Boiler Modification Studies at Gerald Gentleman Station Unit 1

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1.0 Introduction

For several years, Nebraska Public Power District's (NPPD) Gerald Gentleman Station Unit 1 (GGS1) has experienced boiler problems. Specifically, Unit 1 has had difficulty achieving design main steam and reheat steam temperatures. In addition, the economizer exit gas temperature has been too high, and the reheat surface has become routinely fouled.

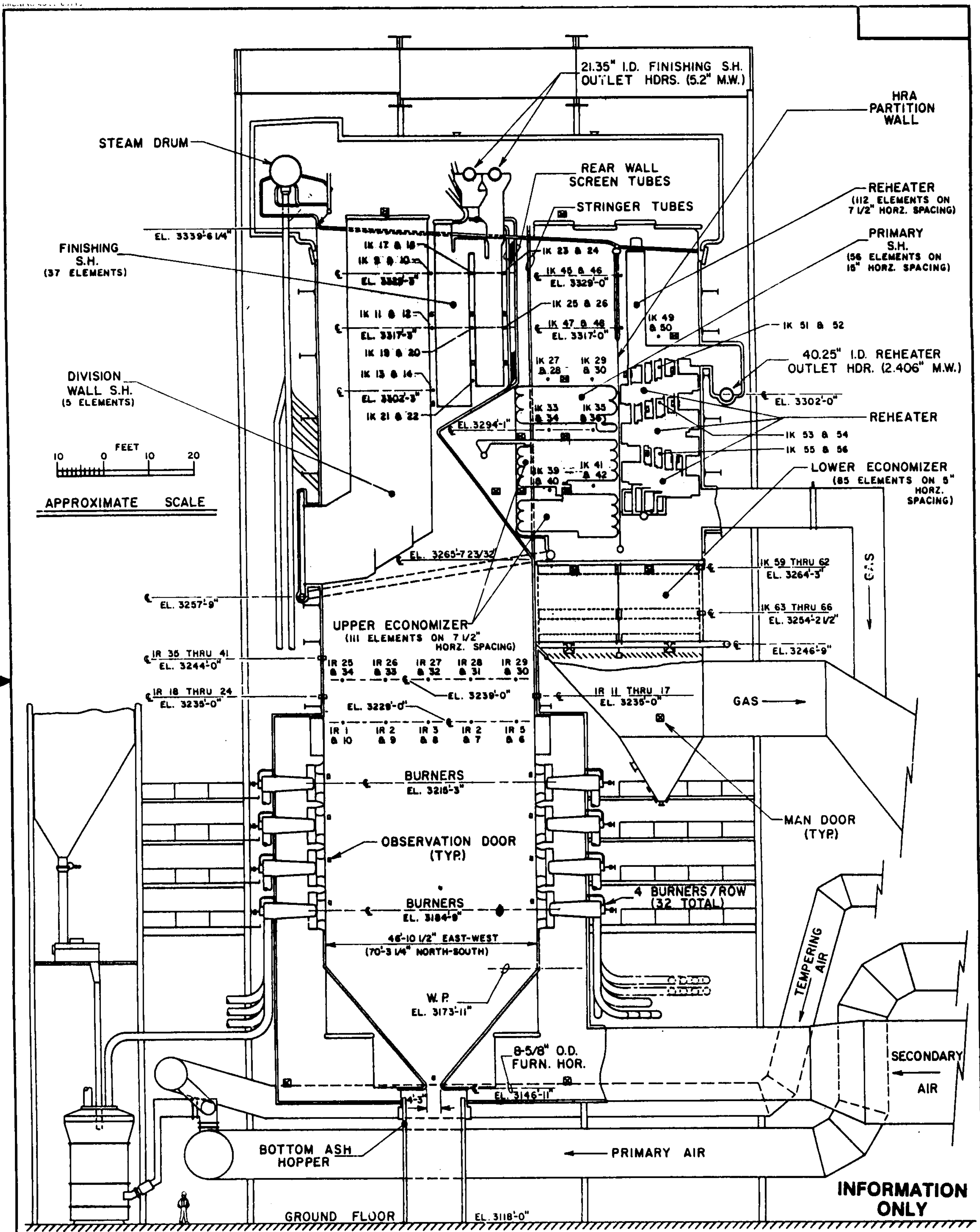
To determine the cause of these problems and to find possible solutions, NPPD contracted with a boiler manufacturer to review results of a recent performance test on the boiler (April, 1993) and offer possible solutions. Some of the solutions offered by the boiler manufacturer were unrealistic, while others offered some promise.

In early 1994, NPPD and Performance Engineering, Inc. (PEI) reviewed the results of the boiler manufacturer using a PEPSE (Performance Evaluation of Power System Efficiencies) model originally developed by NPPD and later modified by PEI. In addition, solutions not offered by the boiler manufacturer were studied. Results of the PEPSE study showed that increases to the reheat and superheat surface areas would increase the steam temperatures to the design levels while decreasing the gas temperature leaving the economizer. However, the studies also showed that keeping the surfaces clean would produce the same effect as adding more area without the capital investment.

The results of the PEPSE study on GGS1 are presented and solutions are offered. A discussion of the PEPSE model and modeling techniques used for this study are also presented.

2.0 Unit Description

Gerald Gentleman Station is a two-unit pulverized coal fired electric generating station located in Sutherland Nebraska, 20 miles west of North Platte. Unit 1 has a boiler designed by Foster Wheeler with a design operating main steam pressure of 2400 psig and design main steam and hot reheat temperatures of 1005 °F. Figure 1 shows an elevation schematic of this boiler.



REVISIONS	
B	LABELED FINISHING S.H. & REHEATER OUTLET HEADERS. BY J.F.A. 6-7-88

NOTES:

1. NOT TO SCALE
2. ACCESS IN AND AROUND IK 51 THRU 56 (REHEATER) IS DIFFICULT.

SIGNIFICANT NUMBER | GROUP 1

Figure 1

SECTIONAL SIDE VIEW

BOILER - LOOKING NORTH

GERALD GENTLEMAN STATION "UNIT I"

DRAWN J.F.A.	DATE 5-31-88
CHECKED JRF	DATE 6-1-88
APPROVED	DATE 6-7-88
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3.0 PEPSE Model and Study

PEI's study consisted of: (1) reviewing and modifying (if required) the existing GGS1 PEPSE boiler computer model, and (2) performing sensitivity studies using this computer model. This effort included verifying, if possible, the studies performed by a boiler manufacturer on GGS1 and, additionally, performing new studies to look at alternatives to improving the boiler performance not included in the boiler manufacturer's study.

Extensive modifications were made by PEI to the existing GGS1 PEPSE model. Input related to the geometry of heat transfer surfaces was reviewed in detail and appropriate changes made to the model. Other data were also checked thoroughly and changed, if required. The model was tuned to the performance test of April, 1993 at three loads: 640 MW, 550 MW, and 400 MW. Figure 2 presents the modified PEPSE boiler model schematic.

Nine case studies were made using the modified model. The first five as listed below paralleled the boiler manufacturer's studies in order to verify (or disprove) their results. The remaining four studies were new and were based upon input from and experience of the NPPD staff and PEI staff. The case studies are as follows:

(1) Additional reheat surface area was added in this study.

(2) Additional radiant superheat area was added in this case.

(3) The primary superheater was completely replaced in this study.

(4) This study was a combination of Case (1) and Case (2).

(5) Radiant superheaters were added as in Case (2) and new reheat surface was added (different from Case (1)) in this study.

(6) The radiant superheat division walls were "cleaned" in this study by enhancing the heat transfer.

(7) The reheat surface was "cleaned" in this study by improving the reheat heat transfer.

(8) The finishing superheater was "cleaned" in this study by enhancing the heat transfer in this section.

(9) This study included the replacement of the primary superheater (as in Study (3)) and the "cleaning" of the reheater and new primary superheater by increasing the heat transfer in these sections.

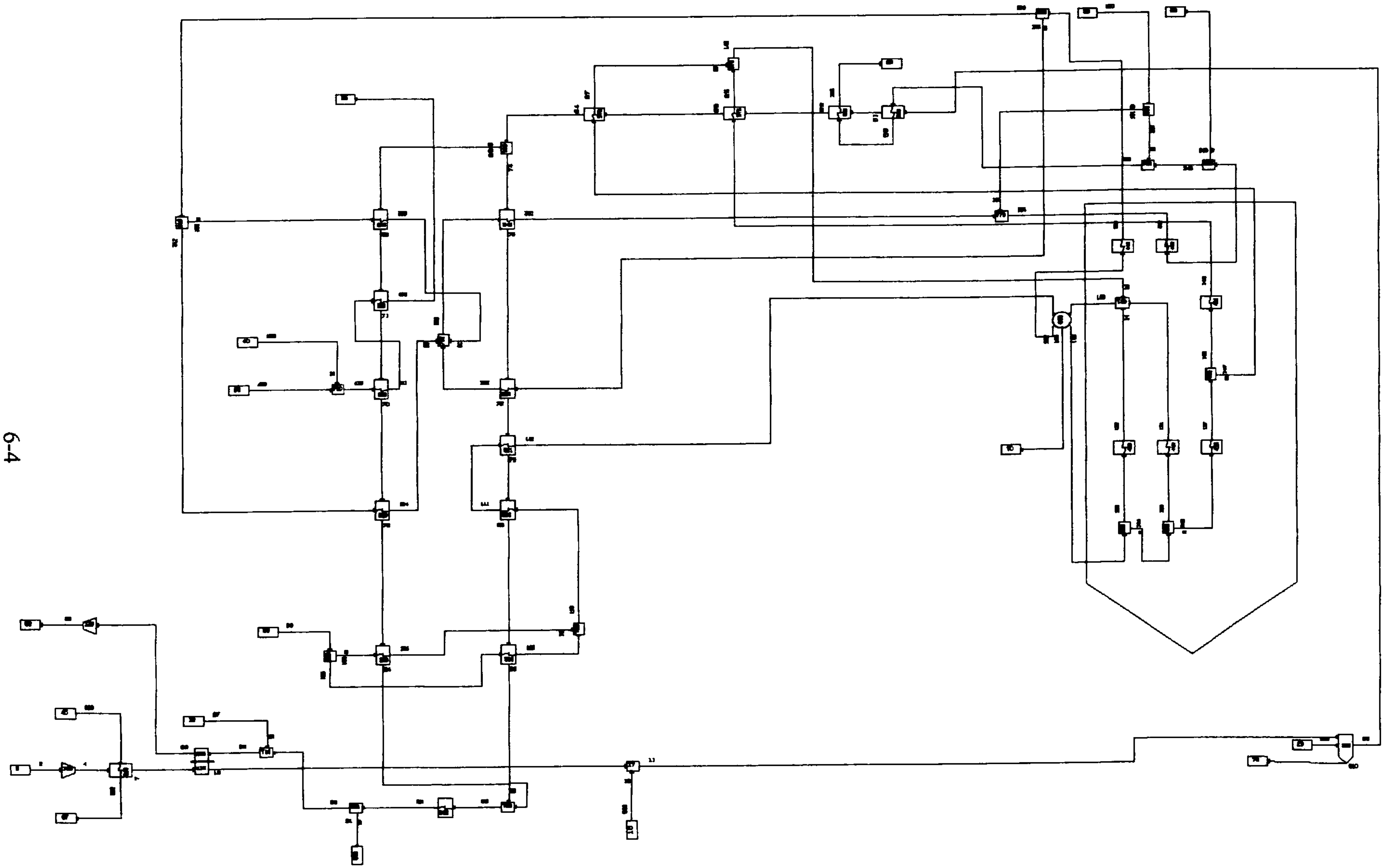

Figure 2

GGS Unit 1 PEPSE Model

The results of these studies are discussed in the next section.

4.0 Case Study Discussion and Results

The nine case studies and their results are discussed in detail here. All base studies were performed at the three test loads (640 MW, 550 MW, 400 MW). If alternate studies were performed, they were done at the maximum load (640 MW) only. Results discussed here will be for the maximum load (640 MW) only. Table 1 summarizes the results of all the studies. All discussions are referenced to the Base Case of Table 1.

Case 1

This study looked at the addition of reheater surface area. The area was added in series with the existing reheat surface at the outlet of the existing reheater. Its position in the flue gas path was at the inlet of the reheat backpass.

A single loop of two tubes with 78 elements across was studied. The tubes were 2-1/4 inch OD with approximately 2000 ft^2 of surface area.

Results of this study showed that this option produces a decrease in hot reheat temperature of approximately 15 °F while producing an additional pressure drop of 270 psi in the reheater. The temperature decrease is caused by an increase in the steam enthalpy due to the extra heating surface and the large decrease in the pressure.

An alternate study was performed, using the additional reheat surface, but forcing the additional pressure drop to zero. This caused no change in the reheat temperature.

For both studies, the final superheat temperature and the flue temperature leaving the economizer were virtually unchanged.

Case 2

This study looked at the effects of adding four additional radiant superheaters in the four spaces between the existing five radiant superheater platens. These additional superheaters had the same dimensions as the existing radiant superheaters, increasing the heating surface by approximately 11,000 ft^2.

Initial results showed an increase in final superheat temperature of 28 °F (to 980 °F) and a decrease in hot reheat temperature of 9 °F (to 986 °F). Economizer flue gas outlet temperature decreased by 3 °F (to 843 °F).

TABLE 1

CASE RESULTS

	Final SH Temp	Final RH Temp	Econ Flue Temp	%SH/%RH Split
	(°F)	(°F)	(°F)	%/%
Design	1,005	1,005	715	--
Base Case	952	994	846	**
Case 1	952	979	844	**
Case 1A	952	994	844	**
Case 2	980	986	843	**
Case 2A	995	1,010	853	**
Case 3	951	999	848	**
Case 3A	978	1,017	856	51/49
Case 3B	1,000	1,006	862	58/42
Case 4	980	989	841	**
Case 4A	990	1,006	848	**
Case 5	942	1,010	814	**
Case 5A	952	1,031	822	**
Case 5B	994	1,005	857	70/30
Case 6	959	991	845	**
Case 7	930	1,014	805	**
Case 8	1,010	972	836	**
Case 9	983	983	853	58/42
Case 9A	999	998	757	58/42

Notes:

** %Superheat/%Reheat Split calculated by PEPSE based on pressure drop, approximately 48%/52%

Base Case - PEPSE model case using performance test results of 4/93, fuel flow = 728,650 lb/hr.
Case 1 - Additional reheat surface, Case 1A is without RH pressure drop
Case 2 - Four more radiant superheater panels, Case 2A is 10,500 lb/hr more fuel
Case 3 - New primary superheater, Case 3A is 10,000 lb/hr more fuel and 3% more flow in superheat backpass, Case 3B is 58%/42% superheat/reheat backpass flow split
Case 4 - Combination of Cases 1A and Case 2, Case 4A is 8,400 lb/hr more fuel
Case 5 - Case 2 and additional reheat area, Case 5A is 8,960 lb/hr more fuel, Case 5B is 70%/30% superheat/reheat backpass flow split
Case 6 - Radiant superheater panels cleaned
Case 7 - Reheat surface cleaned
Case 8 - Finishing superheater cleaned
Case 9 - Case 3 with 58%/42% superheat/reheat backpass flow split, Case 9A is reheat and primary superheat cleaned

An alternate study was performed using the same increase in radiant superheater area but increasing the fuel flow by 10,500 lb/hr. Results showed an increase in final superheat temperature of 43 °F (to 995 °F) and an increase in hot reheat temperature of 16 °F (to 1010 °F). Economizer flue gas outlet temperature increased by 7 °F (to 853 °F).

Case 3

Case study 3 investigated the effects of replacing the existing primary superheater with a new primary superheater. The surface area increased only slightly (+1,000 ft^2), but the open flow area was reduced by reducing the tube bundle spacing from 15 inches to 9.5 inches.

Results of this study showed that the final superheat temperature stayed about the same while the final reheat temperature increased a few degrees. The economizer flue gas temperature increased slightly.

Two alternate studies were performed. In the first, the fuel flow was increased by 10,000 lb/hr, and 3% more flow was directed to the superheat side of the backpass. This raised the final superheat temperature by 26 °F (to 978 °F), the final reheat temperature by 23 °F (to 1017 °F), and the economizer flue gas temperature by 10 °F (to 856 °F).

The second alternate study used the increased fuel flow of the first, but further increased the flow to the superheat backpass to a total of 58% of the total flue gas flow. Temperatures of 1000 °F at the final superheat, 1006 °F at the final reheat, and 862 °F at the economizer flue gas outlet were calculated.

Case 4

This case was a combination of Cases 1 and 2. The reheat pressure drop of Case 1 was set to zero.

Results showed an increase in final superheat temperature of 28 °F (to 980 °F), a decrease in final reheat temperature of 5 °F (to 989 °F), and a 5 °F decrease in the flue gas temperature exiting the economizer (to 841 °F).

An alternate study was performed using the same conditions as the base case but increasing the fuel flow by 8,400 lb/hr. The final superheat temperature increased 10 °F more (to 990 °F), the final reheat temperature increased 17 °F more (to 1006 °F), and the economizer flue temperature increased by 7 °F more (to 848 °F).

Case 5

In this study, the additional radiant superheat surface from Case 2 was combined with additional reheat surface. This additional reheat surface extends into the cavity above the primary superheater and adds approximately 14,500 ft^2 to the total reheat area.

Results of this study show a decrease in final superheat temperature (to 942 °F), an increase in final reheat temperature (to 1010 °F), and a large decrease in the economizer flue gas temperature (to 814 °F).

Two alternate studies were also performed. The first included the additional superheat and reheat area, and increasing the fuel flow by 8,960 lb/hr. This caused the final superheat temperature to increase by 10 °F over the base Case 5 (to 952 °F), the final reheat temperature to increase by 21 °F over the base Case 5 (to 1031 °F), and the economizer flue gas temperature to increase to 822 °F.

The second alternate study was similar to the first alternate, except the superheat/reheat backpass flow split was set to 70%/30%. This resulted in a final superheat temperature of 994 °F, a final reheat temperature of 1005 °F, and an economizer flue temperature of 857 °F.

Case 6

For this case study, the cleanliness of the radiant superheater platens was increased by increasing the overall heat transfer by 25%. Results showed that the final superheat and reheat steam temperatures, and the economizer flue temperature, changed by only a few degrees.

Case 7

Case 7 investigated the effects of cleaning the reheat surface. This was accomplished by improving the reheat heat transfer by approximately 20%. The final superheat temperature decreased to 930 °F, the final reheat temperature increased to 1014 °F, and the economizer flue temperature decreased to 805 °F.

Case 8

The finishing superheater cleanliness was improved for this study. To accomplish this, the heat transfer in the finishing superheater was increased by about 200%. Results showed that the final superheat temperature increased to 1010 °F, the final reheat temperature decreased to 972 °F, and the economizer flue gas temperature decreased to 836 °F.

Case 9

In Case 9, the new primary superheater surface studied in Case 3 was used, but the superheat/reheat backpass flow split was changed to 58%/42%. Both the final superheat temperature and the final reheat temperature were calculated to be 983 °F. The calculated economizer flue gas temperature was 853 °F.

An alternate study was also performed, This alternate started with the base Case 9 while improving the reheat and primary superheat surface cleanliness. The cleanliness was improved by increasing the heat transfer in the reheater and primary superheater by approximately 20% and 100%, respectively. The final superheat and reheat steam temperatures increased to 999 °F and 998 °F, respectively, and the economizer flue temperature was reduced to 757 °F.

4.0 Discussion

For GGS1, steam temperatures can be increased and flue gas temperatures lowered by various combinations of reheat and/or superheat surface area changes. However, cleaning the existing surfaces may have nearly the identical effects but at a lower cost.

Not every possible combination of surface area change and surface cleaning could be studied in the finite time available for this study. However, NPPD has an accurate PEPSE computer model of GGS1 that can be used for future performance predictions.

Finally, computer tools such as PEPSE offer cost-effective methods for studying plant equipment and operational changes. Simulating the plant using detailed computer models provides performance predictions before purchasing expensive hardware of making costly operational changes.

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