Predicting Boiler Performance for An Oil to Gas Conversion

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Abstract:

The effect on the thermal performance of an oil to gas conversion is analyzed using PEPSE. The modeling techniques are refined initially by choosing a unit that has already converted from oil to gas and modeling it with both fuels. The modeling methods acquired from this exercise are then applied to a unit that is currently under consideration for an oil to gas conversion.

In modeling the unit that has already been converted, the oil model is calibrated first to match test data. We then construct the gas model by changing the fuel type and calibrate the new model to match gas test results. The gas calibration is performed by holding all furnace area, heat transfer coefficient and view factor multipliers constant while modifying the fuel, gas recirculation and attemperation flows until reasonable agreement is obtained.

When modeling the unit that has not yet been converted, the model is first calibrated to test data to refine all multipliers. The fuel type is then changed to gas while modifying fuel, gas recirculation and attemperation flows in proportion to the amounts in the unit previously converted.

The results indicate that the furnace exit gas temperature increases by about 123°F when the fuel is changed to gas for the 550 MW boilers that we studied. A boiler efficiency reduction of 4.6 percent is predicted when switching to gas fuel.

Introduction

Collins Station has two 572 MW units (units 1 and 2) and three 550 MW units (units 3 - 5). All units are subcritical(2400 psia, 1005°F main steam). Units 1 - 3 are Babcock and Wilcox boilers shown in Figs. 1 and 2. They have an interesting design in that there are no platen sections hanging in the boiler and the flue gas does not make a 90 degree turn to travel around the nose as it enters the convection pass as in conventional boilers. It travels upward out of the boiler, gets confined to about half of its original flow area and travels past the primary and secondary superheaters and part of the reheater before making a 180 degree turn and traveling downward past the remaining reheater and economizer. Units 4 and 5, which are illustrated in Figs. 3 and 4, are also Babcock and Wilcox boilers but are more of a conventional design. The gas flows past radiant secondary superheat platens before making the 90 degree turn to enter the convection pass and flows through the remaining secondary superheater and the reheater. It then makes another 90 degree turn to enter the primary superheater and the economizer.

The only fuel that the station burned was No. 6 oil until 1993 when units 1-3 were converted to burn both oil and gas. Before this occurred a consultant was hired by our company to evaluate the effects of the fuel switch on furnace performance and to recommend any design modifications. The consultant determined that the units did not need any design modifications except for enlarged attemperator nozzles and that the units would be capable of burning 100% natural gas without taking a derating or experiencing any overheating problems.

The conversion was accomplished in 1993 and adequate test data is presently available to determine the actual effects of the fuel switch on furnace performance. As predicted, the units did not need to take a derating, are able to achieve the design steam temperatures and have not experienced any overheating problems in the convection or radiation areas because reheat and superheat attemperation flows have increased.

Currently the station is evaluating the feasibility of converting units 4 and 5 to gas also. Our Engineering Dept. requested that we perform the thermal analysis to determine if any boiler modifications are necessary. The analysis was conducted with the assistance of the PEPSE computer program.

Units 1-3 Analysis

Since units 1 -3 have already been converted to gas they are modeled using PEPSE first. The station supplied heat rate test data on unit 3 at 550 MW for both the oil and gas cases to assist in benchmarking the model. The PEPSE boiler design mode model shown in Fig. 5 is constructed for both cases.

Units 1-3 have a portion of the primary superheater that is radiant. This configuration is simulated with PEPSE by dividing its four passes into two parts: one pass as a radiant section and the other 3 passes as convection. Since only the first tube in the radiant section is in full view of the flame and the other six tubes are not, a radiant view factor of 25% is chosen which represents an approximate average of the tubes in the section.

Another item of decision presents itself when we model the waterwalls. The waterwalls proceed to the top of the radiant zone and upward to the top of the furnace (see Fig. 1). In a conventional boiler almost all of the waterwall area is in the radiant zone and therefore the modeling is somewhat less complicated. To simulate this configuration accurately the waterwalls are divided into two parts: the radiant section which is inside the boiler, and a convective section which is placed between the two reheat sections in the top of the furnace. Note that the waterwall sections could be divided into more than two parts by installing a small portion between each of the pendants and platens but it was determined that utilizing a less complicated model with only two sections produces sufficient accuracy.

After all design data is entered, attemperators are modeled in PEPSE by utilizing type 50 mixers that mix feedwater with the cold reheat and primary superheat outlet streams. The actual plant data is utilized for the flows and the outlet temperature of the type 50 mixer calculated by PEPSE is compared to the actual steam temperature exiting the attemperator to determine if we simulated reality accurately. The comparison determines that the temperature on unit 3 is within 20°F of the actual measurements. We then utilize PEPSE to adjust the flows until the temperatures agree within 2°F.

Units 1-3 utilize flue gas recirculation for controlling NOx and steam temperature. To assist in controlling steam temperatures the recirculation flow may enter the furnace at the windbox or at the bottom. The entry at the windbox is modeled by utilizing a type 50 mixer with the air heater air outlet. The bottom entry is simulated with the use of the furnace IX port. At full load the plant heat rate test data utilized to calibrate the model dictates that there is no flow at the furnace bottom. Therefore we mix recirculated flue gas with the air inlet at the furnace until the measured furnace windbox temperature is achieved.

The heat transfer in the waterwall sections is constrained with the use of a control written to vary the furnace multiplier(FHTRLS) until the energy imbalance on the steam drum reaches an acceptable level of less than 1000 Btu/hr. After the PEPSE results are calibrated to agree with measured plant data to within 8°F for all temperatures, a furnace multiplier of 1.1 is obtained. The model results are illustrated in Fig. 1. This completes the unit 3 oil model.

The fuel on units 1-3 is then changed from oil to gas. All multipliers determined for the furnace and tube banks for the oil case are held constant for gas. The reheat and superheat attemperation flows in the model are adjusted until the measured superheat and reheat steam temperatures are obtained. The calculated attemperation flow by PEPSE is within 10% of measured plant data.

The gas recirculation is adjusted until it agrees with measured windbox temperature data. When this is achieved the control for the furnace area multiplier (FHTRLS) is calculating the same value as in the oil case (1.1). When the fuel is changed, the furnace size will not physically change unless a modification is performed. Therefore unless an event occurs after a fuel switch that was not evident before, such as slagging, fouling, or increased heating in a particular area, PEPSE should utilize the same furnace area and heat transfer multipliers for both fuels. In this case, for an oil to gas switch, we assume that no such events will occur. Therefore when the PEPSE model calculates the same multipliers for both cases, it provides assurance that the model has been calibrated accurately.

Units 1 - 3 Results

As Fig. 2 illustrates, the furnace exit gas temperature for gas firing increases 123°F relative to the oil case. This is due to the less radiant gas flame not transferring as much heat in the boiler waterwalls. As a result the furnace exit gas temperature increases and causes the unit to attemperate more to control the steam temperatures. When the attemperation flow increases, the heat transfer in the waterwalls is further reduced. This increases furnace exit gas temperature also.

It is interesting to note that the adiabatic flame temperature in the furnace is relatively unchanged for both the oil and gas cases. This is observed to be partially due to the decrease in flue gas recirculation for the gas case. In order to match actual furnace windbox temperatures, less recirculation flow is required.

The boiler efficiency is approximately 4.6% lower for gas than it is for oil. In examining the boiler efficiency output table provided by PEPSE, this difference is observed to be largely due to the greater amount of moisture loss from burning hydrogen for the gas case. The hydrogen unites with the oxygen in the combustion air to form water that is vaporized in the furnace. This consumes more energy for the gas case.

Units 4 and 5 Analysis

The next model constructed is unit 4(see Fig. 6). Actual plant data is utilized to simulate boiler operation with oil fuel. The model is calibrated in a similar manner to that discussed above for units 1-3 except that the waterwall heat transfer does not need to be accounted for in the upper furnace because units 4 and 5 are of a more conventional design with almost all of the waterwall tubes in the radiant section of the furnace. The furnace area multiplier, FHTRLS, is calculated to equal 0.75 for this furnace. The PEPSE results are presented in Fig. 3.

The fuel in the unit 4 model is then changed from oil to gas while following the same procedure employed for unit 3. All tube bank multipliers are held constant and the attemperation flows are increased until the main steam and superheat steam temperatures reduce to the desired values of approximately 1010°F. The gas recirculation flow is then adjusted until the furnace area multiplier matches the 0.75 value obtained for the oil case.

Units 4 and 5 Results

As Fig. 4 illustrates, the predicted superheat and reheat attemperation flows are 520,000 and 510,000 lb/hr respectively. This provides us with some important information because it will assist us in sizing the flow nozzles. If the gas conversion takes place as planned we have volunteered to work with the station to determine if there is a design or operation modification that could be made to the unit to reduce the attemperation flows.

The furnace exit gas temperature increases 123°F as it did for units 1 - 3 and approximately the same boiler efficiency reduction of 4.6% is calculated. The adiabatic flame temperature changes by 70°F (1.9%) for the gas case which is slightly more than it changes for the unit 3 model.

The results of the analysis predict that units 4 and 5 may be converted to gas without taking a derating as long as the attemperator lines and nozzles can pass the increased flows predicted to control steam temperatures. However there is an additional area that must be considered. The effect of the 123°F rise in furnace exit gas temperature on the tube metal temperatures. A detailed analysis was performed to estimate tube metal temperature by utilizing convection and conduction relations to determine if maximum oxidation temperature limits for each material are exceeded. The analysis predicted that they will not be exceeded if gas recirculation and attemperation flows remain as specified in the PEPSE analysis results. No derating was predicted nor will it be necessary to mix the oil and gas fuels to obtain full unit load.

Currently PEPSE does not have the capability to calculate the tube metal temperatures for all the different tubing materials that comprise a tube bank. Future work may occur between the author and NUS to attempt to provide PEPSE with this capability.

Conclusion

The use of a PEPSE boiler design mode model is of valuable assistance in predicting the effects of changing the fuel from oil to gas. It predicts several important parameters:

1. Whether the unit will be capable of reaching design steam outlet conditions

2. The fuel flow which will assist in the design of the gas burners

3. The furnace exit gas temperature which can be utilized in a heat transfer analysis to determine if any tube design changes are necessary

4. The attemperation flows which can be compared to the current nozzle and line design flow passing capability to determine if a modification is necessary and allow the calculation of corresponding heat rate effects

5. The boiler efficiency change

6. The gas recirculation flow(if applicable)

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References

1. W.C. Kettenacker and I.A. Sheikh, "An Oil To Gas Conversion Study Using PEPSE", presented at the 1993 NUS Performance Software Users Group Meeting, Jackson, WY

2. G.L. Minner, et al, "PEPSE Manual Volume I", NUS Corporation, Idaho Falls, Idaho, 1994

3. G.L. Minner, "PEPSE Boiler Modeling Seminar", NUS Corporation, Idaho Falls, Idaho, 1994

4. J.G. Singer "Combustion / Fossil Power Systems", Combustion Engineering Inc. Windsor, CT., 1981

FIGURE 1

PEPSE RESULTS WITH OIL FIRING

COLLINS UNIT 3

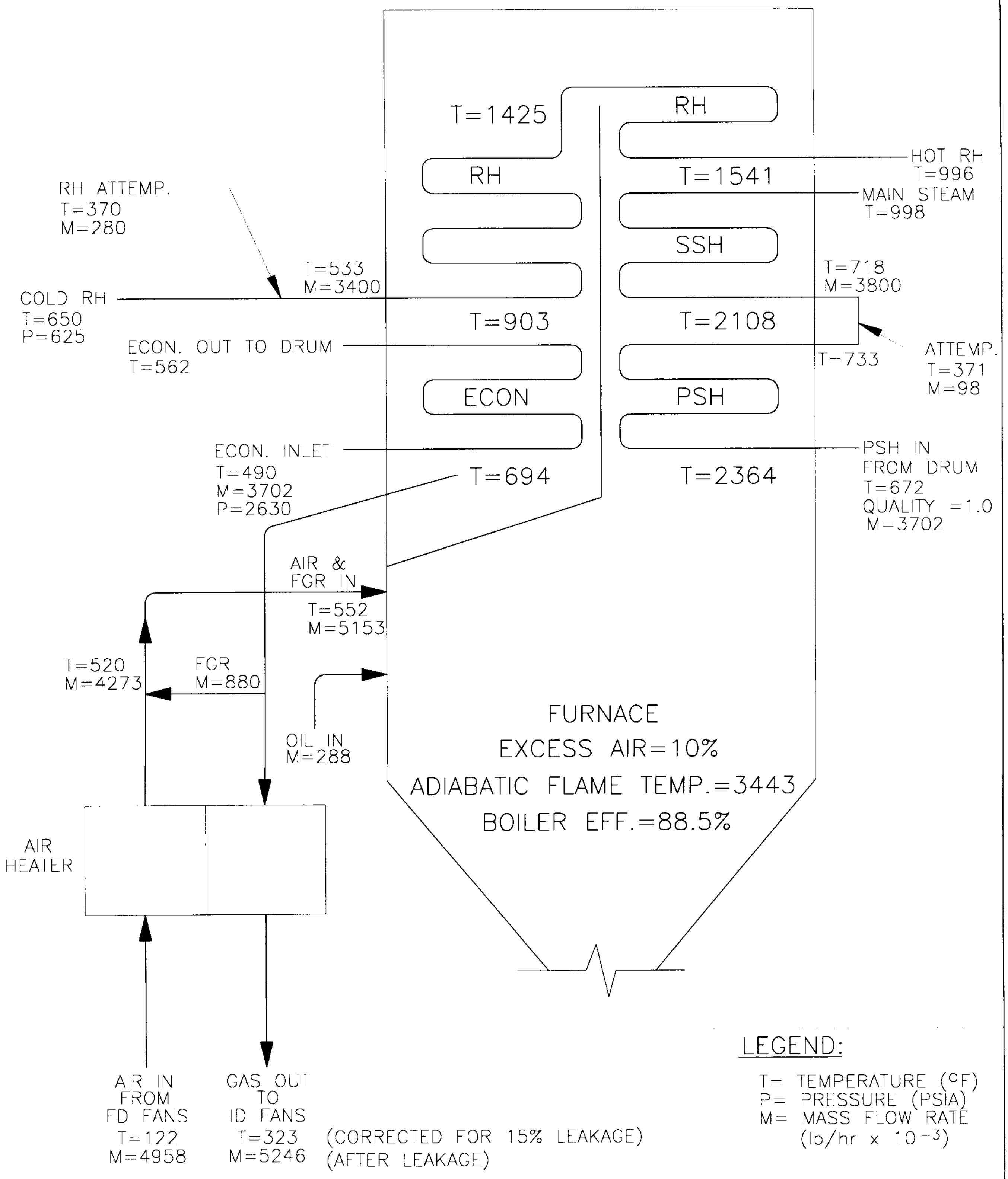

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FIGURE 2
PEPSE RESULTS WITH GAS FIRING
COLLINS UNIT 3

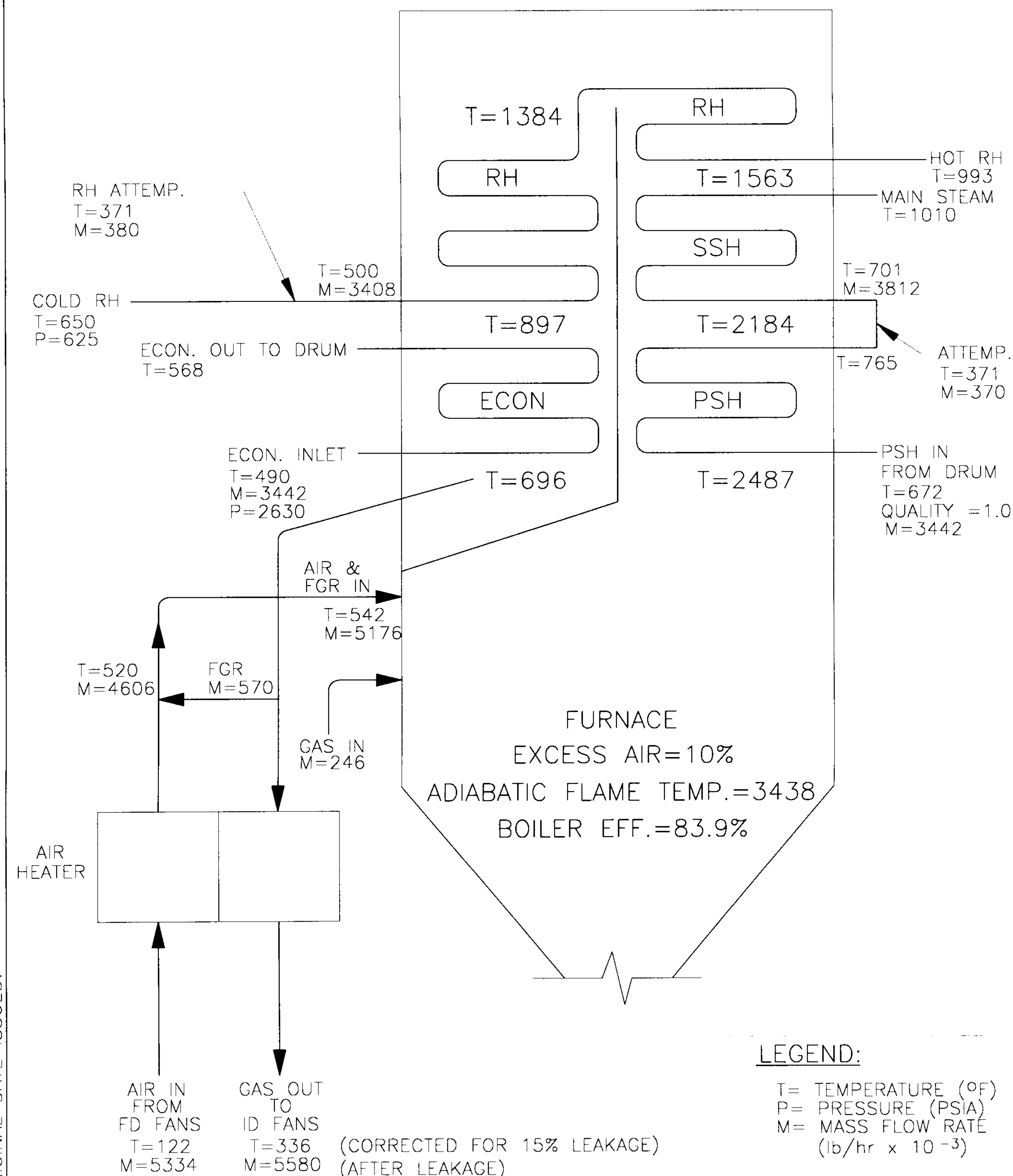

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FIGURE 3
PEPSE RESULTS WITH OIL FIRING
COLLINS UNIT 4

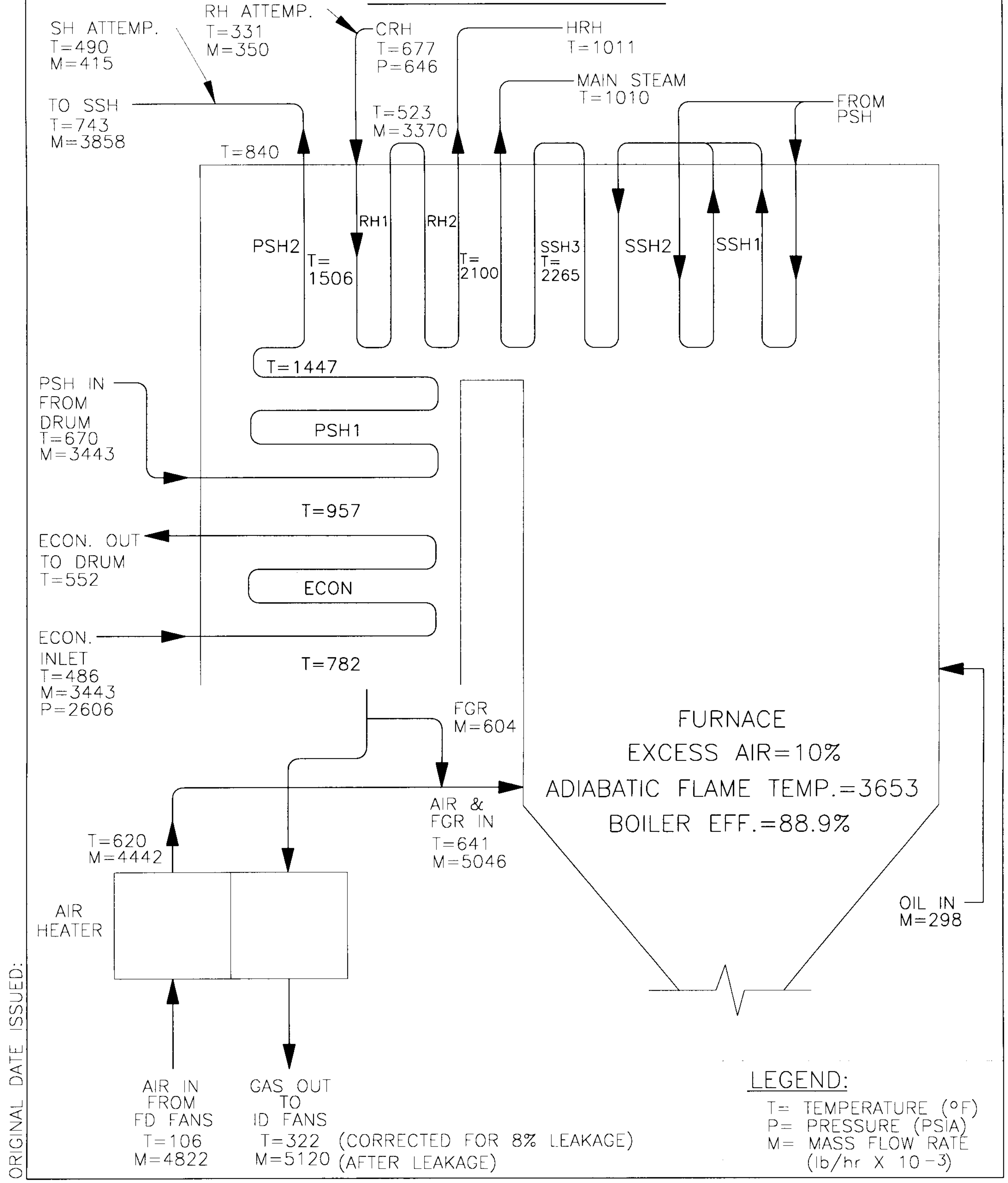

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FIGURE 4

PEPSE RESULTS WITH GAS FIRING

COLLINS UNIT 4

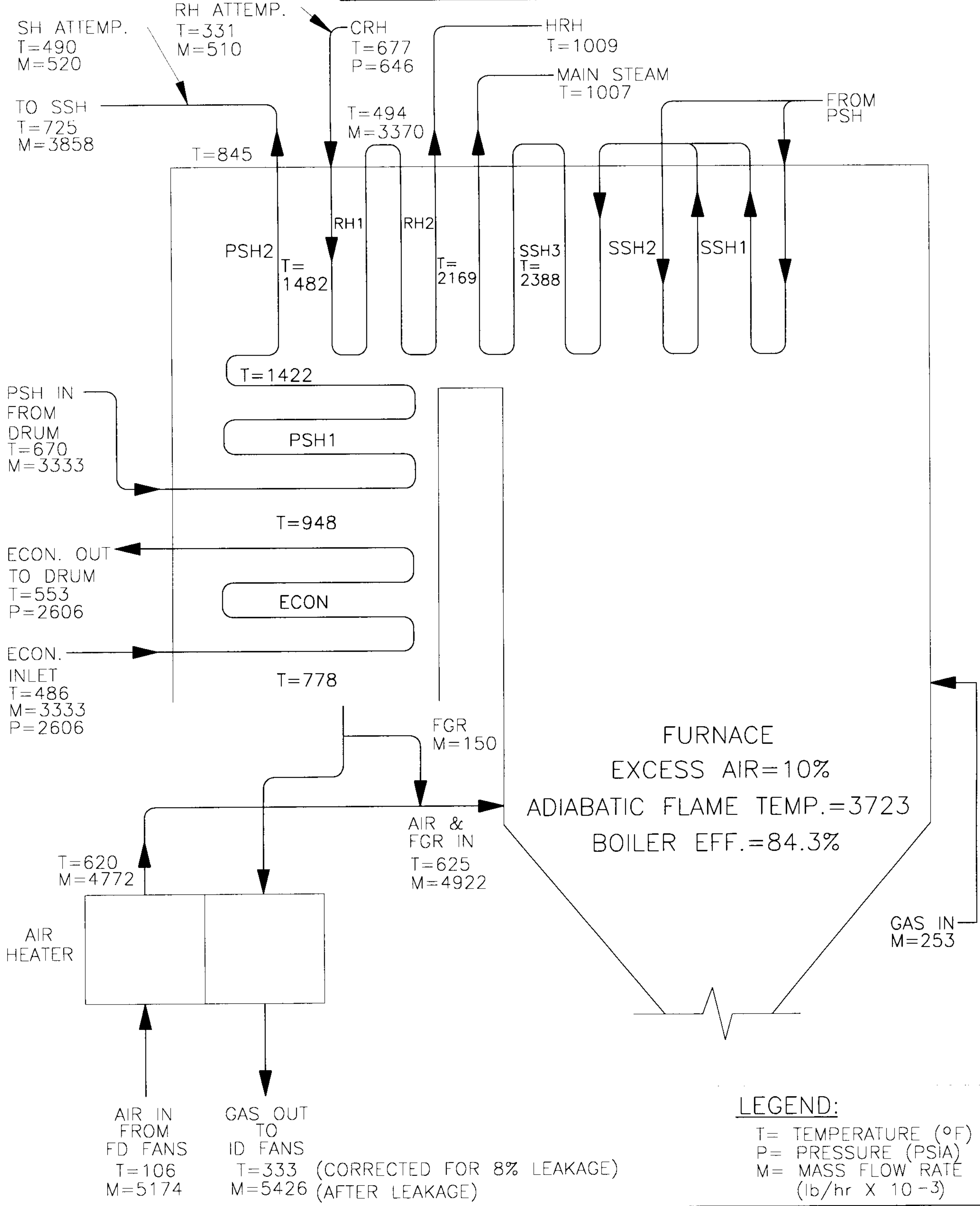

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FIGURE 5

PEPSE BOILER MODEL – COLLINS UNIT 3

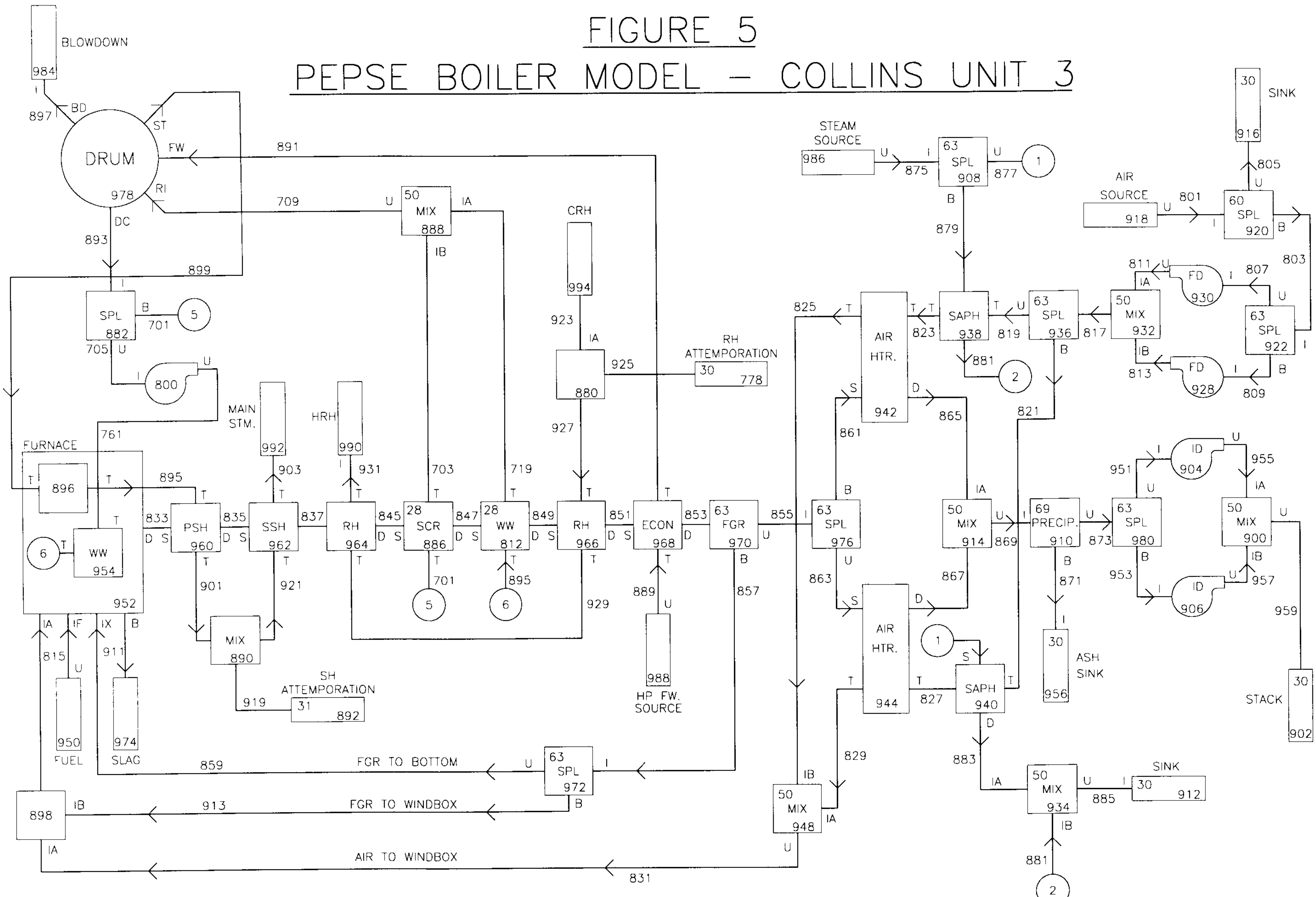

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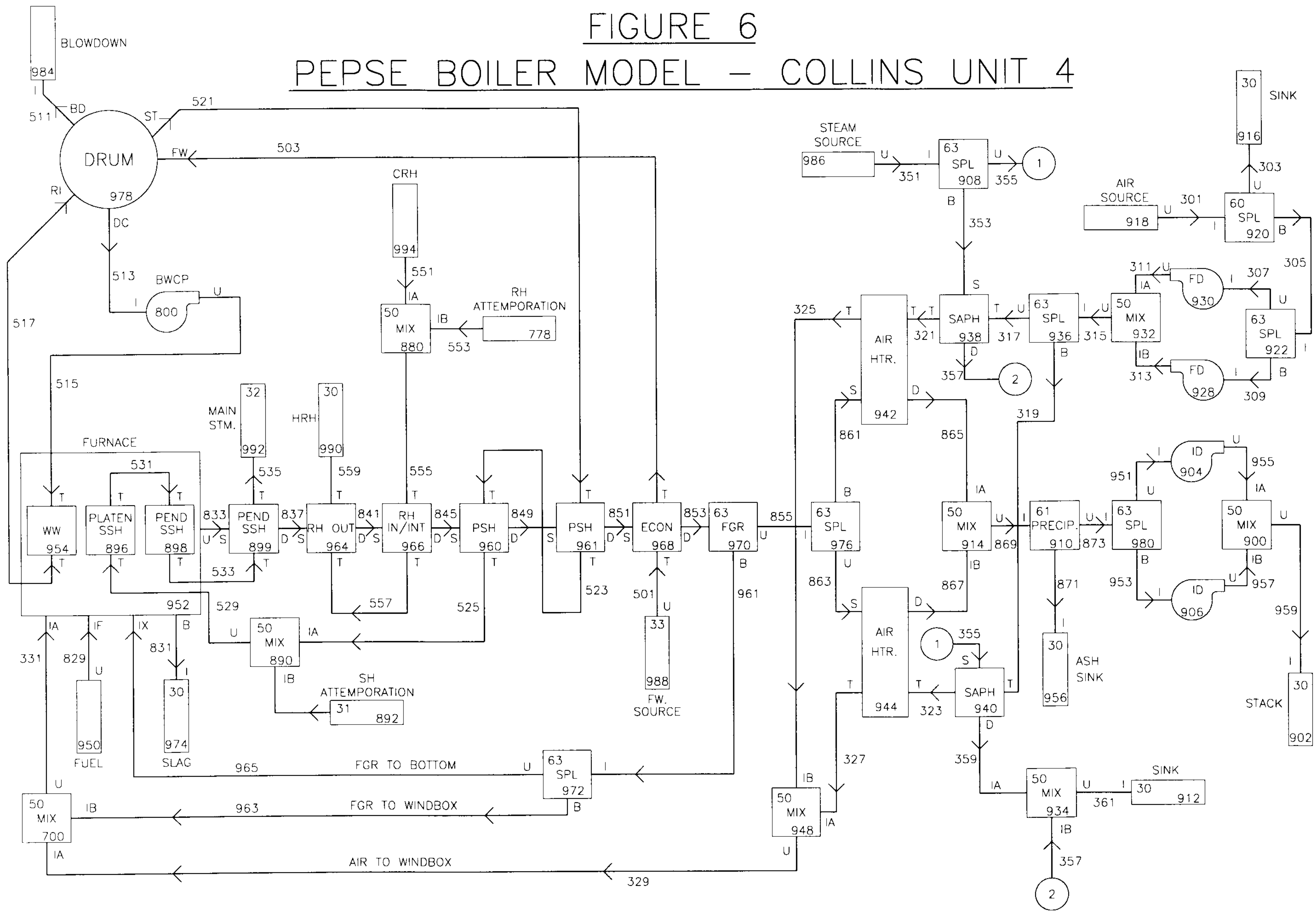
FIGURE 6

PEPSE BOILER MODEL – COLLINS UNIT 4



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