Santee Cooper Operating Heat Rate Program

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ABSTRACT

Santee Cooper began producing weekly heat rate curves in the Spring of 1994 using data provided by the On-Line Performance Monitoring System (OLS). As the heat rate project progressed, valuable insight into the importance of instrument calibration, curve production, and the effect of coal quality was gained. The most important results of this project are the production of current input/output curves for use in system dispatching and continuous monitoring of unit performance. Using the current dispatch curves produced from this program results in savings of $1400 per day in fuel cost over the previous methods.

History of the Heat Rate Program

In the summer of 1993 Santee Cooper began a program to produce weekly unit heat rate curves from its On-Line performance monitoring System (OLS), with the ultimate goal of producing accurate information from which to dispatch.

The OLS provides real time instrument data approximately every seven seconds from seven of Santee Cooper's coal-fired units. Calculated values such as heat rate and controllable losses are also provided with the same frequency. This data is displayed every seven seconds on computers at the stations and at the Moncks Corner Corporate Office.

It was decided that a separate program should be developed to use the test quality instrument data saved every five minutes and calculate a heat rate for the previous week. Work began by taking the code used in the field and simplifying it. The first step was to eliminate artificial values which were needed to keep the field program running when an instrument went bad. This was done by establishing acceptable limits for the normal operating range of each instrument. When any of the instruments used to calculate heat rate indicate a value outside of the normal range, or differ from its duplicate by more than a specified amount, the program skips to the next record without performing a calculation for that scan. Therefore, most unwanted data scans are filtered out. Once the software was in place, with the help of dBase, Lotus, and Harvard Graphics, we began producing curves using the on-line system data.

Before the OLS was available, a complete operating heat rate test was performed in order to produce a heat rate curve. In 1987, 3 people produced 8 heat rate curves during the year. This was improved by 1989 to 14 curves per year. After implementing the Operating Heat Rate Program in 1994, 2 people produced 7 curves each week requiring 2 days effort. Since 1995, after gaining much experience and developing a streamlined procedure, 1 person produces 7 weekly curves in two hours.

Lessons Learned

Development of the operating heat rate program did not occur without problems. Many important lessons were learned.

Importance of Instrument Calibration

For the most part, flow measurement accuracy is fixed. It is possible to adjust the flow by a factor derived from a comparison with a calibrated device, but a welded-in nozzle obviously cannot be calibrated without some difficulty. Coal quality can be measured accurately in the results labs at each station, and then compared against an outside lab. This helps produce accurate results in the lab from the samples we have, but leaves us with the as yet unresolved problem of getting samples that consistently represent what is going into the boiler. The limitations with flow and coal measurement make accurate temperature and pressure measurement even more important.

Santee Cooper excels at calibrating resistance temperature detectors (RTDs) and pressure transmitters. After purchasing an RTD, its resistance value is recorded along with the temperature indicated on a standard platinum resistance thermometer (SPRT) at each of four temperatures. The SPRTs are also calibrated approximately twice a year, or as needs dictate, by use of various metal point cells and a triple point of water cell. The SPRT resistances at the metal point and triple point temperatures are then used in the appropriate National Institute of Standards and Technology (NIST) equation to calculate an accurate temperature. An SPRT calibrated in Santee Cooper's performance lab was also calibrated by NIST. At over 1000°F the difference was only .0079%. We felt this close agreement with our NIST traceable standard satisfactorily confirmed the accuracy of our entire temperature calibration loop. When four pairs of temperature and resistance have been recorded, a second order least squares equation is created for the RTD. These least squares RTD coefficients are entered into calibration files used by the OLS to produce the temperatures recorded and used for calculating heat rates.

Pressure transmitters are calibrated by doing a two point calibration. A COSA deadweight tester with an accuracy of .025% of full scale is the transfer standard for high pressures. A RUSKA pneumatic calibrator with an accuracy of .003% of full scale is the transfer standard for low pressures, and is often used to perform calibrations. Most calibrations are made using a Druck digital pneumatic calibrator, a digital multimeter, and bottled nitrogen gas. A third point at mid span is checked to confirm linearity. For pressure transmitters, the calibration range and any water leg go into the OLS calibration file.

Mechanics of Curve Production

The On-Line System stores all the data in a database file for each unit. A heat rate program uses these database files to calculate heat rates for each unit for the time specified. This data set is then imported into LOTUS. In a spreadsheet, a data regression is executed. From this regression, we obtain our A, B and C coefficients for use with the heat rate curve equation, $Ax^2 + Bx + C$, where x = net generation.

The first generation of curves used a method of moving the intercept constant for the previous four week period up or down, based on the geometric mean of the data scatter for the most recent week. The result of this was one curve shape being moved up or down each week for each unit. This was abandoned after finding too much variation in the shapes of the weekly curves. Now, unique coefficients are produced in LOTUS each week.

The LOTUS spreadsheet is divided into two sections: one week data and four week data. Each week, the previous weeks' data is moved to the four week section where data older than four weeks is rolled off. A data regression is done on the remaining four week data and a four week curve is produced. This curve is plotted on the same graph with the one week curve. This allows us to compare the unit's performance during the previous week to the four week trend, and determine if any problems have occurred with the unit. The four week and one week coefficients are used to calculate heat rates within the load range in 10 MW intervals. The heat rate numbers are then transferred into Harvard Graphics. Harvard Graphics produces a suitable curve for distribution.

A curve like that shown in Figure 1 is produced and distributed on a weekly basis for each OLS unit. Usually, all seven curves are completed by Monday afternoon and delivered to all interested parties by Tuesday afternoon each week.

It is important to always remember that the heat rate curves produced each week are statistics, that is fitted curves, with varying amounts of error attached to them. However, even a curve with a high error value, or a poor fit of the data, may provide information in addition to the coefficients which describe it. For instance, a curve with a low R^2 value is probably due to the load swings the unit went through for that week. Experience suggests that there is some thermal flywheel effect in a boiler when it undergoes consistent swings. This has the effect of producing a wide range of heat rate values at each load. Consequently, the curve will be through the center of the data, but statistically may have a high error value. If the load swings are such that a wide band of heat rate values are produced at a load point where the curve should start to change, a curve with the correct shape cannot be produced. This phenomenon is rare, and other factors, such as bad instruments can also result in data scatter which makes producing a correctly shaped curve impossible.

Effects of Coal Parameters

Another important factor is coal data. There is no inexpensive and accurate way to measure the properties of coal as it enters the boiler. At the time this program began the results lab at each station performed a proximate coal analysis approximately every week. We decided to take this proximate analysis and convert it to an ultimate analysis through the use of equations. The ultimate coal data eventually ends up in ASCII files which are used for the appropriate times by the heat rate program.

A valuable benefit of these coal files is that they have allowed us to measure the effects of each coal property and create equations which describe the relation between

Net Unit Heat Rate

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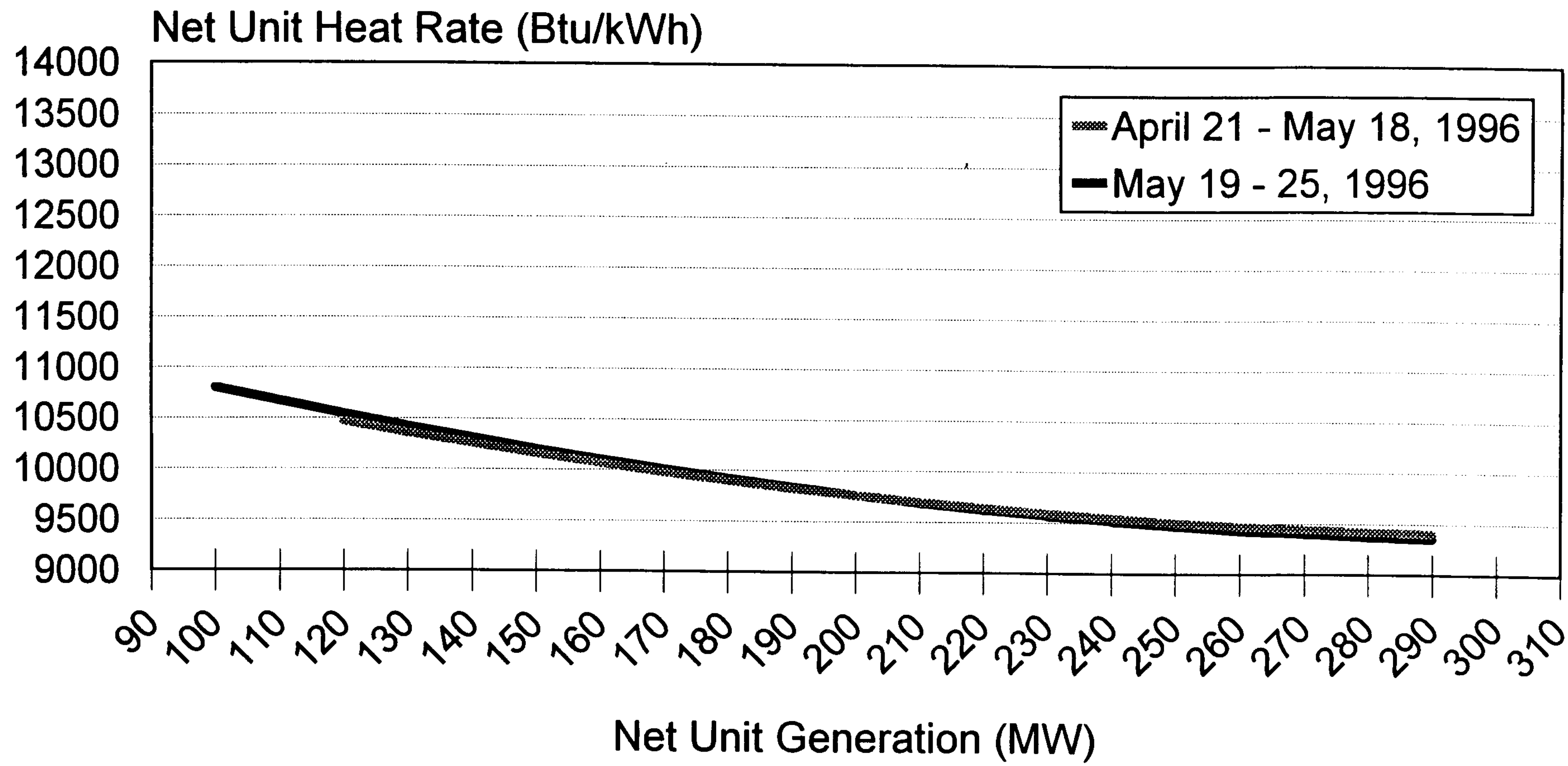
April 21 - May 25, 1996

Performance Services
On-Line Performance Monitoring System



Net Unit Heat Rate = A + B*x + C*x^2,   x = net unit generation (MW)

Coefficients for May 19 - 25, 1996 are: A = 12465.37 B = -19.7644 C = 0.031146

Figure 1. Weekly Heat Rate Curve

a property and boiler efficiency or heat rate. To create these curves and equations, we iterated the heat rate calculations while varying each coal parameter. With the results of these calculations, Tablecurve 2D produced an acceptable equation. These equations are useful when trying to reconcile changes in boiler efficiency.

Benefits of Weekly Curves

Many distinct benefits have resulted from the operating heat rate program.

Input / Output Curves for Dispatch

At the end of each quarter, the weekly heat rate coefficients which typically represent each unit's operation during that quarter are averaged. From these averaged coefficients another regression equation is made to produce a smooth input / output curve for use in the SCADA system for dispatching the units. Regular dispatch updates ensure that equipment problems as well as improvement in a unit's performance are accounted for.

Estimating Fuel Consumption

As a check on the validity of the curves being produced, comparisons have been made against the station monthly reports of generation and fuel use. A heat rate is calculated for a unit using all the available data for a month, along with the coal heating value for that month reported by the station. Using the average hourly net generation along with the heat rate, a boiler input value is calculated for each hour. These values are totalled for the month and divided by the total net generation. The value calculated in this way is then compared against the station unit heat rate as determined by the coal scales and recorded net generation. Although differences for a single unit may sometimes be large, the difference for station totals is usually within two percent. This method was helpful in confirming a problem with a coal scale at one of our stations.

Weekly Data Monitoring

Perhaps the biggest benefit in producing weekly heat rates is that it makes someone look at each unit's performance on a weekly basis. As a result, when big changes appear, key parameters such as boiler efficiency, net generation, and auxiliary power are examined over time. On units where a common station service auxiliary load bus is used, we have seen the effect of one unit's startup power on the other.

Overall Impact on Fuel Purchases

Prior to the weekly heat rate program, the seven OLS units were dispatched based on data collected during operating heat rate tests done in the late 1980's. The cost of dispatching the units by the older curves was compared with the newer curves. According to Santee Cooper's Energy Control Center, dispatching with the new curves for a typical summer load saves $1400 per day.