the Lehigh investigators are taking to solve these problems involves a combination of laboratory experiments, field testing and computer simulations. The laboratory facility consists of a nearly full size coal pipe operating at flow velocities and air-to-fuel ratios which are typical of those in power plants. The flow loop consists of two 20 foot long horizontal pipes and a 11 foot long vertical pipe connected by 90° pipe bends. The pipes have a 6 inch inside diameter. After the flow exits the upper horizontal conveying line, a cyclone separates the particles from the air. The separated coal is returned to the feeder hopper so continuous circulation of the coal is possible. The air and coal feed rates are separately controlled and



Sketch of laboratory flow loop used to study coal flow phenomena in coal pipes.

independently measured. This makes it possible to obtain accurate measurements of air and coal flow rates for comparison to measurements of the air-coal mixture obtained in the vertical pipe section.

A specially designed fiber optic probe was developed to make it possible to obtain detailed information in the structure of the ropes which are formed at the elbows. This miniature probe contains four glass fibers, two of which are used to transmit light into the region of the particle gas flow. Light reflected from particles near the probe tip is transmitted back along the other two fibers to the signal processor. The probe is capable of measuring both velocity of the particles passing by the probe tip and the local particle concentration. Since the probe measures particle velocity and concentration at a point in the flow, it must be traversed over the cross section of the pipe to obtain complete data on flow nonuniformities.

Computer Predictions of Rope Dispersion

In addition to the laboratory measurements, the Lehigh investigators have been performing

computer simulations of the mixing processes which occur in turbulent multiphase flows. These calculations are made possible through the use of a computational fluid dynamics (CFD) software package with the capabilities of modeling the two-phase flow phenomena which occur in pneumatic conveying.

In one study, a computer simulation of the flow of a coal rope through an orifice plate in the pipe was developed to determine the effects of the orifice plate and flow conditions on the dispersion of the rope. Orifice plates are routinely used in pulverized coal piping systems as a means of balancing the air flow from one pipe to the next. The orifice plate causes a pressure drop in the pipe and, if used properly, can lead to relatively well-balanced primary air velocities from one pipe to the next. In addition to causing a pressure drop, an orifice plate also causes mixing of the flow and can lead to the breakup of a rope in the region downstream of the orifice. The effects of the dimensions of the orifice plate and the primary air velocity on the particle mixing patterns were investigated. The required distance for well-dispersed

flow was found to be a strong function of the orifice plate dimensions and, to a lesser extent, on the conveying air velocity. These results show that a device such as an orifice plate can be effective in decreasing the degree of stratification caused by a rope. In addition, the results indicated how far downstream of the orifice plate one must go to reach a region which is free of coal roping effects.

Armed with these results from the computer simulations, the investigators next performed tests in the laboratory both with and without orifice plates to determine the effect of the orifice plate on the degree of stratification caused by the rope. The results were in good agreement with the predicted values.

Now that they know that the use of a device such as an orifice plate can eliminate roping, the Lehigh team is looking at other techniques for roping control, techniques that cause less pressure drop and which would be less susceptible to erosion wear.

Rotor Probe and SMG-10

Because the coal pipe facility is nearly full size and because it permits independent control and measurement of the air and coal flow rates, it can be used to determine the measurement characteristics and accuracy of various instruments. Work has started on the installation of an 8 inch vertical pipe in the flow loop, which will be equipped with measurement ports for two of the instruments presently in commercial use for coal flow rate. One of these, the Rotor Probe, was developed in Denmark specifically for obtaining coal flow samples over the cross section of the coal pipe. The SMG-10, a German import, measures both coal and air flow rates and uses a computer to control the operation of the probe and analyze the results. More information is needed on these instruments to

assist utilities in making a decision on which instrument to use to measure pulverized coal flow rate in coal pipes. The instruments have radically different purchase prices. Other important issues involve measurement accuracy, ease of use and maintenance and manpower requirements. Because of fluctuations in coal pipes and the presence of ropes, guidelines need to be developed on the choice of measurement location, the duration of the readings and the number of readings needed to obtain a desired measurement accuracy. Results are also needed to indicate with what accuracy it is possible to measure coal flow rate and air flow rate in coal pipes. The best achievable accuracy becomes a limiting factor governing the degree to which coal pipes can be balanced. The Lehigh group believes the results that will be obtained in its facility on the accuracies and other measurement characteristics of these instruments will provide answers to many of the questions utilities have about coal flow measurement techniques.

A Collaborative Effort

The Center's work on coal pipe measurement accuracy is being carried out cooperatively with industry. The Pennsylvania Electric Company is providing partial funding for the studies described in this article. An earlier project, supported by a consortium of utilities, enabled the Center to build the test loop and develop a database on a variety of coal pipe issues such as the effectiveness of different burner balancing methods, industry experiences with instrument accuracy and the benefits of operating a boiler with well balanced burners.

The work described in this article is being carried out by a team which includes Ali Yilmaz and Harun Bilirgen, Ph.D. students from Mechanical Engineering, and Nenad Sarunac and Mark D'Agostini,

Research Engineers with the ERC. Some of the earlier studies performed by the Center on field measurement accuracies of the Rotor Probe and SMG-10 were led by Timothy Schmitt, a former Research Engineer. •