Using PEPSE® to Predict the Effects of Different Powder River Coals on Unit Maximum Capacity

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ABSTRACT

The Nebraska Public Power District's Gentleman Station has been receiving its coal from one mine in Wyoming's Powder River Basin. The coal contract will be reopened for negotiation in the near future. With the potential for a change in coal, there was a concern of how different coals would affect station capacity. Five different Powder River coals were tested in the summer of 1994. PEPSE was used to equalize test conditions and help predict the maximum capacity for each coal.

Introduction

Nebraska Public Power District's (NPPD's) Gerald Gentleman Station is located near the village of Sutherland in southwest Nebraska. Gentleman Station is NPPD's largest power plant, consisting of two units with gross capacity ratings of 672 and 681 MW. Due to its size and low production costs, Gentleman Station annually produces approximately 60 percent of NPPD's generation. The major reason for Gentleman Station's low production costs is that it burns coal from Wyoming's Powder River Basin (PRB).

When Gentleman Station was being built, NPPD entered into a long-term contract with ARCO for coal from the Black Thunder Mine. Black Thunder has the largest production capabilities and is one of the better quality mines in the PRB. ARCO and NPPD have had a good relationship, but the contract is due to be reopened in 1996. If NPPD cannot reach an agreement with ARCO, Gentleman Station will have to find a new primary coal supplier.

Knowing that the ARCO contract would eventually end, Gentleman Station has test burned several other PRB coals since 1985. The coals were evaluated for handling, precipitator performance, slagging and fouling characteristics, and ability to make rated unit capacity. When the initial testing was done, capacity was not a major issue and the units were able to reach rated capacity. Gentleman Station's rated capacity is not the true maximum capacity of the station. Unit 1 has been tested at 710 MW gross, and Unit 2 at 730 MW gross. The capacity ratings of the units have never been increased since there was not a demand for the capacity and NPPD's transmission system could not handle the increased capacity. Since the initial coal tests, the capacity demand has increased, and NPPD is planning a transmission system upgrade by 1996. Gentleman Station's capacity will be upgraded when the transmission system upgrade is complete. Since none of the coal testing had been done at maximum capacity, it was decided to test five PRB coals for their effect on maximum capacity in the summer of 1994.

The Testing Procedure

Since the primary purpose of the test was to determine maximum capacity for the coals, only 25,000 tons (two unit trains) of each coal were tested. Unfortunately, due to large demands for PRB coal during 1994, the coals had to be selected by availability instead of by performance. All the coals but one had previously been test burned at Gentleman Station. The test coals were scheduled to be burned during an eight-week period running from mid-June to August.

Both units at Gentleman Station are natural circulation drum-type boilers. Unit 1 was manufactured by Foster Wheeler and has a split convection pass for controlling reheat temperature. Unit 2 was manufactured by Babcock & Wilcox. Unit 2 is a single-convection pass unit using attemperation to control reheat temperature. Both units have eight B&W MPS 89 pulverizers. Under normal operation with Black Thunder coal, only seven pulverizers are needed for maximum capacity. By having the spare pulverizer, Gentleman Station is able to do almost all of its pulverizer maintenance while on line, reducing the lengths of scheduled outages. Operating with eight pulverizers also hinders the station's availability to control NO_X and operate in load-frequency control.

Maximum capacity for the testing was defined as 2520 (5% over pressure) psig throttle pressure, 1000°F. throttle and reheat temperatures, and control valves 100% open. The maximum capacity tests would be run for two hours for each coal. Since PRB coals can cause slagging and fouling problems, sootblowing would be allowed during the testing.

Since only one train of test coal per unit was being burned, timing was important. At the capacity the station was operating, the coal would be in a unit only 35 to 40 hours. A schedule was developed to start reclaiming the test coal with a morning reclaim, and perform the maximum capacity test a day later. This way, the unit would be burning test coal for approximately 24 hours before the maximum capacity test.

The week before the first test burn, both units were tested at maximum capacity conditions on Black Thunder coal. Unit 1 was tested at 674 MW gross. This load was lower than expected due to the boiler being moderately dirty and the turbine being in its fourth operating year after an overhaul. Unit 1's throttle steam and hot reheat steam temperatures were 983°F. and 997°F. respectively. Unit 2's baseline test was run at 728 MW gross. The Unit 2 test was run with a clean boiler and the turbine had just been overhauled. However, Unit 2's economizer gas outlet temperature was 870°F., which is above the station limit of 850°F. To protect the ductwork steel and the precipitator, it was decided to do the rest of Unit 2's testing at 2400 psig instead of 2520 psig.

Unfortunately, system load restraints prevented the data collection for either unit for coal numbers 1 and 3, coal number 2 in Unit 1, and coal number 4 in Unit 2. With a 2400 psig limit, Unit 2's maximum capacity was 700 MW. Coal number 2 was tested at this load in Unit 2 for one hour. Data was taken for coal numbers 4 and 5 in Unit 1 at 2440 psig throttle pressure and 650 MW. Coal number 5 was tested in Unit 2 at 2350 psig and 650 MW.

The Modeling Procedure

Since none of the coals were tested at maximum capacity and working PEPSE models for each boiler were already in place, it was decided to use PEPSE to try to predict the coal flow required for maximum capacity for each test coal. Figures 1 and 2 show the Unit 1 and Unit 2 PEPSE model schematics respectively, which could be done using two methods. The first method was to tune the models to the conditions of the Black Thunder maximum capacity tests. After the initial tuning, the models would be rerun using the test coals for fuel. The second method was to tune the models to the test conditions for the test coals that data was available. After this tuning, the models would be rerun using feedwater and cold reheat conditions from the Black Thunder tests for each coal data was available. The results from method two could be used to check the results from method one. Also, since Unit 1's Black Thunder test had been run at steam temperatures less than 1000°F., PEPSE could be used to predict the fuel flow required to increase steam temperature to 1000°F.

The tuning of the models was completed with very few problems. Measured inputs for the models were feedwater inlet conditions, cold reheat inlet conditions, spray water conditions, excess air, and combustion air conditions. Only an estimate for combustion air flow was input so the model could adjust air flow to match the excess air measurement. Controls were used to adjust heat transfer and pressure drop to match economizer water outlet conditions, superheater outlet conditions, main steam conditions, hot reheat conditions, and air heater air outlet temperature. Coal flow was not considered to be a precise measurement, therefore, it was adjusted manually to match the economizer gas outlet temperature. At this time, Gentleman does not have a way of measuring gas flows through Unit 1's two convection passes, therefore, a control was placed in the tuning models to calculate the gas flows, based on equal pressure drops in each gas pass.

Method one was used to estimate the fuel flows for the test coals for both units. The Unit 1 gas flow split did have to be adjusted manually to get the main steam and hot reheat temperatures matched for some coals. The initial fuel used for each test coal was calculated from the heat input PEPSE calculated for the baseline tests. All the test coal inputs had to be adjusted to match steam outlet conditions.

Unit 1 was modeled using method two by increasing fuel flow and adjusting the gas flow split until the measured maximum capacity steam temperatures were matched. Method two for Unit 2 was not as simple. As previously stated, Unit 2 uses attemperation spray to control all steam temperatures. Since the boiler conditions changed from test to test, the percentage of steam from attemperation spray changed. Controls were written to adjust attemperation sprays to give final and hot reheat temperatures 1005°F. Since spray flows could be adjusted for any fuel flow, the fuel flows projected from method one for coal numbers 2 and 5 were used. This method was also used to project the economizer gas outlet temperature for Black Thunder using the conditions coal numbers 2 and 5 were tested at.

Modeling Results

Coal numbers 4 and 5 were the only test coals that data were taken for on Unit 1. The modeled fuel flows for maximum capacity from methods one and two were within 0.63% for coal number 4 and 0.25% for coal number 5.

Figure 3 shows the maximum capacity fuel flow for Unit 1, which would range from 768,000 lb/hr for Black Thunder to 815,000 lb/hr for coal number 2. For seven-pulverizer operation, the average flow per pulverizer ranged from 109,714 lb/hr for Black Thunder to 116,429 lb/hr for coal number 2, as shown in Figure 4. Figure 3 also shows the model results when increasing Unit 1's steam temperatures to 1000°F. The fuel flow for coal number 2 increased to 830,000 lb/hr, or 118,571 lb/hr per pulverizer. Since the maximum flow per pulverizer is 120,000 lb/hr, Unit 1 should reach maximum capacity with any of these coals. However, the pulverizer flows for coal number 2 are marginal; they do not leave much room for load swings or change in as-fired moisture. The higher heating value of the coal number 2 coal for the Unit 1 test was 8176 BTU/lb, which is the minimum heating value that Unit 1 can expect to reach maximum capacity.

The results in Figure 6 show that the maximum capacity fuel flow ranged from 793,000 lb/hr Black Thunder to 822,732 for coal number 2. Figure 7 shows that flow per pulverizer ranged from 113,286 lb/hr for Black Thunder to 117,533 lb/hr for coal number 2. Coal number 5's pulverizer flow was also high at 117,143 lb/hr. Since Unit 2's maximum pulverizer capacity is 120,000 lb/hr, coal numbers 2 and 5 are marginal coals. The higher heating values for coal numbers 2 and 5 used in the model were 8375 and 8381 BTU/lb. For seven-pulverizer operation, Unit 2 will not reach maximum capacity if the higher heating value drops below 8375 BTU/lb.

The difference in the minimum heating value between Unit 1 and Unit 2 is questionable. Past operating history indicates that the difference should not be this large. It is suspected that the 8176 BTU/lb. heating value for coal number 2 in Unit 1 is incorrect.

Figure 5 shows that Unit 1's economizer gas outlet temperature ranged from 813°F. for coal number 3 to 822°F. for coal number 2. The results in Figure 5 show that when the fuel flow was increased to bring steam temperatures to 1000°F., the economizer gas outlet temperature increased to 818°F. for coal number 3 and 828°F. for coal number 2. A 1.8% increase in fuel flow increased economizer gas outlet temperature 0.72% for coal number 2. The reason the economizer gas outlet temperature did not increase more is that to balance the main steam and hot reheat temperatures, the flue gas split was adjusted for more gas flow through the primary superheater.

Using method one, Unit 2's economizer gas outlet temperature ranged from 861°F. for coal number 3 to 865°F. for Black Thunder, coal numbers 1, 4, and 5. These results are shown in Figure 8. When the coal number 2 test conditions were projected to maximum capacity, the economizer gas outlet temperature was 825°F., compared to 863°F. for coal number 2 from method one. The results from projecting the coal number 5 test conditions to maximum capacity show an economizer gas outlet temperature of 836°F., compared to 865°F. When Black Thunder was modeled using the coal numbers 2 and 5 test conditions, the economizer gas outlet temperature was 827°F., and 835°F. respectively. The model results indicate that the soot blowing practices during the base line Black Thunder test increased economizer gas outlet temperature 30°F. to 40°F.

Conclusions and Recommendations

Although none of the test coals were tested at maximum capacity, the PEPSE models for Gentleman Station were able to provide an approximation of fuel flow required for maximum capacity. Some of the PRB coals with lower heating values will present capacity problems at Gentleman Station. None of the coals had a significant effect on economizer gas outlet temperature.

It also appears that Gentleman Station may be able to improve steam temperature and lower economizer gas outlet temperature by diverting more gas flow to the primary superheater pass.

This theory needs to be proved by actual testing.

1995 projections indicate that Gentleman Station will burn 1.2 million tons of coal more than the minimum it is required to take from ARCO. Gentleman Station will be able to use this 1.2 million tons to do more coal testing. Items that need to be addressed to help determine a suitable replacement for Black Thunder are:

- Since the PEPSE results are only approximations, it has been recommended that more maximum capacity tests be performed to determine a minimum heating value for each unit that maximum capacity can be reached.

- 25,000 tons is not enough coal to conduct a good test. There is a possibility that all the silos might not have been completely transferred to the test coals when the capacity tests were run.

- More of coal number 4 needs to be burned to determine its effect on slagging and fouling, precipitator performance, and overall performance.

- To account for variations in the coal quality, more than one maximum capacity test needs to be run on each coal.

Gentleman Station would prefer to burn the higher quality PRB coals, but NPPD must maintain competitive rates. With both the utility industry and the market for PRB coal constantly changing, Gentleman Station needs to develop the flexibility to burn several PRB coals. This flexibility needs to be developed without a major effect on capacity or station operation. Continued coal testing and PEPSE modeling will lead to the flexibility required to maintain competitive rates.

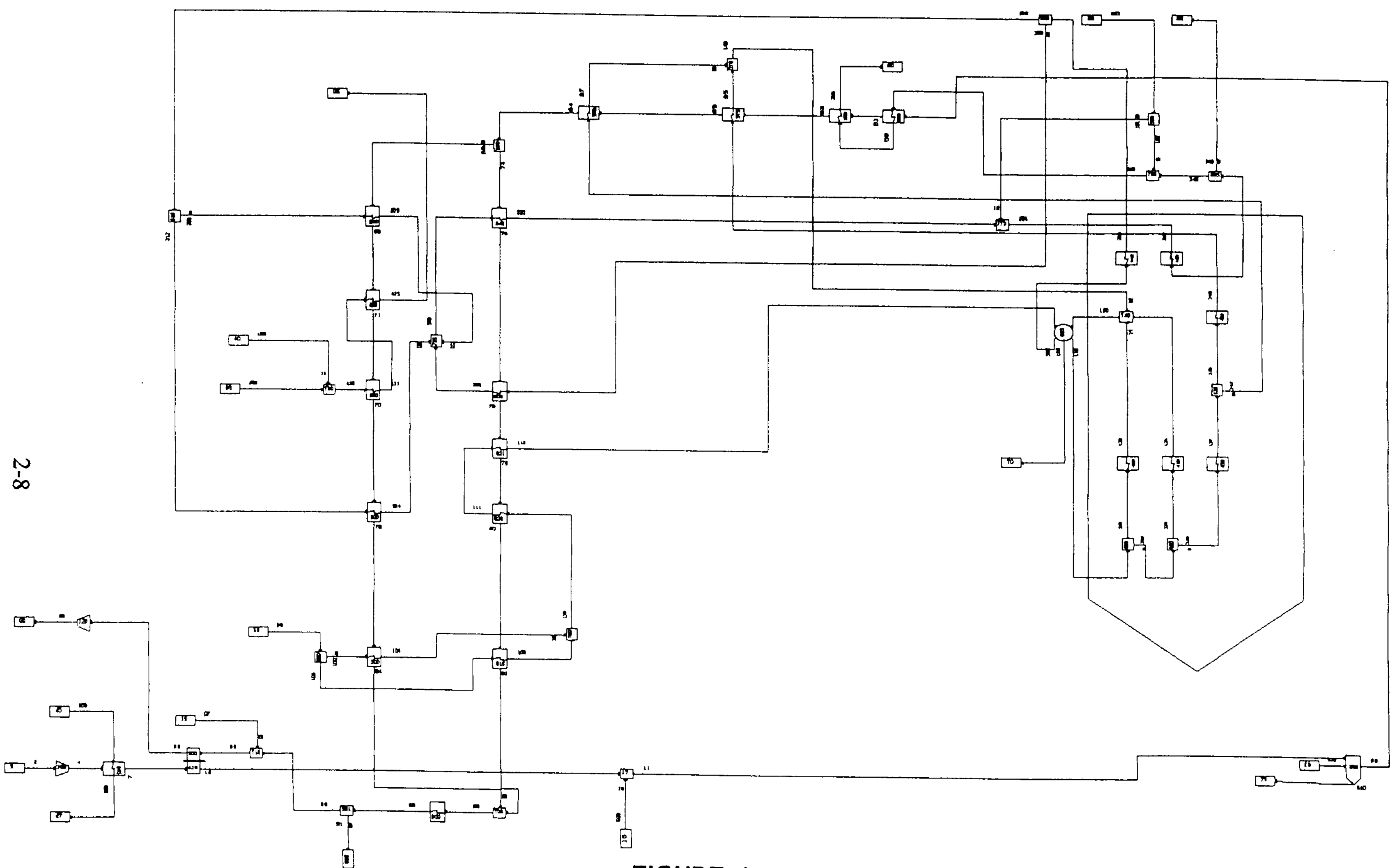
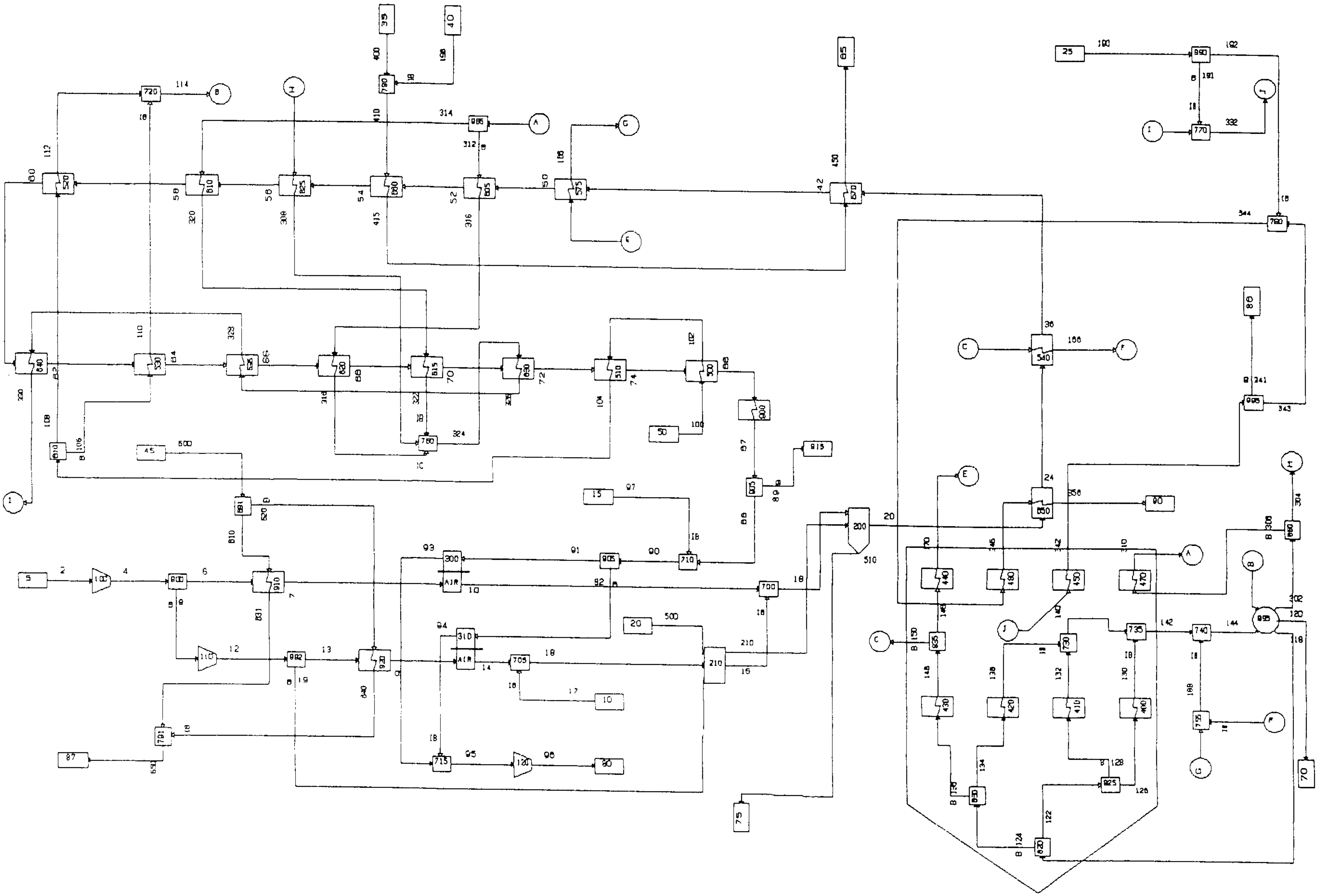


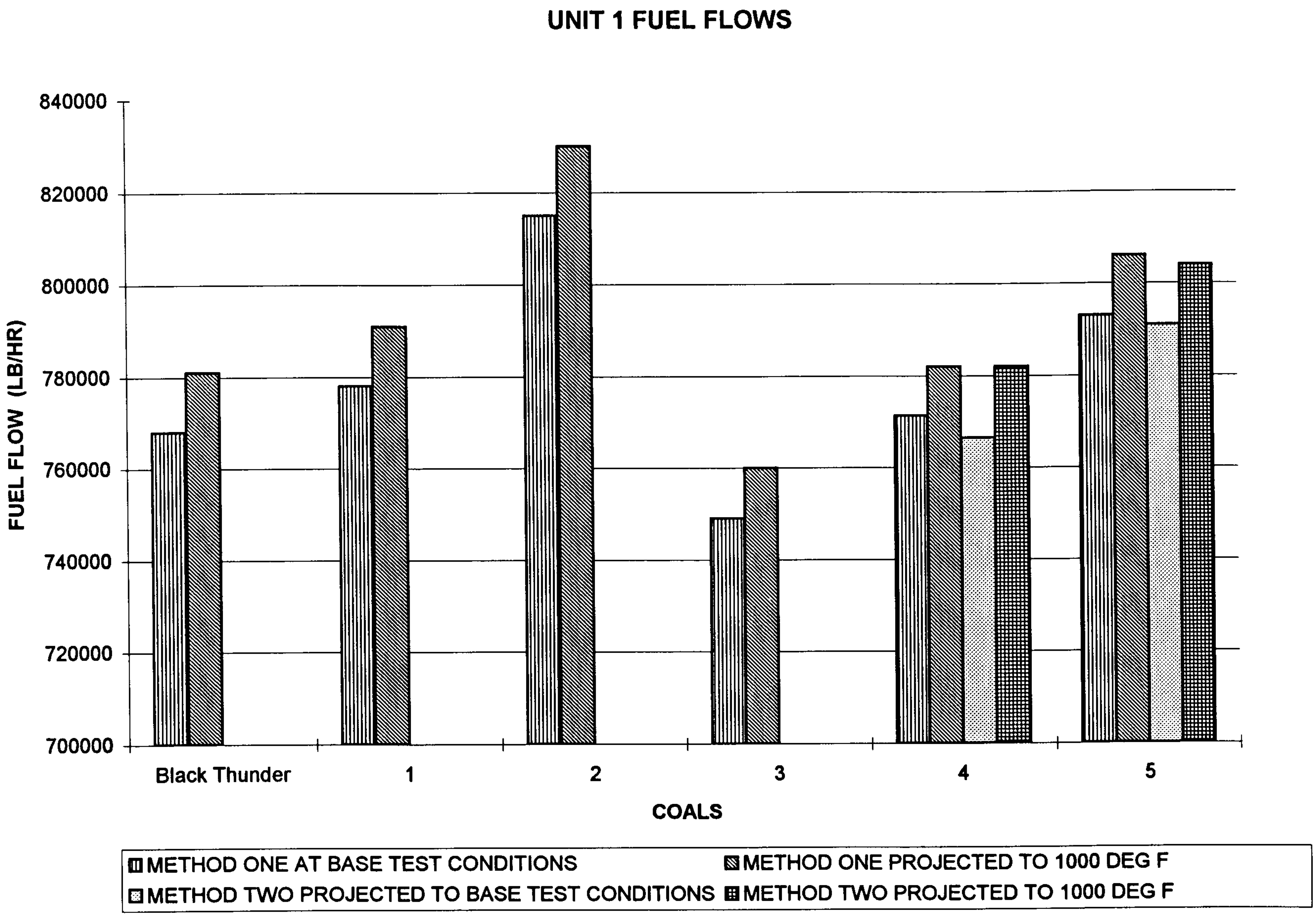
FIGURE 1

GGS UNIT 1 PEPSE BOILER MODEL



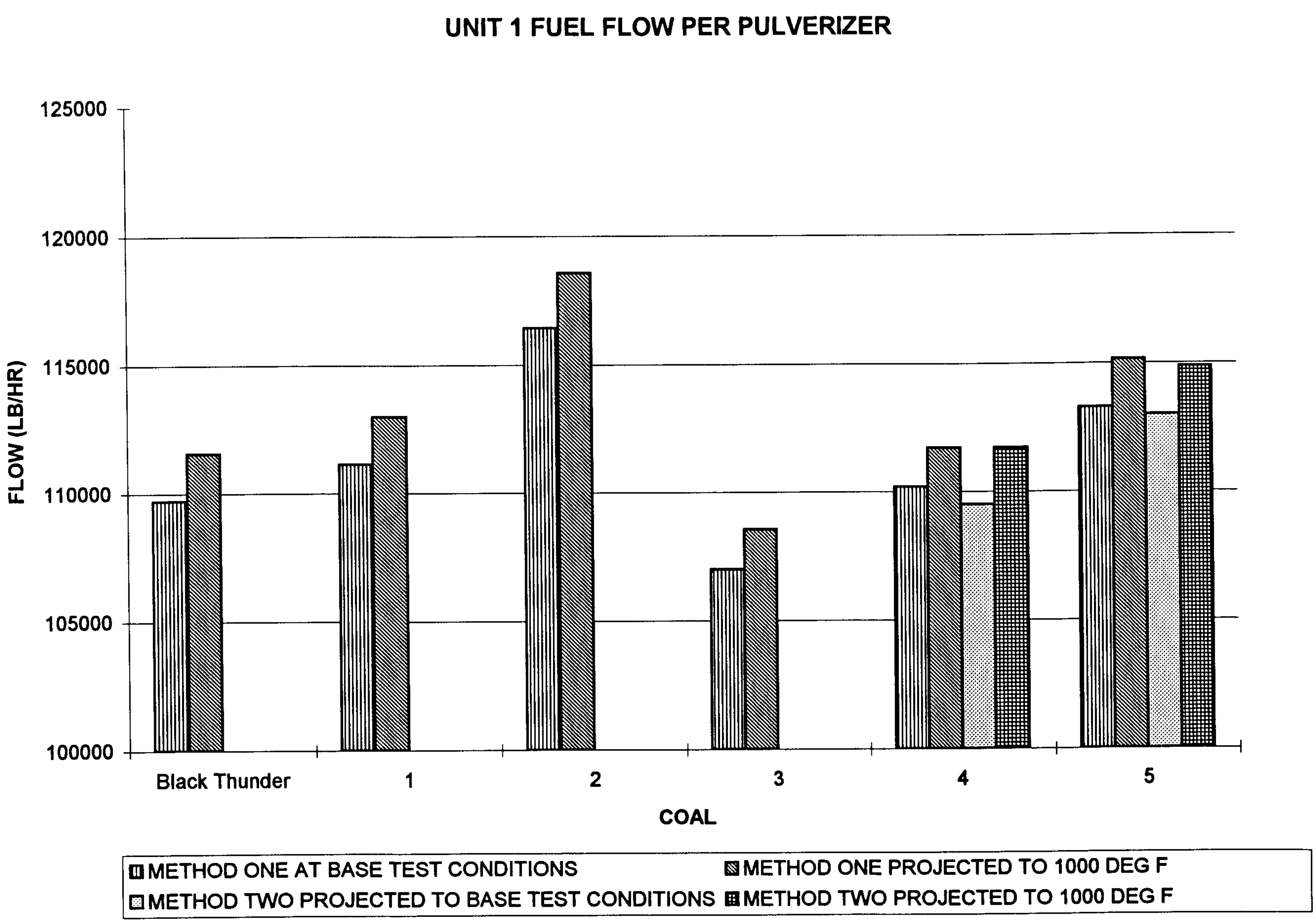
GGS UNIT 2 PEPSE BOILER MODEL

FIGURE 2



UNIT 1 FUEL FLOWS
840000
820000
800000
780000
760000
740000
720000
700000
FUEL FLOW (LB/HR)
Black Thunder
1
2
3
4
5
COALS
METHOD ONE AT BASE TEST CONDITIONS
METHOD ONE PROJECTED TO 1000 DEG F
METHOD TWO PROJECTED TO BASE TEST CONDITIONS
METHOD TWO PROJECTED TO 1000 DEG F

FIGURE 3



UNIT 1 FUEL FLOW PER PULVERIZER
125000
120000
115000
110000
105000
100000
FLOW (LB/HR)
Black Thunder
1
2
3
4
5
COAL
METHOD ONE AT BASE TEST CONDITIONS
METHOD ONE PROJECTED TO 1000 DEG F
METHOD TWO PROJECTED TO BASE TEST CONDITIONS
METHOD TWO PROJECTED TO 1000 DEG F

FIGURE 4

UNIT 1 ECONOMIZER GAS OUTLET TEMEPERATURES

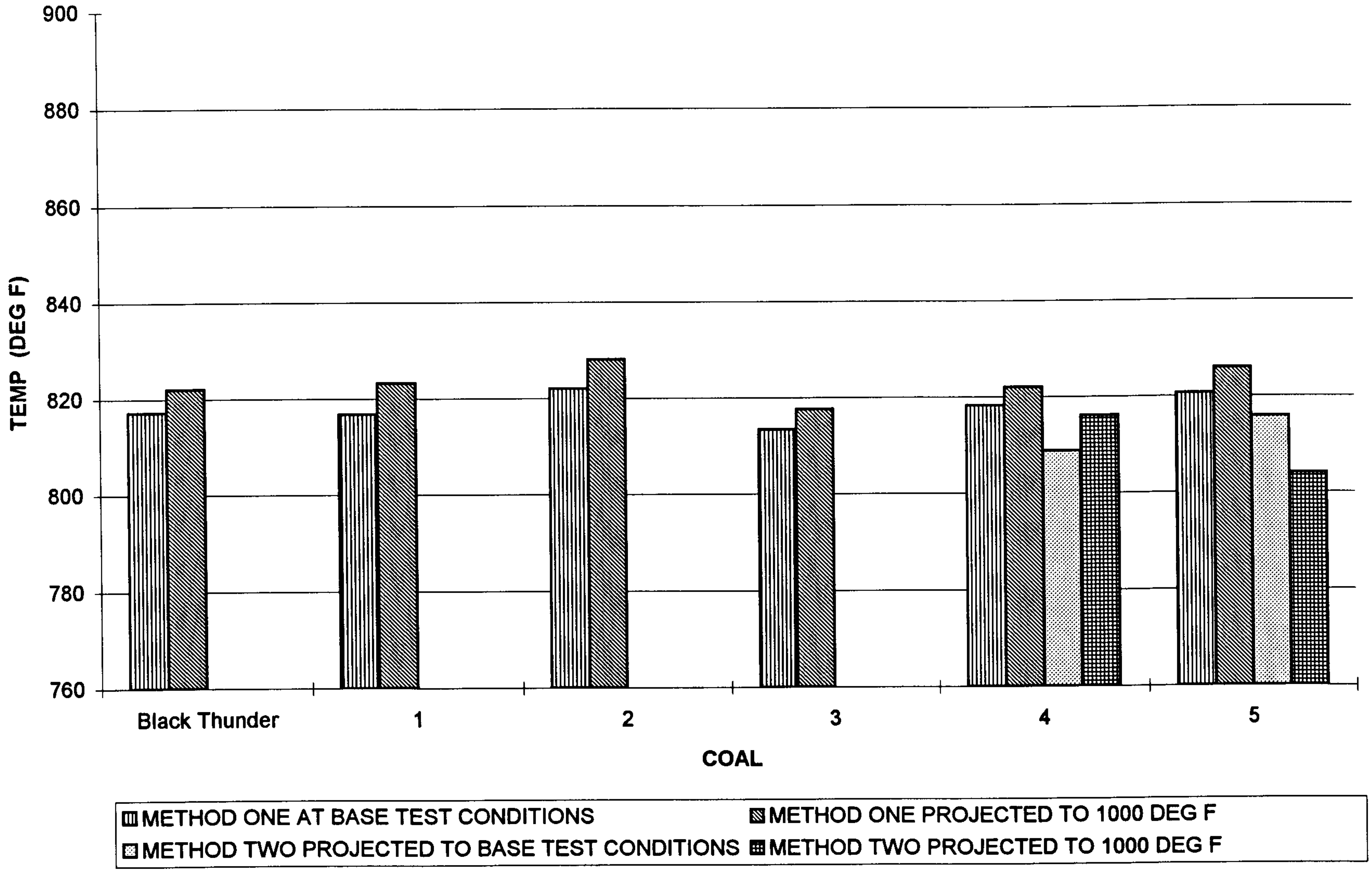


FIGURE 5

UNIT 2 FUEL FLOW USING METHOD ONE

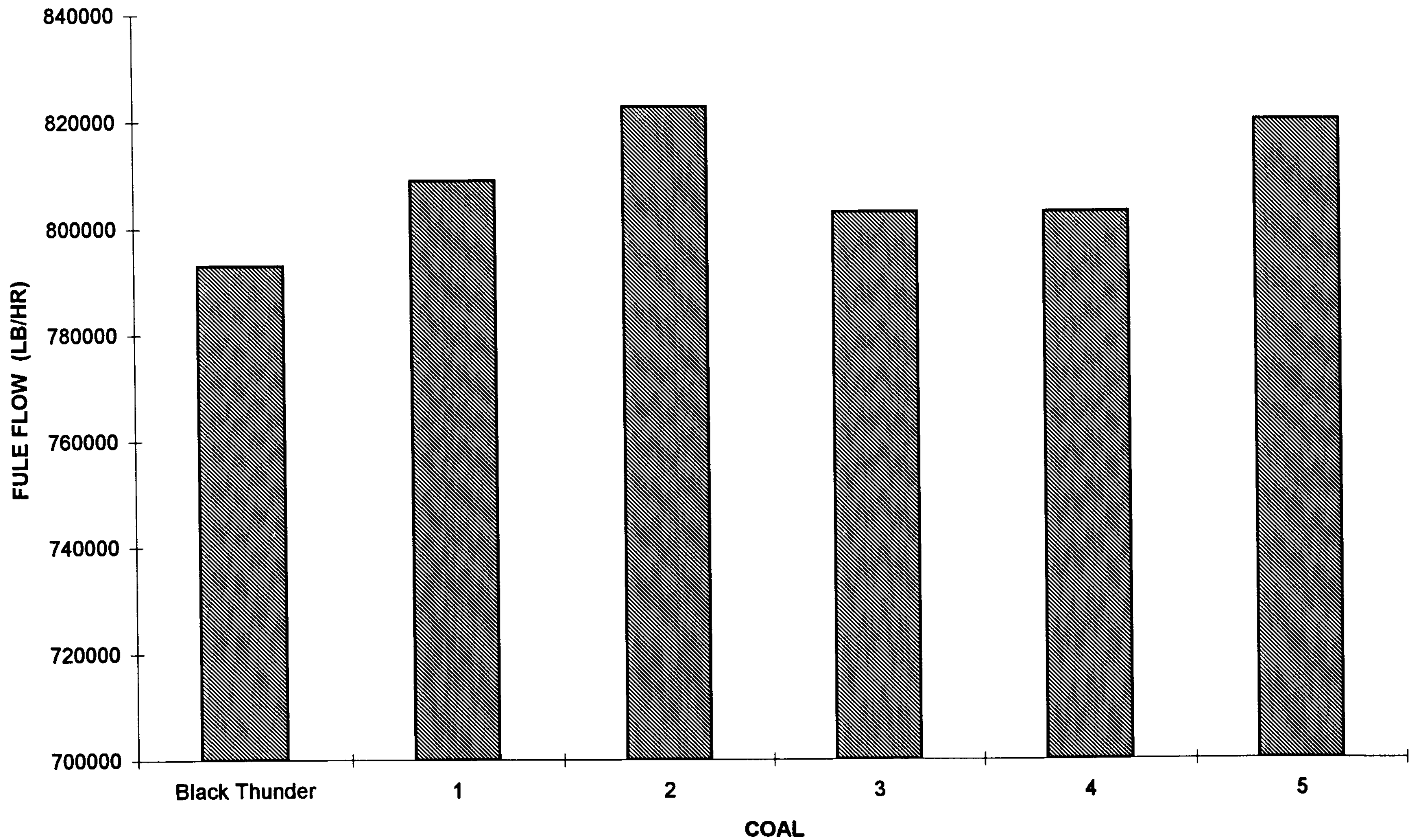


FIGURE 6

UNIT 2 FUEL FLOW PER PULVERIZER USING METHOD ONE

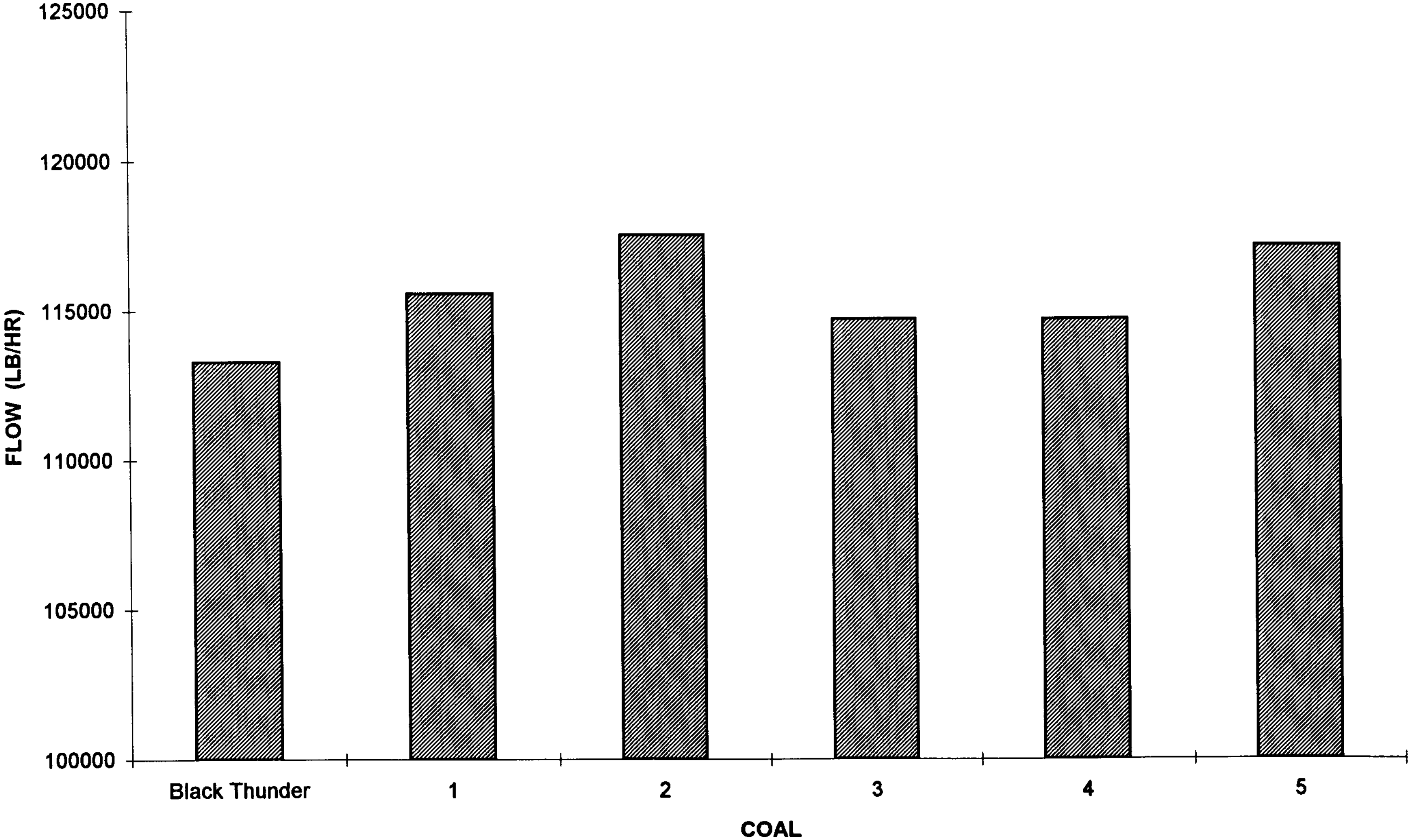


FIGURE 7

UNIT 2 ECONOMIZER GAS OUTLET TEMEPRATURE

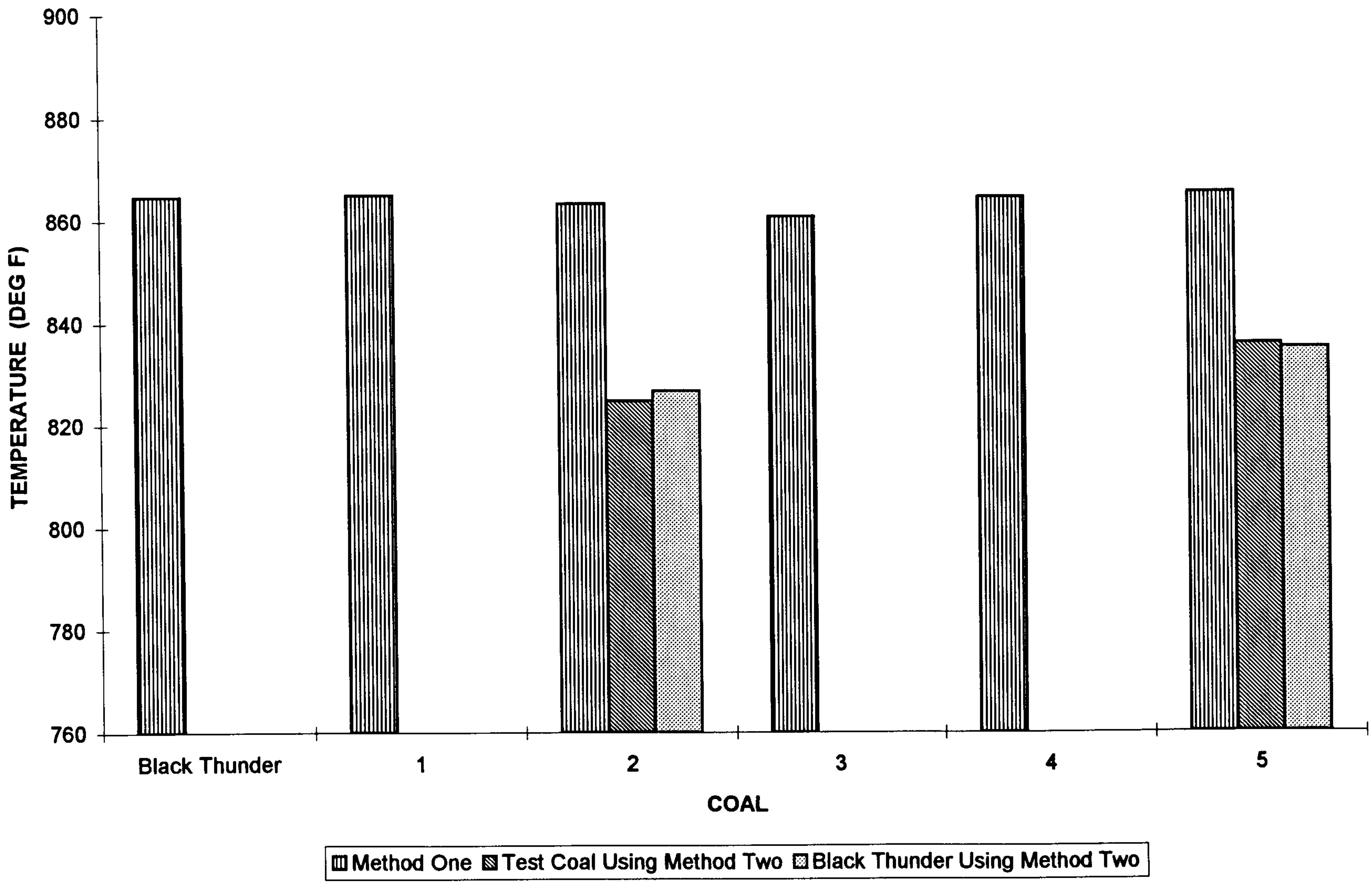


FIGURE 8

REFERENCES

1. PEPSE COMPUTER CODE, NUS Corporation, PO Box 50736, Idaho Falls, ID., Version 59, 1994

2. PEPSE Manual: Volume I, NUS Corporation, PO Box 50736, Idaho Falls, ID., Version 59, 1994