Faced with changes in the economic and regulatory climate, electric utilities are beginning to place greater emphasis on improving unit heat rate. In addition, as many utilities are upgrading their plant information systems, they are becoming increasingly interested in on-line monitoring of key operating and performance parameters. Availability of continuous emissions monitoring systems (CEM) at many coal-fired plants provides utilities with the opportunity to utilize data from the CEM as an input parameter to the calculation of unit heat rate.

Two techniques have the capability of converting CEM measurements into heat rate, although they differ in their data requirements, costs to implement, and the measurement accuracy they are capable of achieving. One of these, the Output/Loss method, was developed by the Energy Research Center for EPRI and has been thoroughly field tested by the Center. The second approach relies on use of the EPA F-Factor with CEM data. Compared to the Output/Loss method, the F-Factor approach is relatively inexpensive to implement, but it is less accurate. The F-Factor approach, however, might be suitable for power plant applications where measurement of heat rate with an uncertainty of a few percent is acceptable.

The Energy Research Center’s involvement in the development and evaluation of unit heat rate measurement techniques goes back to the early 1980’s. At that time a team of investigators from the Center was involved in an EPRI funded project which dealt with heat rate improvements and monitoring of coal-fired power plants. One of the tasks the Lehigh team undertook was an assessment of the accuracies and instrumentation requirements of existing techniques for measuring unit heat rate of pulverized coal units. As part of that effort, a new method, which became known as the Output/Loss method, was developed. Output/Loss utilizes information on turbine cycle performance, flue gas flow rate, and unburned carbon along with more commonly available data such as economizer \( \text{O}_2 \) level, gas and air temperatures, and gross and auxiliary power. The principal sources of uncertainty in the Output/Loss method are uncertainties in turbine cycle performance and flue gas flow rate, although the technique is affected by a much lesser extent by errors in flue gas flow rate. A ten percent uncertainty in flue gas flow rate leads to slightly less than a one percent uncertainty in unit heat rate, while a one percent
uncertainty in turbine cycle heat rate leads to a one percent uncertainty in unit heat rate. This approach can be used to measure heat rates with uncertainties significantly less than one percent, provided accurate information is available on the turbine cycle and the uncertainty in flue gas flow rate measurement is less than five percent.

The Output/Loss method is suitable for continuous on-line heat rate measurements. The method has been implemented at several units at the Potomac Electric Power Company (PEPCO), where it is routinely used for on-line performance monitoring. At PEPCO the sensor signals are fed to EPRI’s Plant Monitoring Workstation, where the necessary calculations are performed.

The Energy Research Center’s work in the heat rate measurement area is led by Nenad Sarunac, a research engineer with the Center. According to Sarunac, “Over the years we’ve performed extensive testing of the Output/Loss method to determine its measurement characteristics and to determine what it is that affects its accuracy. We’ve found with accurate input, this approach does have the ability to give information on heat rate which is extremely accurate. At PEPCO’s Morgantown Unit 2, we saw bias errors in unit heat rate which were in the range of 0.6 percent and random errors in the 20 to 30 Btu/kWh range at full load conditions. With measurement uncertainties which are this small, it is possible to use this method to determine the effects of changes in unit operating conditions on heat rate. In one test in which the wall sootblowers were activated, we actually were able to determine the effect of sootblowing on heat rate. In other tests, we were able to measure heat rate impacts of changes in stack gas temperature and economizer O₂ level.”

Unit heat rate can also be obtained from CEM data using an approach referred to as the F-Factor method. The F-Factor is a parameter used by EPA to relate the volumetric flow rate of flue gas to the rate of heat input to the boiler. When combined with measurements of flue gas flow rate obtained from the CEM, concentration of flue gas CO₂ obtained from the CEM, and measurements of gross and station service power, the F-Factor can be used to calculate unit heat rate.

The EPA regulations provide values for the F-Factor as a function of fuel type, and in addition, for better accuracy, the regulations provide utilities with the ability to calculate F-Factors from equations that utilize information on the ultimate analysis of the fuel. There are some aspects of the combustion process which the EPA F-Factor ignores. This does not affect the accuracy of the results in cases where the F-Factor is being used to determine total tons per hour of SO₂ or NOx emissions. However, if the F-Factor is being used to convert CEM measurements into unit heat rate, more accurate forms of the F-Factor need to be utilized.

The Energy Research Center recently completed an evaluation of the F-Factor method for heat rate measurement to determine the types of accuracies which are obtainable with this approach. The results show that in order to achieve the best accuracy, the form of the F-Factor corrections that are used must properly account for the non-ideal nature of the combustion process. In preliminary calculations, it was found that failure to do this properly can lead to errors in heat rate in the two to three percent range. However, potentially larger sources of error were found to be due to uncertainties in flue gas flow rate and CO₂ concentration. Unless measurements of these quantities are handled properly in the analysis, errors in flue gas flow rate and CO₂ concentration can lead to relatively large errors in measured heat rate.

Sarunac adds, “Because it relies on information normally available in a power plant, the F-Factor approach is relatively inexpensive to implement, compared to the costs of implementing the Output/Loss method. Use of the F-Factor approach, however, should be restricted to those power plant applications where measurements of heat rate with an uncertainty of a few percent or more are acceptable. Our evaluation of this technique showed that additional work is needed to determine the best accuracies which can be obtained from the F-Factor method and to develop procedures for accomplishing this level of accuracy on a routine basis. Software should also be developed for correctly calculating heat rate by this method, and guidelines need to be developed on how to correctly implement the F-Factor approach.” Additional work is also needed on the Output/Loss method to make it easier for utilities to use this approach. Versions of the software for calculating heat rate by this method are needed for use with the variety of types of plant data systems used in the industry. This would make it possible for a wider range of utilities to use the method. In addition, guidelines are needed on how to use the Output/Loss method to achieve a desired level of accuracy.”