USE OF REAL-TIME MONITORING
TO IMPROVE PLANT PERFORMANCE

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ABSTRACT

Minnesota Power's heat rate improvement effort initially began as routine equipment tests performed at periodic intervals.

Equipment performance tests are useful in that they monitor the mechanical condition of various plant components. Because they are conducted only three or four times a year, they are not much help in analyzing the day-to-day operation of a plant.

The advent of plant computers with the power to analyze plant operating parameters on a real-time basis has bridged the gap left by routine equipment tests.

Minnesota Power embarked on a program in 1981 to design a system which would use an existing L & N 5400 plant computer to display operating parameters and their associated effect on heat rate to the plant operators.

This paper traces the evolution of this program and outlines the role PEPSE has played in the development of Minnesota Power's Controllable Loss Program.

INTRODUCTION

Minnesota Power began a formal program for improving system heat rate in 1977. This program had its primary emphasis on routine performance tests of the main turbine, feedwater heaters and condenser.

The addition of Clay Boswell Unit #4 in 1980 brought with it new opportunities to optimize unit heat rate. Unit #4 brought with it a plant computer that could use Fortran programs written in-house to analyze the heat rate effect of operating parameters and display this effect via CRT's to the plant operators.

In 1981, Minnesota Power initiated a program to design a system which would use the Unit #4 plant computer to display real-time heat rate information to the operators.

This paper traces the evolution of this program and outlines the role PEPSE has played in its development.

HEAT RATE DEVIATION PROGRAM

Minnesota Power first attempted to monitor operating parameters on a real-time basis in 1981 using a system entitled "Heat Rate Deviation Program".

This was a relatively modest system which analyzed the effects of the operating parameters listed in Table 1.

Table 1

HEAT RATE DEVIATION PARAMETERS

HEAT RATE DEVIATION PARAMETERS
Superheat Steam Temperature
Reheat Steam Temperature
Superheat Attemperating Spray Flow
Reheat Attemperating Spray Flow
Excess Flue Gas Oxygen

For each parameter measured, the PEPSE code was used to predict the change in plant heat rate as the parameter varied from design.

The PEPSE heat rate predictions for main steam temperature, as it varies from the design point of 1000°F, are shown in Table 2.

Table 2

HEAT RATE PENALTY - MAIN STEAM TEMPERATURE

Main Steam Temperature	Gross Station Heat Rate (Btu/kWh)	Penalty (Btu/kWh)
1000	9240	0
990	9258	18
980	9275	35
970	9291	51
960	9310	70

The PEPSE analysis shows that each 1°F drop in main steam temperature adds approximately 1.75 Btu/kWh to the heat rate.

Once the relationship between main steam temperature and heat rate has been established, an equation of the following form can be entered into the plant computer:

Heat Rate Penalty (Btu/kWh) = (1000 - Main Steam Temperature) x 1.75

This equation enables the plant computer to calculate how plant heat rate increases as main steam temperature varies from design. The heat rate penalty incurred is then presented to the operator using the CRT graphic display shown in Figure 1.

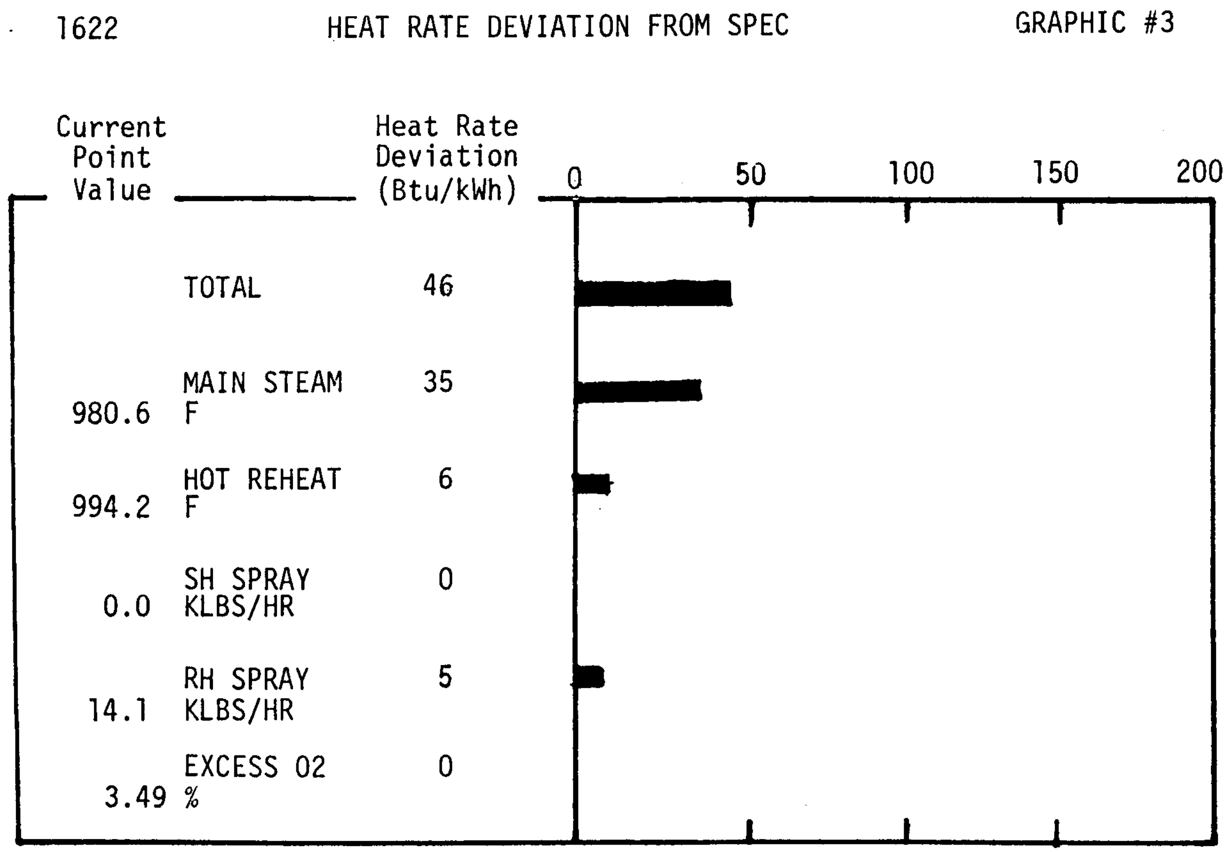

Figure 1

The process used to develop the heat rate penalties for the remaining four parameters follows the same methodology used for the main steam temperature.

The Heat Rate Deviation Program has achieved significant results. Plant personnel have demonstrated their ability to use real-time information to correct problems which increase station heat rate. As Figure 2 shows, over the last two years the plant heat rate on Boswell Unit #4 has improved approximately 40 Btu/kWh producing a savings in 1983 of $150,000.

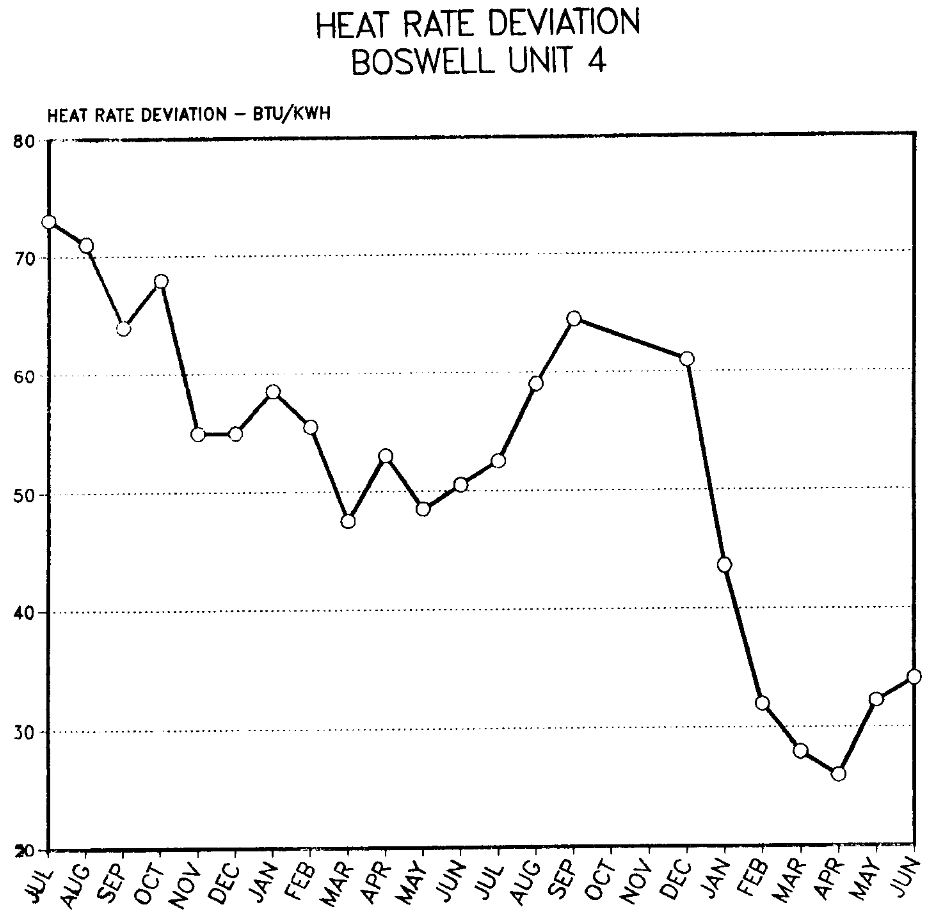

Figure 2

CONTROLLABLE LOSS PROGRAM

Based on the positive results obtained by use of the Heat Rate Deviation Program, a year ago Minnesota Power decided to design a Controllable Loss Program which expanded the list of plant parameters monitored to those shown in Table 3.

Table 3

CONTROLLABLE LOSS PARAMETERS

Superheat Steam Temperature
Reheat Steam Temperature
Superheat Attemperating Spray Flow
Reheat Attemperating Spray Flow
Excess Flue Gas Oxygen
Feedwater Heater #1 Terminal Temperature Difference
Feedwater Heater #2 Terminal Temperature Difference
Feedwater Heater #1 & 2 Alternate Drain Flow
Condenser Back Pressure
Unburned Carbon in Ash
Boiler Blowdown Flow
Cycle Make-up Flow
Air Heater Cold End Average Temperature
Air Preheating Coil Usage
Glycol Heating Coil Usage
Plant Heating System

As with the Heat Rate Deviation Program, each variable was analyzed using the PEPSE code to quantify the heat rate effects. The information is entered into the L & N 5400 computer and this enables the plant computer to calculate the change in heat rate that occurs as each parameter changes. A CRT display is utilized to display this information to the operators.

In addition to the real-time information displayed to the operators, daily and monthly summary reports are produced. These reports list the losses incurred for the reporting period and the associated cost of each loss. An example of this report is shown in Table 4.

Table 4

MINNESOTA POWER - CLAY BOSWELL UNIT #4

DAILY LOSS REPORT FOR THURSDAY, JULY 14, 1983

Total Minutes Monitored: 1440	Total Minutes in Period: 1440	Percent of Time Monitored: 100.00

Fuel Cost = $1.15/MBtu

LOSS CATEGORY	- ACTUAL - AVG HEAT RATE EFFECT	VALUE	- COMPENSATED - AVG HEAT RATE EFFECT	VALUE
	Btu/kWh	$	Btu/kWh	$
SUPERHEAT STEAM TEMP				
REHEAT STEAM TEMP				
SUPERHEAT SPRAY FLOW				
REHEAT SPRAY FLOW				
EXCESS FLUE GAS OXYG				
FEEDWATER HTR #1 TTD				
FEEDWATER HTR #2 TTD				
HTR 1&2 ALT DRAIN FL				
CONDENSER BACK PRESS				
EXCESS CARBON IN ASH				
BOILER BLOWDOWN				
MAKE-UP				
PLANT HEATING SYSTEM				
AIR PREHEATING COILS				
AH COLD END AVG TEMP				
GLYCOL HEATING COILS				
TOTALS				

Dollar losses tabulated on the Loss Report appear under the headings of "Actual Value" and "Compensated Value." The difference in the two columns attempts to account for the fact that certain losses, such as system make-up flow, arise in the natural course of operating a plant and can never be zero.

Therefore, in the column marked "Actual Value" is found the cost of all the make-up used during the period. Assuming make-up was designed to be .5% of feedwater flow, the "Compensated Value" then becomes the "Actual Value" less the cost of .5% make-up flow.

The "Compensated Value" column then reflects how close the plant operates to an established target or standard.

CONCLUSION

The PEPSE code has played an important role in the development of Minnesota Power's Controllable Loss Program. PEPSE calculated the heat rate effect of key operating parameters. This allowed equations to be written which, when entered into the plant computer, enabled a real-time analysis to be made of the heat rate penalties incurred by off-design operation of key parameters.

Display of a real-time operating parameter and effect on heat rate has proven itself to be an effective method for improving heat rate.