Low Pressure Feedwater Heater Performance Studies using PEPSE$^{\theta}$

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Abstract

Low-pressure feedwater heaters play an important role in turbine cycle performance. This study determines the impact that the #2 low-pressure feedwater heater has on the heat rate of Pleasants Power Station Unit #1 as determined by a Pepse model. It explores the effect that degraded #2 feedwater heater performance has on unit heat rate, as well as the impact of removing the heater from service. Pepse predicted results are then compared to actual test data.

This is a classic use of Pepse, as it is an excellent tool for analyzing how feedwater heater performance influences turbine cycle heat rate. Once an accurate model of a turbine cycle is built, simulating changes to feedwater heater performance, or analyzing the consequences of removing a heater from service, are tasks that are easily accomplished.

Introduction

Pleasants Power Station, located near Parkersburg West Virginia, is owned and operated by Allegheny Energy Supply. Unit #1 is an Allis-Chalmers turbine / generator with a rated output of 714 MW gross, at 4930 klb/hr-steam flow. Design operating conditions are 1000/1000 F main steam/hot reheat temperature at 3500-psi main steam pressure and 2.00 inches hg. condenser pressure. The boiler is a Foster Wheeler pulverized coal supercritical unit designed to output 5035-klb/hr steam flow. An SO2 scrubber provides emissions control.

This was a two-part Pepse study done to determine how the performance of the #2 feedwater heater impacts the turbine cycle heat rate. As implied, the #2 feedwater heater is the second low-pressure heater, with extraction steam supplied from double flow low-pressure turbines.

The first part of the study determines the effect that degraded #2 heater feedwater performance has on heat rate. This was a simplistic study done by varying the TTD and DCA of the #2 heater with the heater in performance mode.

The second part of this study ascertains the turbine cycle heat rate degradation caused by physically removing the #2 heater from service. The initial analysis was done with the next higher pressure heater, the #3 heater, in performance mode. A subsequent analysis was then performed with the #3 heater in simplified design mode. Modeling the #3 heater in simplified design mode more accurately accounts for the fact that the #3 heater will not perform at design TTD and DCA conditions given the resulting cooler condensate inlet temperatures it will receive while the #2 heater is out of service. Pepse predicted results are then verified with actual test data.

Pepse Modeling

The benchmark Pepse model for Pleasants Unit #1 was built from recent Siemens Westinghouse heat balances. Schedules have been input to simulate the entire operating range of the unit. This study, however, will concentrate on full load data only, since it is at full load that degraded heater performance has the most significant impact on unit heat rate. The benchmark Pepse model is shown in Figure 1.

For the first part of the study, the TTD and DCA of the #2 heater are degraded from design conditions to determine their influence on heat rate. Design TTD for the #2 heater is 5.0 degrees and the design DCA is 10.0 degrees. Both the TTD and DCA are degraded up to 30 degrees from design heater conditions in various increments. The #3 feedwater heater is kept in performance mode for the initial cases. The cases are later run again with the #3 heater in simplified design mode.

The second part of the study determines the heat rate penalty when the #2 heater is removed from service. This study involves routing the #3 heater drains to the condenser. This is necessary because the normal drains from the #3 heater to #2 heater will not be available once the #2 heater is physically removed from service. This involved some minor geometry changes to the base model. A mixer component #340 was added to the model and the drain from the #3 heater was routed through the mixer to the condenser. Changes to the base model are shown in Figure 2.

Stream 235 OPNCLO was then set to CLOSE to shut off the extraction steam to #2 heater and effectively remove it from service. The model was initially run with

#3 feedwater heater in performance mode at its design TTD of 5.0 and design DCA of 10.0.

The next step was to model the #3 feedwater heater in simplified design mode, to more accurately account for its performance given the lower temperature condensate that it would receive once the #2 feedwater heater is removed from service. Most of the information needed by Pepse to place the heater into simplified design mode was readily available from feedwater heater design sheets. The number of baffle plates in the drain cooling section and the flow area around them were approximated from heater design drawings. A control was written to calculate the condensing section heat transfer coefficient (UALLC) and the drain cooler heat transfer bypass flow factor (BPHDC). Calculating these two factors allows for the heat transfer needed to obtain design TTD and DCA values.

Finally, a two-hour set of actual operating test data was collected with Pleasants Unit #1 near design full load to determine the actual operating TTD and DCA of the #3 feedwater heater with the #2 heater out of service. The measured TTD was 15.8 and the DCA was 25.0. For modeling purposes, the #3 feedwater heater was placed back into performance mode with these measured TTD and DCA values applied. The results of all case studies are then compared.

PLEASANTS POWER STATION
PEPSE TURBINE CYCLE MODEL
Upgraded Heat Balance

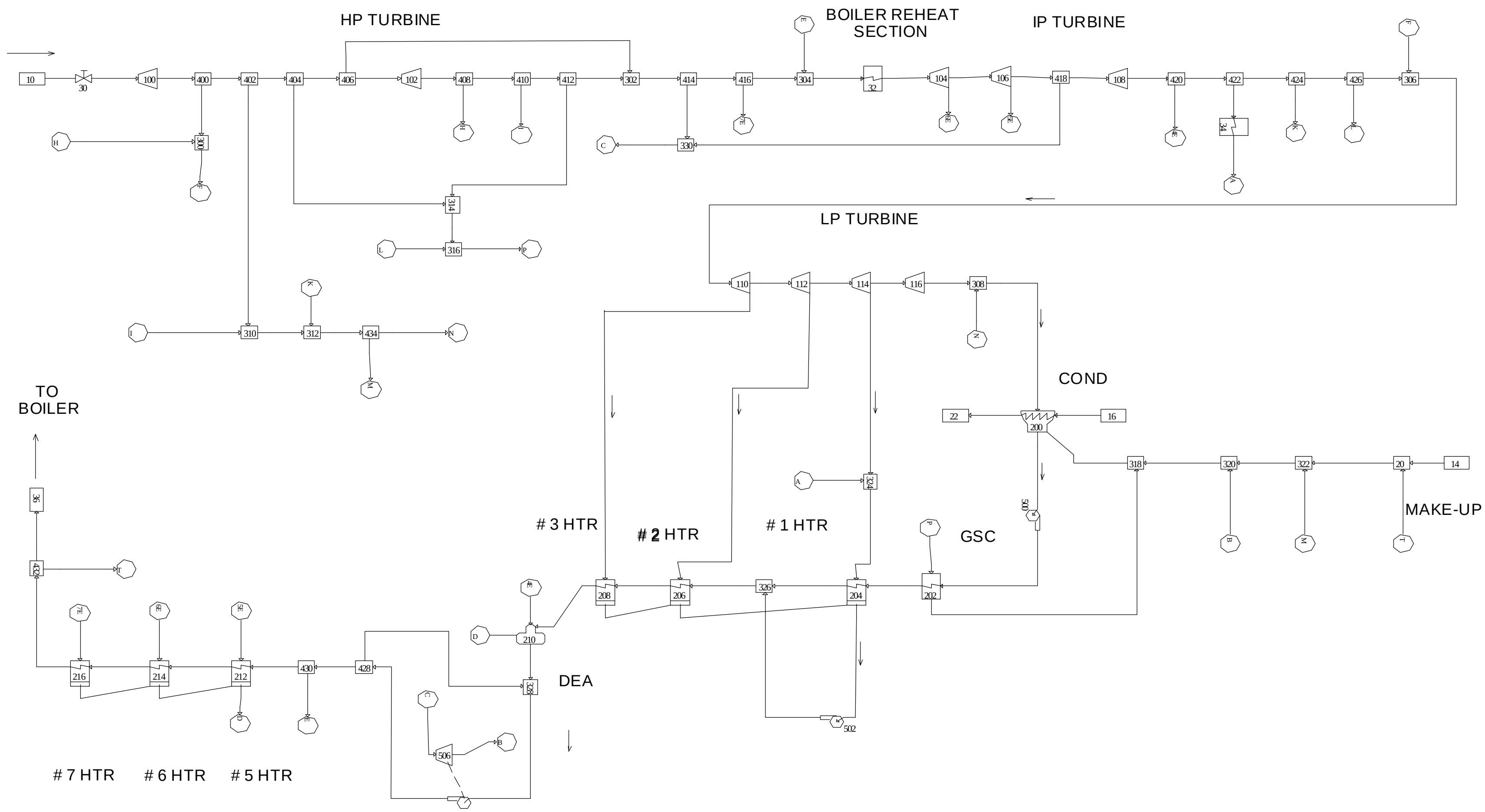

FIGURE 1 - Pepse Schematic of Pleasants Upgraded Base Model

PLEASANTS POWER STATION
PEPSE TURBINE CYCLE MODEL
Upgraded Heat Balance

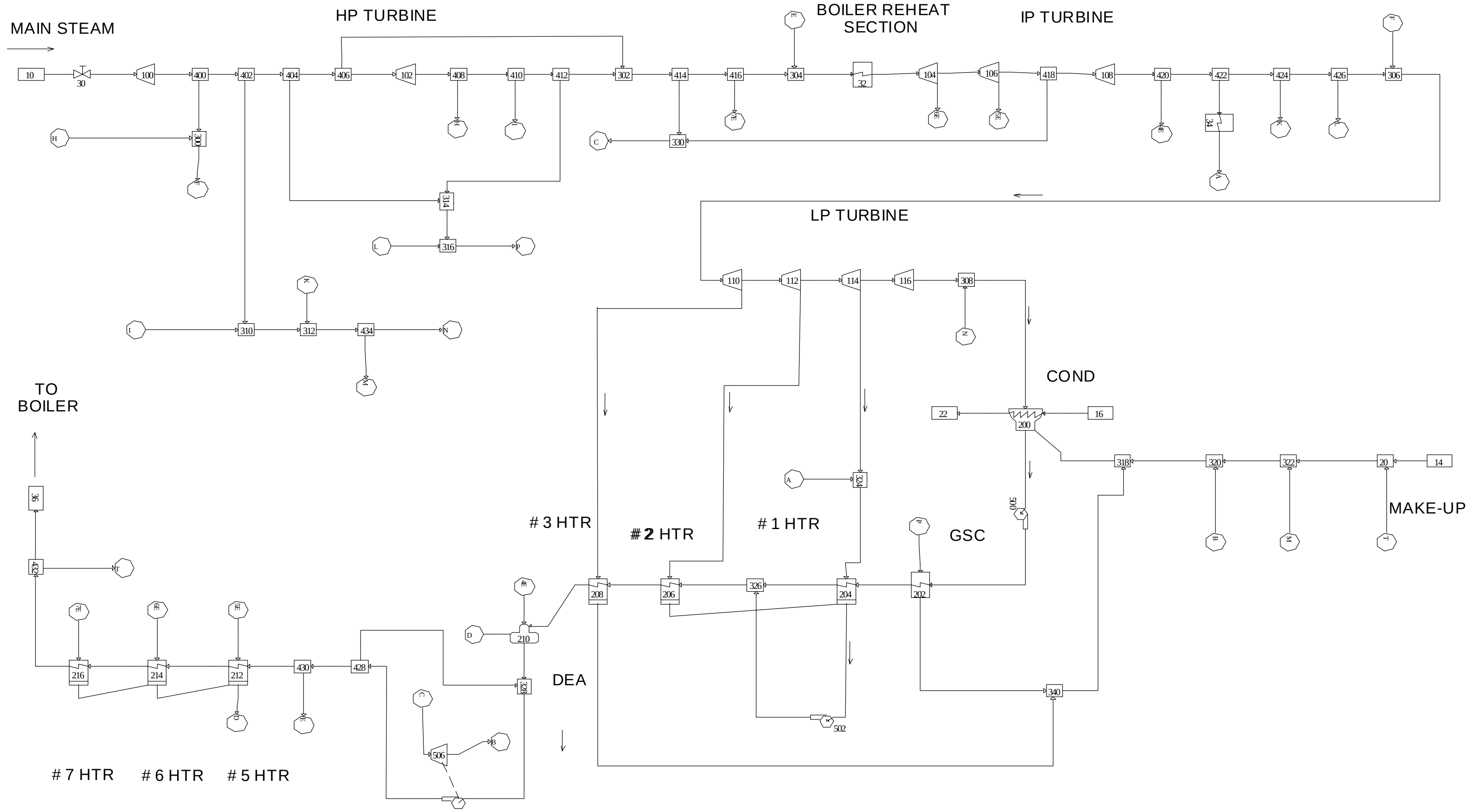

FIGURE 2 - Pepse Schematic of Pleasants Upgraded Base Model with #2 Feedwater Heater Out of Service

Results

The results of degrading the TTD and DCA of the #2 feedwater to determine the heat rate penalty are shown in table #1. They are benchmarked against design conditions as calculated by Pepse. For the TTD ranges shown in table #1, there is only a maximum of 1 Btu/Kwh heat rate penalty difference ascertained by calculating results with the #3 heater in simplified design mode. Therefore, the heat rate penalty results shown are calculated with the #3 heater in performance mode.

Table 1

Results of Degrading #2 Feedwater Heater Performance

Case	Description	TTD Deg f	DCA Deg f	Heat Rate Penalty Btu/Kwh
1	Design	5.0	10.0	0
2	Degrade both TTD and DCA 5 degrees from design	10.0	15.0	4
3	Degrade both TTD and DCA 10 degrees from design	15.0	20.0	8
4	Degrade TTD by 5 degrees and DCA by 10 degrees from design	10.0	20.0	4
5	Degrade TTD by 5 degrees and DCA by 20 degrees from design	10.0	30.0	6
6	Degrade TTD by 10 degrees and DCA by 20 degrees from design	15.0	30.0	10
7	Degrade TTD by 5 degrees and DCA by 30 degrees from design	10.0	40.0	8
8	Degrade TTD by 10 degrees and DCA by 30 degrees from design	15.0	40.0	11
9	Degrade both TTD and DCA 20 degrees from design	25.0	30.0	16
10	Degrade both TTD and DCA 30 degrees from design	35.0	40.0	24
Note:	For this study, the difference in heat rate by operating the #3 heater in design mode vs. performance mode is negligable: 1 btu / kwh worse case.			

Table #2 compares the heat rate and generation penalties caused by removing the #2 feedwater heater from service. Case 2 shows the results of Pepse runs made with the #2 heater out of service and the #3 heater in performance mode. These are compared to case 3 runs, which were made with #3 heater in simplified design mode. The Pepse models accuracy with #3 heater in simplified design mode is then verified when actual operating test results for the #3 heater are applied to the model in case 4. These are the actual performance test parameters for the #3 heater taken with the #2 heater out of service. The #3 heater was placed back into performance mode and the tested heater TTD and DCA input to accomplish this.

Pepse calculated a TTD of 14.0 for the #3 heater in simplified design mode for case 3. As expected, this calculated TTD was relatively close to the measured TTD of 15.6 that was applied to the performance mode #3 heater in case 4. The difference between the calculated and measured TTD can probably be attributed to some combination of instrument error and possibly some heater fouling.

Table #2

#2 Heater Removed from Service

Case	Description	Heatrate Penalty Btu/kwh	Generation Mw	Generation Penalty Mw
1	Design heat balance (All heaters in service & in performance mode)	-----	713.1	-----
2	#3 heater in performance mode with design TTD & DCA (#2 heater out of service)	48.0	708.8	4.3
3	#3 heater in design mode (#2 heater out of service)	58.0	707.7	5.4
4	#3 heater in performance mode with measured TTD & DCA (#2 heater out of service)	57.0	707.8	5.3

Once the #2 feedwater heater is removed from service, heaters number 1 and 3 both extract more steam, but the condensate temperature leaving #3 heater is still colder than design model conditions. Ultimately, the Deaerator is able to heat the condensate back to design conditions at its exit. But it must extract more steam at a higher energy level than the #2 extraction from the turbine cycle to accomplish this. The result is less steam flow through the LP turbine blade path, thus resulting in decreased megawatt generation and increased heat rate, given constant steam inlet conditions to the model. Table 3 shows calculated Deaerator and LP turbine stage extraction flows and generation comparing the benchmark model to the #2 feedwater heater out of service models.

Table 3

Case	Deaerator extraction flow (Klb/hr)	LP turbine inlet flow (Klb/hr)	#3 heater extraction flow (Klb/hr)	#2 heater extraction flow (Klb/hr)	#1 heater extraction flow (Klb/hr)	LP turbine exhaust flow (Klb/hr)	Gross generation MW	Heat rate penalty BTU/kwh
Design Benchmark (all heaters in perf. mode)	238	3489	215	282	164	2827	713.1	-----
#3 heater in perf. mode (#2 heater out of service)	262	3466	460	0	192	2814	708.8	48
#3 heater in design mode (#2 heater out of service)	296	3431	431	0	190	2810	707.7	58
Conclusion: Deaerator ultimately makes up the lost temperature in the condensate, but it must extract more steam to do so. #3 and #1 heaters also extract more steam. The result is less steam flow through the lp turbine bladepath resulting in a decrease in megawatt generation.								

Conclusions

Pepse is a very useful tool for analyzing feedwater heater performance issues. Performance degradation calculations are easily accomplished with the heater or heaters in question in performance mode.

Heater out of service analysis may be performed with other pertinent heaters in the turbine cycle in performance mode or in design mode. Keeping the heaters in performance mode requires less modeling time. But, as is evidenced with this studies comparison to actual operating data, design mode analysis of the remaining heaters appears to provide more accurate results.

Summary

Using the Pepse software to analyze the performance of the #2 feedwater heater at Pleasants Power Station Unit #1 allowed us to quantify the costs of its degraded performance. Pepse also helped us to explore the possibility and associated costs of temporarily operating the unit with the #2 heater removed from service.

Since this study was done, the original #2 heater at Pleasants unit #1 has been replaced and the #2 heater at the sister unit, Pleasants #2 is scheduled for replacement.

References

1. Pepse Manual Volume I, Version GT 4.0, Scientech Inc., 440 West Broadway, Idaho Falls, Idaho.

2. Gene L. Minner, "Feedwater Heater Out of Service Analysis – Comparisons of Results Using Design & Performance Modes in Pepse", Pepse Users Group Meeting, Charleston Sc., June 1996.