Development of a Multi-Furnace PEPSE® Boiler Model

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1.0 Introduction

A single PEPSE boiler model of Ontario Hydro's Lakeview Generating Station Units 5 through 8 boilers was developed using Version 54 of the PEPSE computer program[1]. These four boilers are similar enough in design and performance to allow the use of one PEPSE model to simulate all four.

The design includes a furnace split into three separate parts by two division water wall sections spanning the entire length of the boiler from floor to roof. This not only separates the furnace into three sections but also separates the secondary superheater and portions of the primary superheater and reheater into three sections. This arrangement adds significant complexity to the model, increasing the number of modeled components and the computer running time.

The model contains significant complexity in other areas, too, such as gas recirculation, multiple air heaters, and pulverizer modeling. In addition, it includes all major boiler components modeled using PEPSE's more rigorous and detailed design mode input option. This level of complexity offers detailed calculations of each boiler section's performance in addition to providing the boiler's overall performance and response.

The boiler model was tuned to the boiler acceptance test results[2]. Three cases were chosen as representative of this entire test and were used for tuning the model and for model checkout: Tests 3, 4, and 5 representing 50% load, 75% load, and 100% load, respectively. The PEPSE model successfully matches these test cases.

2.0 Unit Description

The Lakeview Thermal Generating Station is located in the city of Mississauga on the north shore of Lake Ontario[3]. It has eight 300 MW coal-fired generating units. Unit 5 came on-line in May, 1967, and units 6 through 8 were put in service in January, 1969.

Units 5 and 6 have turbine/generator sets manufactured by Associated Electrical Industries, and Units 7 and 8 have turbine/generator sets manufactured by C. A. Parsons. Units 5 through 8 all have sub-critical, single drum, natural circulation, front-fired boilers manufactured by Babcock and Wilcox. The units have a rating of 2,000,000 lb/hr of steam at 1000 F and 2450 psig, with reheat at 1000 F and 490 psig. Design coal flow at full load is 220,000 lbm/hr.

Figure 1 shows a schematic of the Lakeview Units 5-8 boilers.

3.0 Model Development

3.1 Sources of Information

Information required to construct the PEPSE model came from several sources in the following order:

(1) Plant drawings

(2) Equipment descriptions

(3) Design information

(4) Discussions with Lakeview plant personnel

3.2 Model Construction

A detailed model consisting of components representing each boiler section and heat transfer section was constructed. Three furnace components were used to simulate the triple furnace. The front convective pass was split into three separate flow paths to distinguish the three areas separated by the two division water walls extending to the roof. This high level of modeling detail was included to provide a large degree of flexibility and accuracy when using the PEPSE model for design or analytical studies.

Figure 2 shows the PEPSE model constructed for the Lakeview Units 5-8 boiler. The remainder of this section discusses this model in detail.

3.2.1 Flue Gas Path

Furnace air to the forced draft (FD) fans is introduced into the system through a source component (Component 410). The incoming air is split upstream of the two FD fans using a splitter (Component 525) and then proceeds on to the fans (Components 415 and 530). Upon exiting the fans, a portion of the air from each fan discharge is split (Component 420 after FD fan "A" and Component 535 after FD fan "B") to mix with the flue gas recirculation (Components 555 and 395). The main air proceeds through steam heating coils (Components 430 and 540) and mixes with the primary air (Components 440 and 495).

Primary air is introduced through a source component (Component 445) and splits (Component 450) to go to the two primary air fans (Components 455 and 460). At the primary air fans' discharge, the primary air is mixed (Component 465) to simulate a temperature equalizing duct, and is re-split (Component 470) to go to the two air heaters. Before reaching the air heaters, a portion of the primary air is split (Components 475 and 500) to act as tempering air to the pulverizer. The main primary air passes through steam heating coils (Components 505 and 480), mixes with the main furnace air (Components 440 and 495) and is heated with the main furnace air in the two air heaters (Components 585 and 560). Upon leaving the air heaters, the primary air portion of the air mixture from each air heater is split (Components 580 and 565), mixes together (Component 570), and combines with the tempering air (Component 590) before going to the pulverizer (Component 595).

Leakage air enters the boiler system through a source (Component 605) at the pulverizer. A combination of the primary air, the tempering air, and the leakage air exits the pulverizer and mixes with the main furnace air (Component 610). The total air mixture then proceeds to the furnaces (Components 5, 105, and 205), with the air to the furnaces being fed by several splitters (Components 615 and 255).

Coal enters at the pulverizer through a source (Component 600). The coal exits the pulverizer (Stream 82) and is fed to the three furnaces through a series of splitters (Components 620 and 625).

Hot flue gas exits each furnace (Stream 146 for the right furnace, Stream 210 for the center furnace, and Stream 268 for the left furnace) and enters the convective flow path. It first passes over the first platen of the secondary superheater (Component 60 on the right, Component 160 in the center, and Component 260 on the left) and then over the second platen of the secondary superheater (Component 65 on the right, Component 165 in the center, and Component 265 on the left). Exiting the secondary superheater, the flue gas proceeds to the first platen of the reheater (Component 80 on the right, Component 180 in the center, and Component 280 on the left) and then to the first platen of the primary superheater (Component 85 on the right, Component 185 in the center, and Component 285 on the left).

The flue gas then mixes in a series of mixers (Components 295 and 290) and enters the backpass, passing across the saturated steam roof walls (Component 329), through the second and third platens of the primary superheater (Components 330 and 335, respectively), and across the saturated steam backpass walls (Component 336). Next, the flue gas passes across the economizer backpass "walls" (Component 337), through the second, third and fourth platens of the reheater (Components 340, 345, and 350, respectively) and across the main economizer section (Component 355).

Exiting the economizer, the flue gas is split to the two air heaters (Components 380 and 385), while some of the flow is split for gas recirculation. The main flue gas flow enters the air heaters (Components 585 and 560), exits the heaters and enters the precipitator (Components 630, 635, 645, and 650), passes through the induced draft fans (Components 640 and 655), mixes (Component 660), and exits the stack (Component 665).

Gas recirculation is split off the main flue gas flow before air heater "B" using a splitter (Component 385) and passes through the gas recirculation fan (Component 390). It then mixes with cold main furnace air through a mixer (Component 395), and finally splits to the three furnace components through a series of splitters (Components 400 and 405).

3.2.2 Water/Steam Path

Feedwater from the turbine cycle enters the model through a source (Component 360) and passes through the main economizer section (Component 355) and the economizer backpass "wall" section (Component 337). Leaving the economizer, the feedwater enters the drum (Component 95).

Water leaves the drum and enters the downcomer (Stream 160). The downcomer splits to the three furnaces through several splitters (Components 55 and 155). Entering each furnace, this flow splits (Component 10 in the right furnace, Component 110 in the center furnace, and Component 210 in the left furnace) to either the division water walls or the side/front/rear water walls. The water walls are also distinguished by their location in the furnace, either by being in the radiant zone or the convective zone above the furnace proper. The radiant division water walls (Component 25 in the right furnace, Component 125 in the center furnace, and Component 225 in the left furnace), the convective division water walls (Component 30 in the right furnace, Component 130 in the center furnace, and Component 230 in the left furnace), the radiant side/front/rear water walls (Component 35 in the right furnace, Component 135 in the center furnace, and Component 235 in the left furnace), and the convective side/front/rear water walls (Component 40 in the right furnace, Component 140 in the center furnace, and Component 240 in the left furnace) all reside in the furnace components. The water wall sections mix in each furnace (Component 45 in the right furnace, Component 145 in the center furnace, and Component 245 in the left furnace) and then mix with each other (Components 190 and 90) before returning to the drum.

Saturated steam leaves the drum and is heated in the saturated roof wall (Component 329) and the saturated backpass wall (Component 336). The steam then enters the third platen of the primary superheater (Component 335), the second platen of the primary superheater (Component 330), and is split (Components 300 and 195) among the first platen sections of the primary superheater (Components 85, 185, and 285). This steam exits the three first platen sections and mixes with superheat attemperation flow (Components 70, 170, and 270). The superheat attemperation is introduced through a source (Component 215). After mixing with the attemperation flow, the steam enters the first platen sections of the secondary superheater (Components 60, 160, and 260) and on to the second platen sections of the secondary superheater (Components 65, 165, and 265). The steam exits the second platen sections, mixes together (Component 320), and leaves the system as main steam (Component 325).

Cold reheat enters the system through a source (Component 375) and immediately mixes (Component 370) with reheat attemperation flow, also introduced into the system through a source (Component 365). This mixture then enters the fourth, third, and second platens of the reheater (Components 350, 345, and 340, respectively). Leaving the second platen, the reheat steam splits (Components 305 and 200) to the three sections of the reheater's first platen (Components 80, 180, and 280). The reheat steam exits the first platen sections, mixes together (Component 310), and leaves the system as hot reheat (Component 315) returning to the turbine cycle.

3.2.3 Modeling Assumptions

Several assumptions and modeling judgements were made during the construction of the PEPSE boiler model schematic. These include the following:

- Only a single pulverizer component was modeled rather than all six. PEPSE is a heat balance program and is used mainly for thermodynamic analyses rather than mechanical component studies. A single pulverizer was considered adequate in representing the thermodynamic response of all six. This does not preclude modeling all six at a later date if sufficient reason exists to do so.

- All leakage air was introduced into the system through a single source on the pulverizer component. In reality, air leaks into the system at many locations. A single source of leakage air was used to avoid unnecessary complication of the model. Other air leakage locations may be added later, but the location of the air leakage will have a small effect on the overall results.

- All air to each furnace was introduced at a single inlet port to that furnace. No air was introduced to the furnaces with the coal. This is a PEPSE limitation - air may enter each furnace at only one port. However, this causes no noticeable effect on the results because the total amount of required (and excess) air reaches each furnace through this one air port.

- The flue gas convective stages were modeled to correspond to the major convective stages in the boiler. In the real plant, tube geometry changes, such as tube thickness or tube pitch, occur within a single convective stage. In PEPSE, no intra-stage tube geometry changes are allowed unless separate stages are added to reflect the changing geometries. To avoid unnecessary modeling detail, these separate "sub-stages" were not included - a single stage geometry was used for the entire convective stage. However, the plant intra-stage changes are small and the PEPSE results will not be noticeably affected by their absence.

- The main furnace air introduced into the system by the forced draft fans and the primary air introduced into the system by the primary air fans were mixed before entering the air heaters. At Lakeview, these two air streams actually remain separate until they reach the windbox (trisector air heater). However, there will be no effect on the overall system results by merging the two air streams prior to heating (Note: They were re-separated in the PEPSE model after heating.). The effect of this mixing will be noticed if detailed air heater studies are required.

3.3 Input

3.3.1 Geometry Input

Input describing the geometry of a component, such as tube length or tube diameter, was obtained from a specific drawing for that component or portion of the boiler containing that component. When the drawing was not available, the Ontario Hydro boiler tube specification[4] was used for the input geometry descriptions.

3.3.2 Performance Input

Input related to the performance of a component, such as air heater air outlet temperature, was obtained from the Lakeview Unit 5 Boiler Acceptance Test Report. When the information was not available in the Acceptance Test Report, design information was used.

3.3.3 Boundary Conditions Input

Boundary conditions, which include all pressures, temperatures and some flows at all the source components, were obtained from the Acceptance Test Report. Values for Tests 3, 4, and 5 representing 50% load, 75% load, and 100% load, respectively, were used for tuning the model. These values appear in Table 1. The superheat attemperation flow was not reported in the Acceptance Test Report. Instead, a curve relating this flow to main steam flow, extracted from the design data, was used. This curve appears as Figure 3.

Boundary conditions generally change for every case based on the user's particular analysis study. Geometry input and component performance input, however, seldom change unless a design change has taken place in the boiler or the performance of a component has deteriorated.

3.3.4 Major Assumptions

One major assumption made in the development and tuning of the model was that the three furnaces were identical in performance during the test. This assumption is reflected in the model by having equal furnace exit temperatures in the three furnaces. No data was presented in any of the sources which indicated any performance differences among the three. However, the geometry of the center furnace is slightly different from the left and right furnaces because the left and right furnaces include the side water walls.

The convective sections were considered to be identical in geometry and performance, although there were indications that the performance was not identical during the test. The plant drawings indicated equal tube dimensions, hence equal geometries. However, the Acceptance Test Report results presented various readings in the boiler, such as "East" and "West" superheater and reheater outlet temperatures. These values were often slightly different, which might be explained as performance differences in the various boiler sections. However, the East and West measurement locations were not defined and could not be correlated to the three convective sections included in the PEPSE model. Therefore, the average values presented in the Acceptance Test Report were used.

3.4 Model Tuning

Development of the model schematic and preparation of the model input are only a portion of the process of developing a useable PEPSE boiler model. Once built, the model must be "tuned" to match some set of performance criteria, the most common being the original design, the acceptance test results, or the results from a recent performance test. The Lakeview Units 5-8 boiler model was tuned to the boiler acceptance test results.

Tuning is the process of modifying the PEPSE-calculated pressure drop characteristics and heat transfer characteristics to match a set of design conditions or measured plant conditions. In the design input mode, PEPSE's heat transfer components' pressure drops and heat transfer are calculated based on industry-accepted first principles calculations. Details of these calculations are given in the PEPSE theory manual[5]. These first principles calculations must be modified to account for the actual design or performance of the plant. The modifications, or tuning parameters, account for the boiler vendor's adjustments to boiler performance based on years of design and testing experience, or account for the deterioration, fouling, or other performance changes of the boiler sections over a period of time.

3.4.1 Tuning Factors

Several factors are available to use as tuning parameters in PEPSE. For pressure drop tuning, the form loss coefficient (k), the friction factor (f), or a combined form loss and friction factor (f*L/D + k) may be modified to achieve the desired pressures throughout the boiler. For Lakeview, the combined factor was used.

For heat transfer tuning, the tube inside film coefficient, the tube outside film coefficient, the fouling resistance, the tube thermal conductivity, or a combined factor which represents the entire thermal resistance from the inside to the outside of the tube may be modified. For radiant stages representing water walls, or for pendants which reside in the furnace itself, a radiant stage view factor may also be used for tuning. In addition, the effective heat transfer area may be changed to modify the total amount of heat transferred. In tuning the Lakeview boiler model, the combined thermal resistance factor was used. It should be noted that this does not preclude the use of another of the heat transfer parameters in the future for secondary tuning, i.e., tuning over this "base-line" tuning. For example, a fouling resistance may be added on top of the combined tuning factor obtained here to signify fouling that has occurred since the acceptance test.

Because of the lack of design data for the air heaters, the performance of the air heaters was calculated using the reference-based predictive mode. This mode can be thought of as an intermediate mode between the performance and design mode input options. For this option, the tuning parameter used was the heat exchanger constant, a value which represents a heat transfer performance parameter for the heater.

A tuning parameter may be input directly, or it may represent a multiplier on the PEPSE-calculated value for that parameter. If input directly (i.e., direct input of a heat transfer coefficient), the value usually must be changed for each load because the actual value changes with load. If input as a multiplier, however (i.e., 85% of the PEPSE calculated value), the value is generally good for all loads or variations of a particular load. This is true because PEPSE is calculating the actual parameter based on the current load or condition while the tuning multiplier is modifying it based on the characteristics of the boiler.

For the Lakeview model, tuning multipliers, rather than actual parameters, were used to tune the model.

3.4.2 Tuning Process

The tuning process uses PEPSE's control feature to calculate the tuning parameters to match pressures and temperatures throughout the boiler. The process is carried out as follows:

(1) Performance criteria to which the model will be tuned (initial plant design, acceptance test, recent performance test, etc.) are chosen and the data representing the plant response to this condition are secured. This includes the model boundary conditions, such as feedwater inlet conditions, reheat inlet conditions, fuel flow and composition, and any other mass and energy which enters the system boundary. Data representing the response of the boiler to these boundary conditions includes inter-stage pressures and temperatures, and all output conditions such as main steam conditions and hot reheat steam conditions.

(2) PEPSE's control feature is used to calculate the tuning factors for the individual stages to achieve the inter-stage conditions and overall outlet conditions. This may involve setting up many controls. Eleven controls were used to tune the Lakeview model.

(3) PEPSE is run using these controls at several system loads to determine the tuning factors over the load range.

(4) The controls are removed from the PEPSE model and the tuning parameters calculated by the controls from step (3) above are inserted. If a calculated tuning parameter is relatively constant over the load range, the tuning parameter is input as a

constant. If not, it is inserted in a schedule (curve) versus some load parameter such as main steam flow. All of the calculated Lakeview tuning parameters were input as schedules.

(5) The model is now ready for general use.

3.4.3 Tuning Values for Lakeview

Table 3 presents the list of tuning parameters used for the Lakeview boiler model and the values calculated from the tuning (control) cases.

3.4.4 Tuning Assumptions

3.4.4.1 Tuning Parameters for Entire Section

One assumption made in the tuning process for Lakeview was that the same tuning parameter value was valid for all the stages of a particular boiler section. For example, a control was used to calculate the heat transfer coefficient multiplier for the first platen of the right side secondary superheater component (Component 60) to achieve the measured main steam outlet temperature (in Stream 186) from the acceptance test. The multiplier calculated from this control was then applied to the second platen of the right side secondary superheater (Component 65), and to the first and second platens of the secondary superheaters for the center and left sides (Components 160, 165, 260, and 265). This assumption was required because no intra-section temperatures were measured, i.e., no temperatures (either steam or flue gas) were measured entering or leaving the individual platen sections of the secondary superheaters. Only the main steam temperature was measured and reported. Therefore, determining individual platen stage tuning parameters (heat transfer coefficient multipliers) was impossible. The technique of applying the same tuning value to all the components of a section when intra-section data is missing is common in boiler modeling.

3.4.4.2 Furnace Coal Flows

Equal amounts of coal were delivered to each of the three modeled furnace components. No data in the Acceptance Test Report indicated coal flow differences.

3.4.4.3 Furnace Air Flows

An assumption was made related to the amount of air delivered to each furnace. Furnaces are "demand" components in PEPSE, requiring (demanding) a certain amount of air to stoichiometrically balance the furnace reaction plus take care of excess air requirements. For Lakeview, each furnace "demands" flow from a different component (Component 410 for the right furnace, Component 255 for the center furnace, and Component 615 for the left furnace). Because only one excess air value was reported in the Acceptance Test Report for each load, that value had to be used for each PEPSE furnace component. Then, because all the furnaces were modeled as having the same amount of delivered coal, the air flows to the furnaces were identical. If more information becomes available on the furnaces' excess air differences, coal delivery differences, or performance differences, the model may be re-tuned to reflect the new values. PEPSE's air flow mechanism is automatic, requiring no user intervention to calculate the required air flow requirements to each furnace based on changes to either the excess air or coal flow.

3.4.4.4 Data Inconsistency Resolution

A problem surfaced when using the data presented in the Acceptance Test Report. For two of the three cases used as benchmarks for the PEPSE model, the data presented in the report caused too much heat to be delivered to the PEPSE boiler model system (or caused too little heat removal). This occurred for Tests 3 and 4, representing the 50% and 75% load cases, respectively. The PEPSE full load case, representing Test 5, showed nearly identical results to those presented in the Acceptance Test Report.

This problem was first noticed during the initial tuning phase when all boiler outlet conditions were successfully matched except the gas temperatures to the air heaters. These temperatures were at times 200 degrees F higher than those reported in the acceptance test results. Possible causes for this discrepancy were investigated, as follows:

(1) Error in the PEPSE model

(2) Poor assumptions used in the PEPSE model to fill missing data not in the Acceptance Test Report

(3) Incorrect data in the Acceptance Test Report

A careful and rigorous review of the PEPSE model made option 1 a remote possibility, especially since the full load case matched the acceptance test results so well. The problem was not with the internal characteristics or response of the model, but rather with the total energy flow into and out of the system.

Assumptions concerning missing data were also reviewed. One assumption made in developing the model was to use the design correlation for superheat attemperation flow from the design data (see Figure 3). No superheat attemperation flow data was presented in the Acceptance Test Report. If the attemperation flows used in PEPSE were significantly different from the actual test values, the symptoms described above could occur.

However, the superheat attemperation flow was abandoned as the cause of the problem. The flows are low and would therefore have a small impact on the results.

For Test 3 (50% load), the reported coal high heating value was nearly 4% higher than the heating value reported for either Test 4 or Test 5. If this was an error in heating value, then this could be a possible candidate for the extra heat energy in Test 3.

However, after careful consideration, the coal flow reported in the Acceptance Test Report was considered the most likely cause of the high flue gas temperatures calculated by PEPSE at the lower loads. Coal flow measurements are difficult to obtain accurately, and their value affects the results significantly. A 1% error in coal flow translates into a 1% error in boiler efficiency.

In order to determine values of coal flow that would make the PEPSE results match the Test 3 and 4 results, a simplified boiler model was developed, and a sensitivity study performed. A simplified model contains only 15 or 20 components, all in the performance mode, and runs in a fraction of the computer time when compared to a full design mode tuning model.

The sensitivity study, reported in Appendix A, involved running several PEPSE cases at 50% and 75% load using different coal flows, and noting which value of coal flow for each test provided the best match to the acceptance test results. Because the boiler was receiving too much heat, these best match coal flows were lower than the flows reported in the Acceptance Test Report. Table 2 summarizes the best match coal flows and the flows from the acceptance test.

For Test 3, the sensitivity study also included using a lower coal high heating value, one that was the average of Tests 4 and 5, to determine its sensitivity to boiler performance.

These best match values of coal flow and heating value (Test 3 only) were then used in the tuning process, and the best match results using the full PEPSE tuning model were then input into the generalized model reported in Section 3.5 below. It should be noted that after reviewing the results of the sensitivity study, the heating value reported in the acceptance test was used for the final Test 3 tuning: only the coal flow was changed, as shown in Table 2.

3.5 Generalized Model

The generalized model is the final model to be used for design, performance, or other boiler studies. The tuning parameters, as described in Section 3.4, are incorporated into this model. Table 4 shows how the Lakeview 5-8 generalized boiler model results compare with the acceptance test results at selected points in the boiler system.

4.0 Discussion

The Lakeview Units 5-8 PEPSE boiler model presented in this report successfully reproduces the results presented in the boiler Acceptance Test Report over a wide range of loads. This model is ready for use by Ontario Hydro's personnel for design or analysis studies of the Lakeview boilers.

References

1. G. L. Minner, E. J. Hansen, W. C. Kettenacker, and P. H. Klink, "PEPSE Manual: User Input Description", Vol. I, Revision 14, January 20, 1989, EI International, Inc., Idaho Falls, Idaho.

2. "Report on Steam Generator Performance Acceptance Tests, Lakeview G. S. - Unit 5".

3. "Thermal Station Data - Lakeview TGS".

4. "Boiler and Auxiliary Tube Materials and Specifications of Ontario Hydro's Fossil-Fuel-Fired Generating Stations", CTS-31000-2, TG-31000, NA27-31000-2, December 21, 1979.

5. G. L. Minner, E. J. Hansen, P. H. Klink, and W. C. Kettenacker, "PEPSE Manual: Engineering Model Description", Vol. II, Revision 6, March 1, 1988, EI International, Inc., Idaho Falls, Idaho.

Table 1

Boundary Conditions Used for Tuning

	Test Case		
	3	4	5
Main Steam Flow (lbm/hr)	934,888	1,436,750	1,940,830
Feedwater:			
Temperature (F)	409.0	441.1	470.2
Pressure (psia)	2,456.7	2,539.6	2,653.7
Flow (lbm/hr)	--- Calculated by PEPSE ---		
Cold Reheat:			
Temperature (F)	560.7	584.6	618.9
Pressure (psia)	270.6	392.9	516.6
Flow (lbm/hr)	813,185	1,265,896	1,735,595
Fuel:			
Flow (lbm/hr)*	99,600	154,200	201,189
Flow (lbm/hr)**	105,932	156,430	201,189
HHV (Btu/lbm)	13,227	12,762	12,804
Carbon (%)	72.60	70.99	71.79
Hydrogen (%)	4.88	4.82	4.81
Nitrogen (%)	1.40	1.40	1.39
Sulfur (%)	2.14	2.55	2.26
Ash (%)	7.63	8.95	8.40
Oxygen (%)	6.26	4.96	4.96
Moisture (%)	5.09	6.35	6.40
Superheat Attemp Flow (lbm/hr)	--- Figure 3 ---		
Reheat Attemp Flow (lbm/hr)	0	0	0
Blowdown (lbm/hr)	0	0	0
Air:			
Outside Air Temp (F)	80.0	80.0	80.0
To AH "A" (East) Temp (F)	98.5	97.9	106.0
To AH "B" (West) Temp (F)	98.4	97.8	104.9
Moisture Fraction (-)	.009	.009	.014
Excess Air (%)	29	23	19

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* Fuel flow used in PEPSE model

** Fuel flow reported in Acceptance Test Report[2]

Table 2

Comparison of Coal Flow Rates

	Test Case		
	3	4	5
Acceptance Test Report Coal Flow Rate (lbm/hr)	105,932	156,430	201,189
PEPSE Tuning Coal Flow Rate (lbm/hr)	99,600	154,200	201,189
Difference (%)	-5.98	-1.43	0.00

TABLE 3
Tuning Parameters and Values

Tuning Parameter	PEPSE Variable	Location	VALUES Test 3	Test 4	Test 5	Value Used in Generalized Model	REMARKS
Combined Friction Factor and Form Loss Coefficient	FRMLS	Component 355	-2.9700	-0.9218	-2.9700	Schedule as a constant over the load range.	Also use for component 337
Combined Friction Factor and Form Loss Coefficient	FRMLS	Component 329	-3.9481	-4.1179	-3.9204	Schedule ends	Also use for components: 336, 335, 330, 85, 60, 65, 185, 160, 165, 285, 260, 265
Combined Friction Factor and Form Loss Coefficient	FRMLS	Component 350	-2.1247	-1.9072	-1.6490	Schedule	Also use for components: 345, 340, 80, 180, 280
Overall Heat Transfer Coefficient	HTTIRH	Component 60	-1.2252	-1.0676	-0.9354	Schedule	Also use for components: 65, 160, 165, 260, 265
Overall Heat Transfer Coefficient	HTTIRH	Component 329	-1.1055	-1.1195	-1.1713	Schedule	Also use for components: 336, 335, 330, 85, 185, 285
Overall Heat Transfer Coefficient	HTTIRH	Component 350	-1.6097	-1.6082	-1.6218	Schedule ends	Also use for components: 345, 340, 80, 180, 280
Overall Heat Transfer Coefficient	HTTIRH	Component 355	-1.0581	-1.1227	-1.2590	Schedule	Also use for component 337
Heat Exchanger Constant	CHETEX	Component 585	65.2777	75.3927	83.0877	Schedule	
Heat Exchanger Constant	CHETEX	Component 560	87.7336	84.1881	91.0338	Schedule ends	

TABLE 4

Generalized Model Results

Parameter	Results From Accept. Test Test 3	PEPSE Results Test 3	Results From Accept. Test Test 4	PEPSE Results Test 4	Results From Accept. Test Test 5	PEPSE Results Test 5
TEMPERATURES (F)						
Main Steam	992.8	991.1	993.0	992.6	992.0	990.8
Hot Reheat	1004.1	996.2	1002.8	999.3	1007.6	1004.8
PSH Ave Outlet	876.0	873.0	848.0	846.6	832.0	830.1
Downcomer	644.5	635.5	647.3	642.2	655.3	650.8
FW Exiting Econ	462.0	463.1	481.1	481.3	505.2	505.3
Air from AH 'A'	449.4	460.7	475.1	481.1	503.0	509.3
Air from AH 'B'	479.6	489.1	486.7	498.4	512.6	518.5
Gas to AH 'A'	535.2	560.5	566.2	580.0	596.7	600.8
Gas to AH 'B'	550.1	560.5	578.2	580.0	616.3	600.8
Gas from AH 'A'	216.9	272.4	244.5	274.7	271.6	289.7
Gas from AH 'B'	237.5	251.3	248.4	261.6	271.3	282.0
Gas to Econ	642.0	640.5	666.0	652.2	696.0	676.1
PRESSURES (PSIA)						
Main Steam	2378.0	2383.6	2413.5	2399.3	2428.5	2420.5
Hot Reheat	253.0	254.1	368.0	369.6	487.0	488.6
Drum	2420.7	2422.4	2509.7	2487.8	2580.7	2575.7
EFFICIENCIES						
Heat Loss Method	90.6	89.4	90.2	89.6	89.8	89.7
Input/Output Method	85.7	89.9	89.0	89.9	90.0	89.8

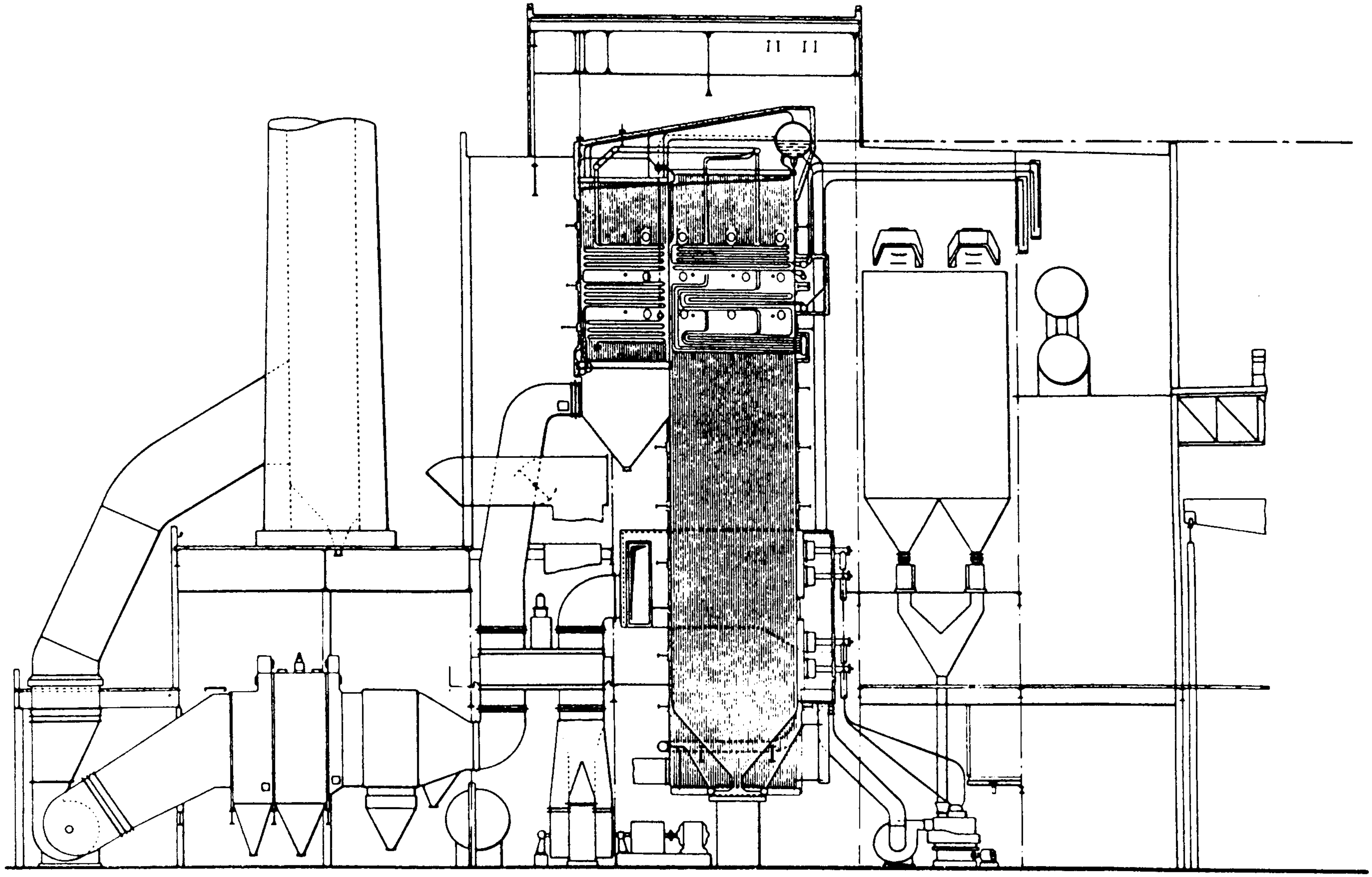


FIGURE 1
LAKEVIEW UNITS 5-8 ELEVATION SCHEMATIC

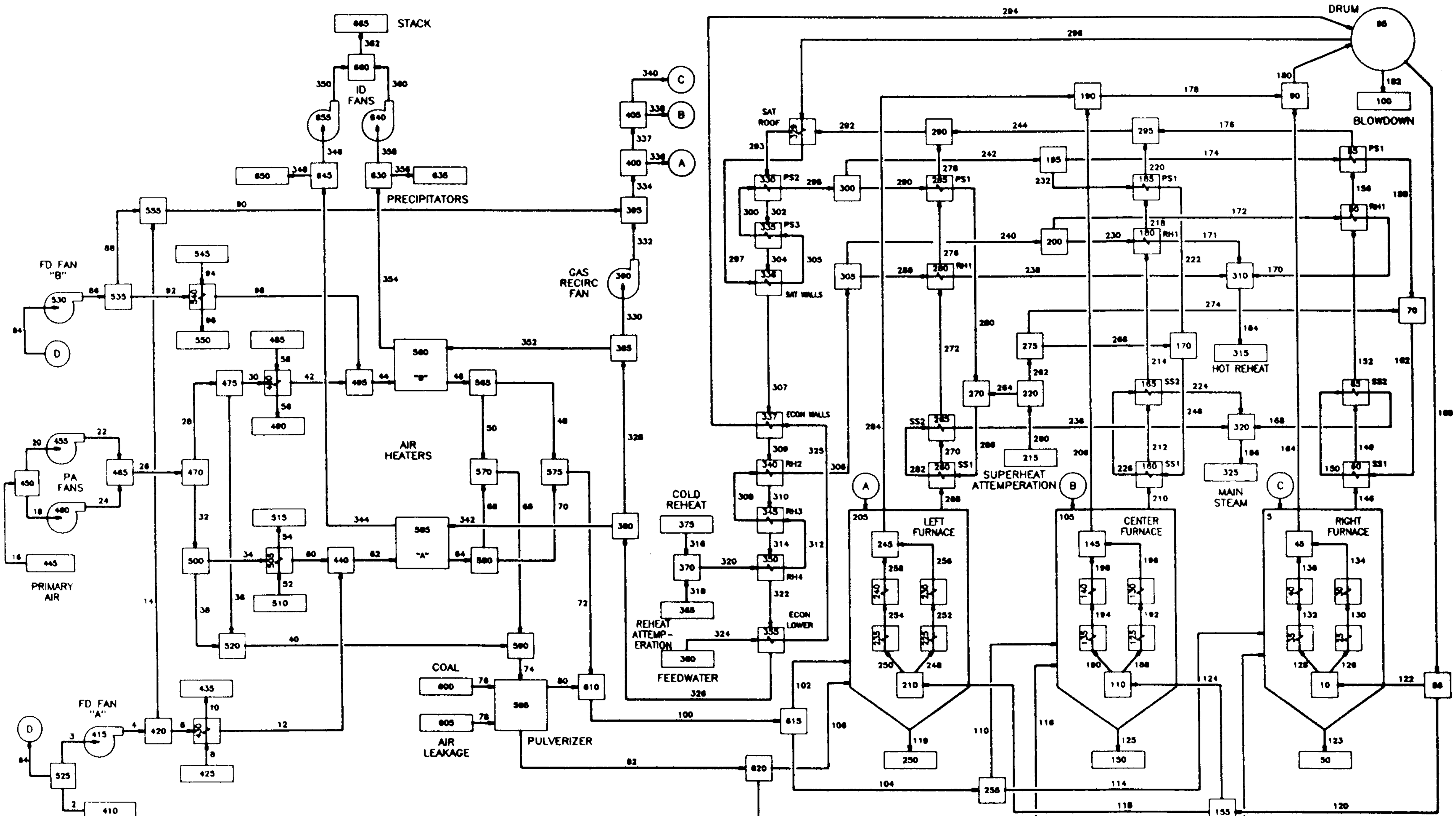
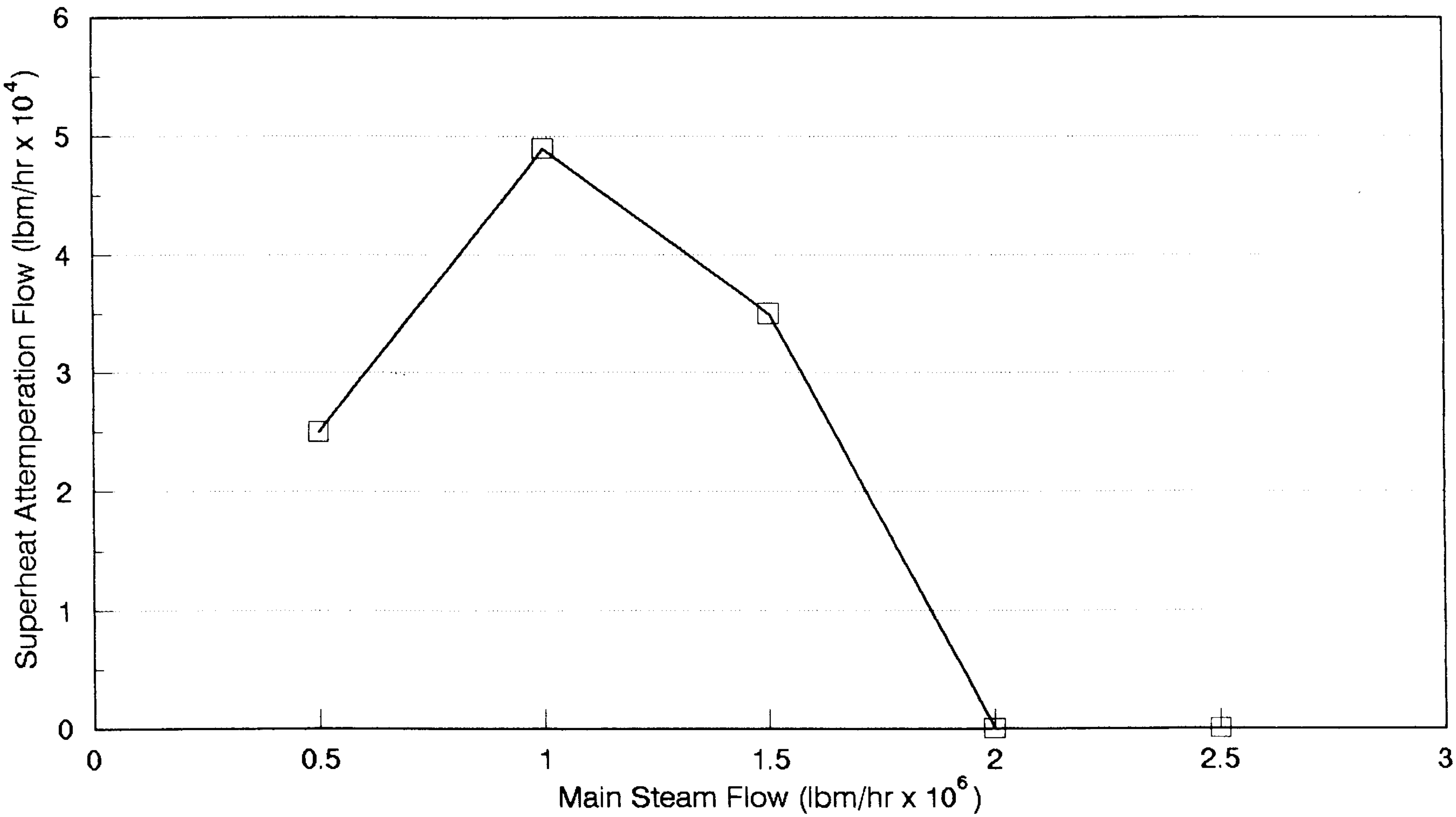


FIGURE 2

LAKEVIEW UNITS 5-8 PEPSE BOILER MODEL

<u>FIGURE 3</u>

Superheat Attemperation Flow



APPENDIX A

Lakeview Units 5-8 Simplified Boiler Model Results

Lakeview Units 5-8 PEPSE Boiler Model
Results and Input Listing

Figure A-1 shows the simplified PEPSE boiler model used to run sensitivity studies on the Lakeview boiler. These studies became necessary when it was discovered early in the tuning process that too much heat was being delivered to the boiler using the data presented in the Lakeview Unit 5 Steam Generator Acceptance Test Report. Specifically, this excess heat was present in Tests 3 and 4, representing 50% and 75% load, respectively. A simplified model was chosen as the method to investigate this problem because it runs in a fraction of the computer time of the full tuning model.

It was determined that the excess heat was most likely due to an incorrect value of the reported coal flow rate. In addition, it was thought that the high heating value for Test 3 may be in error because its reported value was approximately 4% higher than that reported for Tests 4 and 5.

The sensitivity cases performed using the simplified boiler model involved running several cases for Test 3 using various values of coal flow and two values of high heating value: the reported value and an average value from Tests 4 and 5. In addition, several cases for Test 4 were performed using various values of coal flow. For both tests, the goal was to find the value of coal flow rate that gave the gas temperatures to the air heaters reported in the Acceptance Test Report.

Figure A-2 shows the results of the sensitivity study for Test 3, and Figure A-3 shows the results for Test 4.

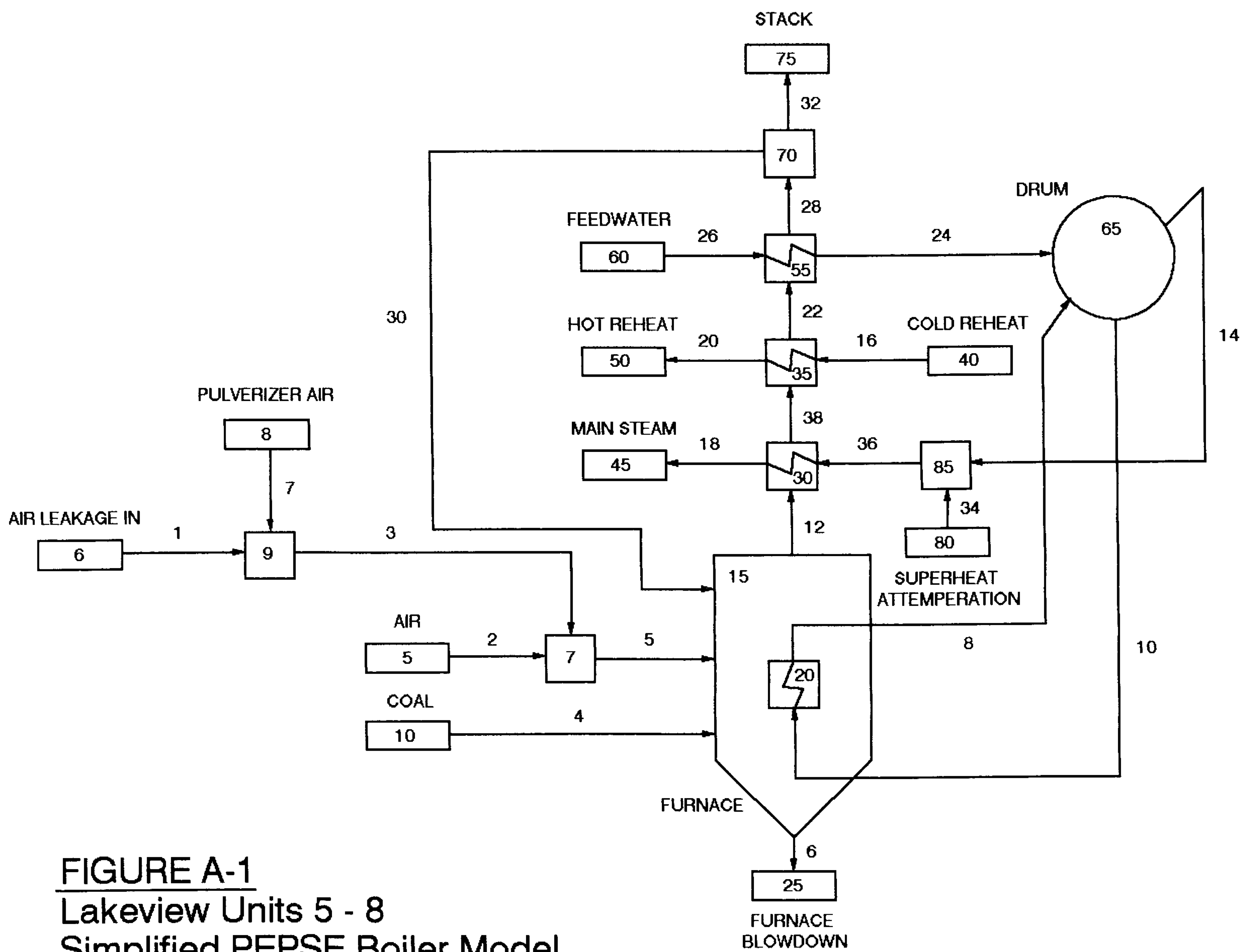


FIGURE A-1
Lakeview Units 5 - 8
Simplified PEPSE Boiler Model

FIGURE A-2

Gas Temp to Air Heaters vs Coal Flow

(Test 3 of Lakeview 5 Boiler Acceptance Test)

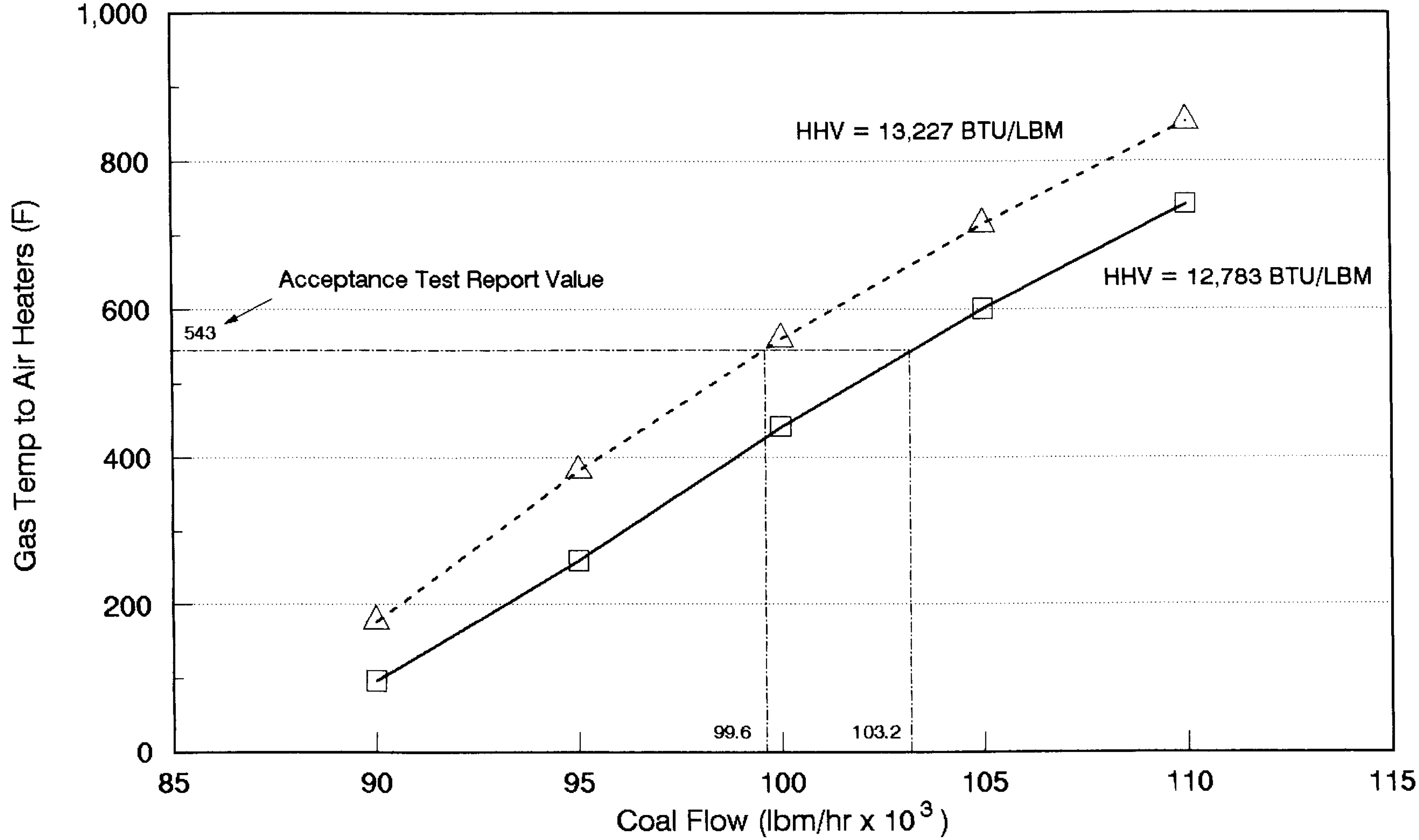


FIGURE A-3

Gas Temp to Air Heaters vs Coal Flow

(Test 4 of Lakeview 5 Boiler Acceptance Test)