Using PEPSE® to Predict the Effects of Circulating Water Inlet Temperature on Plant Performance

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USING PEPSE TO PREDICT THE EFFECTS OF CIRCULATING WATER INLET TEMPERATURE ON PLANT PERFORMANCE

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ABSTRACT

Nebraska Public Power District's Gentleman Station receives its cooling water from an irrigation system. Due to the thermocline of a large reservoir in the irrigation system, the plant has been able to operate with relatively cool circulating water temperatures. The potential exists that the reservoir level may be lowered to a level that will break the thermocline. PEPSE was used to predict the effects of increasing circulating water temperatures on Gentleman Station's once through cooling system.

Introduction

Gerald Gentleman Station is Nebraska Public Power District's (NPPD's) largest power plant consisting of two units with gross capacity ratings of 672 and 681 MW. Gentleman Station annually produces approximately sixty percent of NPPD's generation making it an important part of NPPD's generation system. Gentleman Station is a once through cooled plant that gets its cooling water from either the Sutherland Reservoir or the irrigation canal system that diverts both North and South Platte River water to the Sutherland Reservoir. The discharged circulating water is returned to the Sutherland Reservoir after passing through a 2.4 mile canal and a 200 acre cooling pond.

Lake McConaughy sits behind Kingsley Dam on the North Platte River upstream of the beginning of NPPD's canal system. Depending on the season, the lake can contain 1,790,000 acre-feet or more of water. Depths in the lake may reach 110 feet, resulting in a thermocline that provides cool water for Gentleman Station's circulating water system. The operating license for the dam and irrigation system has expired, and is currently in the relicensing, process. The possibility exists that after relicensing, the lake may be operated at levels low enough to break the thermocline.

The potential exists that Gentleman Station's cooling water temperatures may reach 80°F for a portion of the summer. The higher cooling water temperatures will affect Gentleman Station by turbine exhaust pressures, turbine exhaust hood temperatures, circulating water discharge temperatures, and equipment cooling water temperatures, resulting in higher heat rates. If the return temperature of the circulating water to the irrigation system becomes too high, cooling towers may have to be installed. NPPD needed to know how the possibility of higher cooling water temperatures would affect current plant operation and any future the capacity upgrades. It was decided to use PEPSE to predict how much heat rate and circulating water discharge temperature would increase, and if turbine exhaust pressure would cause potential unit deratings when operating with hotter circulating water inlet temperatures.

Addressing the Problem and Building the Model

The turbines at Gentleman Station are tandem-compound reheat turbines with dual shell condensers. Both units have two separate condensers for their boiler feed pump turbines. All of the condensers had previously been modeled in design mode for a previous project. There are also three equipment cooling water heat exchangers on each unit. The previous models were updated for plugged condenser tubes and the circulating water system remodeled to include the equipment cooling water heat exchangers. Figure 1 shows the circulating water system for the Unit 1 for PEPSE model.

It would have worked best to have gathered test data for the entire turbine cycle at several load ranges for one or more circulating water temperatures. The test data would be used to calculate heat transfer coefficients for the condensers when calibrating the models. However, time constraints prevented this kind of testing. It was decided to retrieve data from the archiving system on the stations's distributed control system. Due to the accuracy of some of the station instrumentation, it was decided to only retrieve temperatures and pressures around the condensers; and use vendor heat balance data for the balance of the cycle information. Data was gathered for loads of 280, 400, 530, 620, and 650 MW at a circulating water inlet temperature of 70°F. for both units. Data was also gathered for lower circulating water inlet temperatures at a load of 650 MW for Unit 1.

Operating data for the equipment cooling water heat exchangers was not available from the archiver. Fortunately the amount of heat absorbed in the heat exchangers is small compared to the condensers. The temperature rise of the circulating water through the heat exchangers was measured manually while the units were operating at a high load. The heat exchangers were modeled as one general heat exchanger with a specific heat source (component type 27) for each unit.

Determining how much circulating water flow went to each condenser and heat exchanger each was another problem. The total circulating water flows per unit for the project were provided by NPPD's Environmental Department. But there was not any way of measuring how much circulating water went to each condenser and heat exchanger in house. Time constraints did not permit hiring a consultant to obtain flow measurements by dye testing or other methods, so it was decided to try to have PEPSE calculate the flow splits.

Calibrating the Model

The first step in calibrating the model was to develop controls to calculate the measured turbine exhaust pressures and condenser circulating water outlet temperatures. After experimenting with different parameters, it was decided to adjust the circulating flow splits to calculate the measured circulating water temperature. The turbine exhaust pressures could be calculated by controlling the condenser heat transfer coefficients. Another control was written to control the circulating water temperature rise in the equipment cooling water heat exchangers.

Since the circulating water flow split should not change in actual operation, a split that would work with all the load ranges would have to be found. The Unit 1 data set for 650 MW was ran with all the controls active. The results PEPSE calculated for the circulating water flow splits were entered for the 620 and 530 MW data sets. These data sets were ran with the circulating water outlet temperature controls shut off. The sequence was repeated using the 620 MW data set with all the controls running to determine the flow split, and the 650 and 530 MW data sets were used to check the flow split. The flow split that best matched the circulating water outlet temperatures for the three data sets was used for the other data sets.

The 280 and 400 MW data sets were ran to calculate their heat transfer coefficients. The condenser heat transfer coefficients from all five cases were scheduled versus shell side steam flow for use in the predictive model.

There was some concern that changing the circulating water inlet temperature would affect the condenser heat transfer coefficients. The 650 MW data set for Unit 1 was ran at two lower circulating water temperatures with controls for the heat transfer coefficients running. The changes in the condenser heat transfer coefficients were insignificant.

The calibration procedure was repeated for the Unit 2 model.

The Predictive Model

The predictive model was ran using circulating water temperatures of 40, 50, 60, 65, 70, 75, and 80°F. for both units. The Unit 1 model was ran at loads of 200, 300, 400, 500, 600, 650, 660, 706, and 710 MW. The Unit 2 model was ran at loads of 200, 300, 400, 500, 600, 650, 680, 732, and 742 MW. The model was ran with circulating water flows to simulate both one and two circulating water pump operation for each unit.

Since one circulating water pump operation is not a normal operating mode for the station, data from the archivers was not available. The same circulating water flow split percentages for the condensers that were used in the two pump operation model were used.

Model Results

After the modeling was completed, data for turbine exhaust pressures, condenser circulating water outlet temperatures, circulating water system outlet temperature, circulating water system heat rejection, and gross turbine cycle heat rate were transferred to a spreadsheet. The spreadsheet was then utilized to trend and analyze the results.

If Gentleman Station's summer water temperatures were to increase from the 65 to 70°F range to 80°F, PEPSE predicts the following results should occur based on two circulating water pump operation.

1. Based on projected capacity factors, Unit 1's heat rate may increase 1.5 to 2.0 percent. Unit 2's heat rate may increase 0.8 to 1.0 percent.

2. At 80°F circulating water inlet temperatures and a gross generation above 680 MW, the circulating water discharge temperatures will exceed 103°F for both units. This will cause problems when operating at upgraded capacities, since on hot humid days the circulating water typically cools 10°F after it leaves the station before it is returned to the irrigation system, and the maximum permitted return temperature is 94°F. Figure 3 shows the projected system circulating water outlet temperatures for both units.

3. At 80°F circulating water temperatures, PEPSE predicts that the low pressure turbine B-1 exhaust pressure will alarm at approximately 640 MW. It appears that the turbine vendor recommended a conservative alarm set point of 3.5 "hga. The alarm set point is 5 "hg below the turbine trip set point of 8.5 "Hga. If Gentleman Station does have to operate at a circulating water temperature in the 80°F range, it should contact the vender about raising this alarm set point. Since the exhaust pressure did not exceed 4.0 "hga at 710 MW, operating at this exhaust pressure should not be a problem if the turbine exhaust hood temperatures remain below alarm levels. Turbine exhaust pressure should not be a problem with Unit 2 or the boiler feed pump turbine condensers. Figure 4 shows the predicted low pressure turbine B exhaust pressures for both Units.

There have been incidents when only one circulating water pump is available for a unit. When these incidents happen, the higher circulating water temperature will have a greater effect on operation. The predicted results for one circulating pump operation are:

1. At 80°F circulating water temperature, the low pressure turbine B-1 exhaust pressure may alarm at approximately 400 MW. This alarm point may be reached with circulating water temperatures as low as 60°F. At 80°F circulating water temperature, the low pressure turbine B-2 exhaust pressure may alarm at approximately 460 MW. Unit 2's low pressure turbine alarm point may be reached with circulating water temperatures as low as 65°F.

2. When operating with one circulating water pump, the boiler feed pump turbine exhaust pressure may dictate when the second boiler feed pump is placed in service instead of boiler feed pump capacity.

3. The model results show that system circulating water outlet temperatures may reach 120°F or more when operating with only one circulating water pump per unit. This condition should never occur, since low turbine exhaust pressures will prevent the unit reaching generation levels that will produce these temperatures.

4. The increase in heat rate could increase up to 4% for Unit 1 and 2.2% for Unit 2.

Project Summary

NPPD's Environmental Department is planning to perform a test to verify PEPSE's results for the system circulating water outlet temperatures in the spring of 1993. Depending on system generation demand and circulating water inlet conditions, Gentleman Station will try to verify the exhaust pressure and heat rate results during the summer of 1993. NPPD has recently purchased its own dye testing equipment.

This equipment may be used to measure the circulating flow through each condenser and heat exchanger.

Two items that were not addressed with the models are low pressure turbine exhaust hood temperature and equipment cooling water temperature. Operating history indicates that sometimes turbine exhaust hood temperatures increase faster than exhaust pressures when there is a problem with the circulating water system. If more information is gathered on how exhaust hood temperature changes with generation and circulating water temperature, a schedule can be developed to predict this. A schedule may also be developed for the equipment cooling water system after more information is gathered on this system.

Negotiations for the relicensing of irrigation project are continuing. Hopefully the new license will enable Lake McConaughy to continue to be a cold water lake. If the thermocline in Lake McConaughy is broken, it will have some negative effects on Gentleman Station's operation. Under normal operating conditions, summer heat rates could increase up to 2%. There is the potential that Unit 1 may be derated due to low pressure turbine exhaust pressure for both its current and upgraded capacities. When two circulating water pumps are operating, there should be little impact on Gentleman Station's permits for returning the circulating water to the irrigation system.

Figure 1

UNIT 1 CIRCULATING WATER SYSTEM

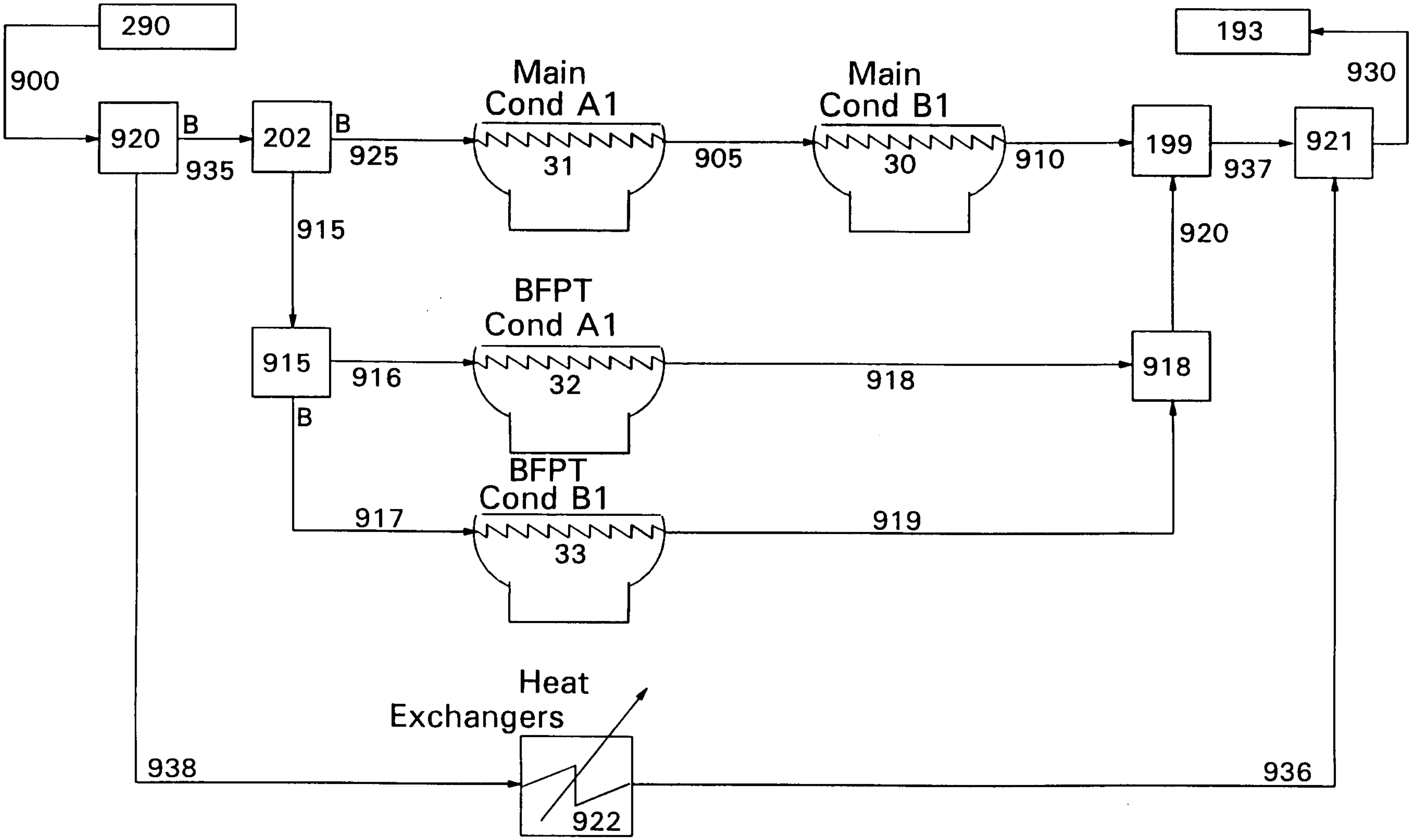
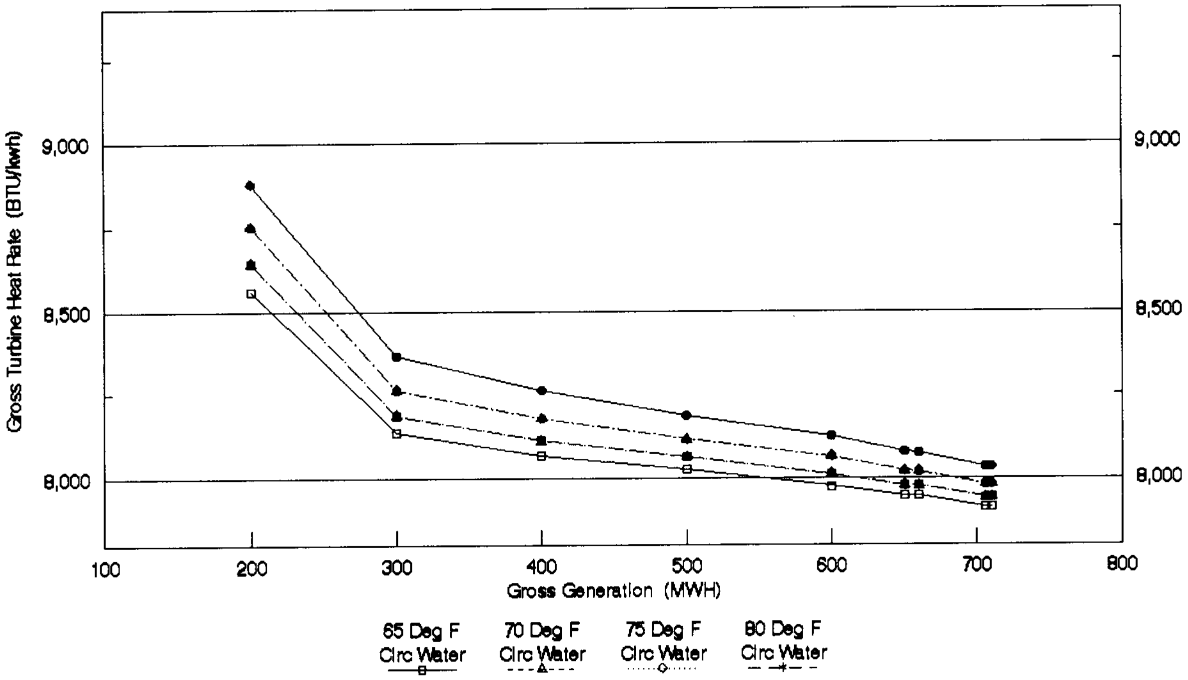
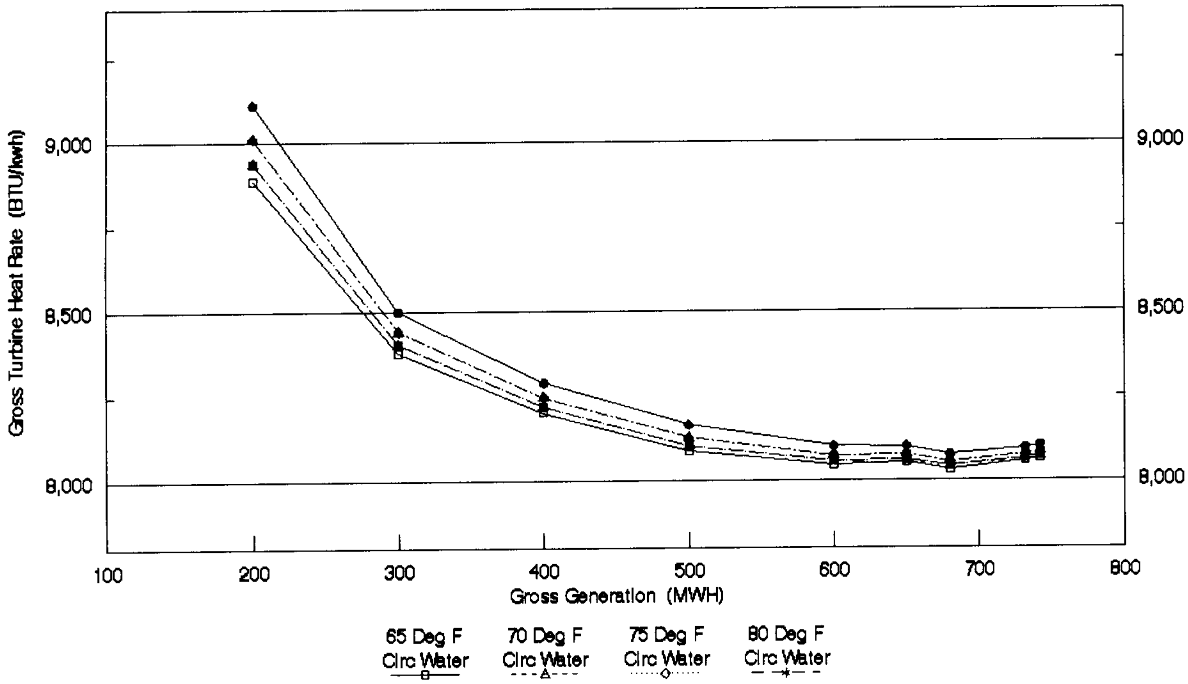


Figure 2

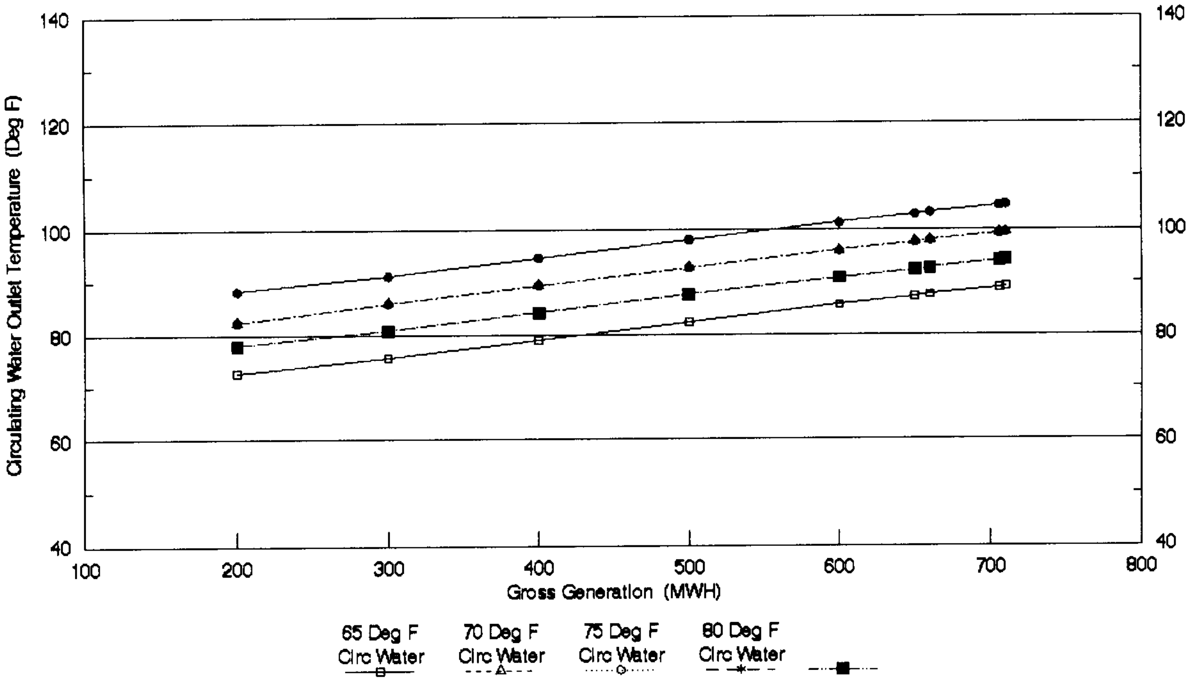


GROSS TURBINE HEAT RATE
GGS UNIT 1
596 Cfs Circulating Water Flow



GROSS TURBINE HEAT RATE
GGS UNIT 2
590 Cfs Circulating Water Flow

Figure 3


CIRCULATING WATER OUTLET TEMPERATURE
GGS UNIT 1
586 Cfs Circulating Water Flow

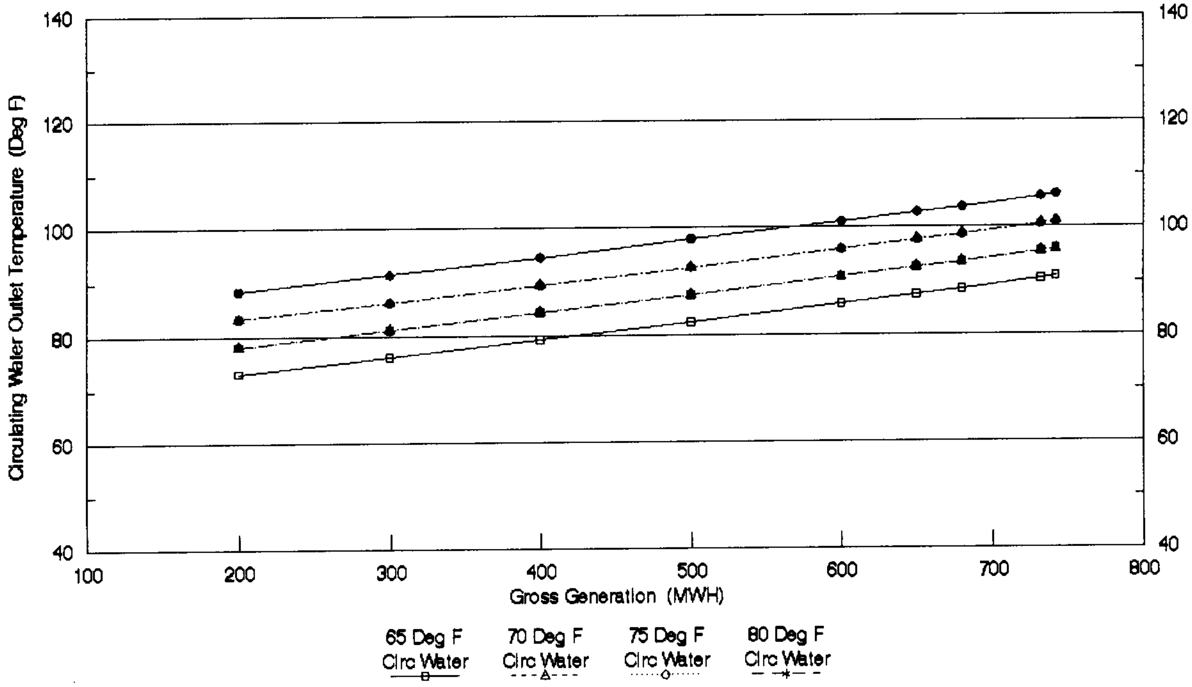
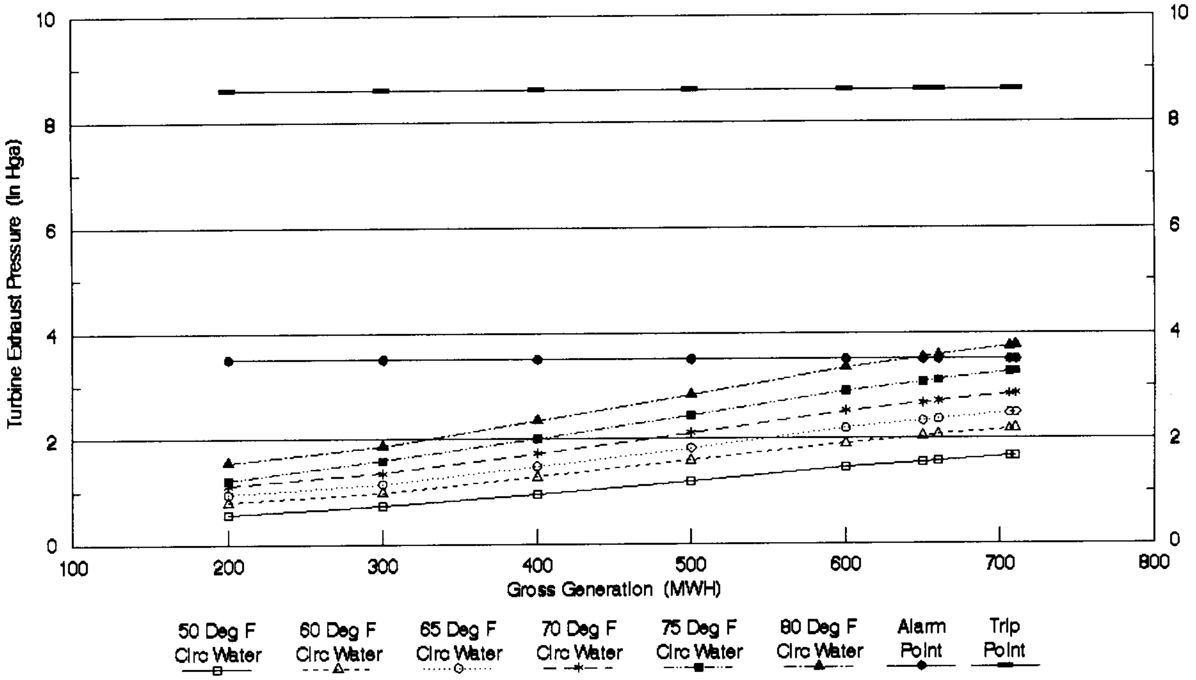

CIRCULATING WATER OUTLET TEMPERATURE
GGS UNIT 2
590 Cfs Circulating Water Flow

Figure 4

LP B-1 TURBINE EXHAUST PRESSURE

GGS UNIT 1

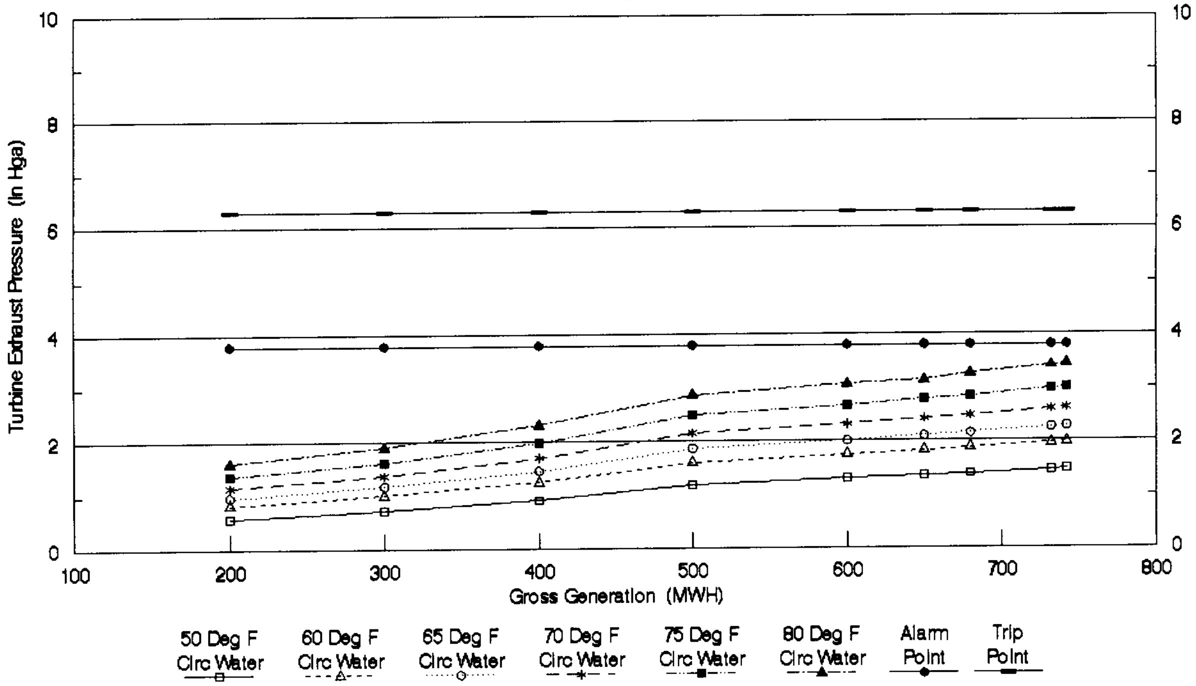
686 Cfs Circulating Water Flow



LP B-2 TURBINE EXHAUST PRESSURE

GGS UNIT 2

690 Cfs Circulating Water Flow



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