Utilization of the Hawthorn 5 PEPSE® Boiler Model

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Abstract

Kansas City Power & Light Company determined the need to acquire a static modelling program to predict the performance of their steam generating units. The PEPSE modelling program was chosen for this purpose.

Since its development, the PEPSE predictive boiler model at Hawthorn Unit 5 has been used to develop a new predictive performance data sheet and to analyze the thermal effects of burning various coal types in the unit. Hawthorn presently performs actual "test burns" of coal types to see how operating parameters are affected by burning these coals. Data was gathered during a recent test burn to validate the predicted performance from the PEPSE boiler model. In the future, it is hoped that PEPSE can be utilized to eliminate actual test burns on the unit and to aid in the selection of the best fuel for Hawthorn Unit 5.

Introduction

Kansas City Power & Light Company purchased an on-line performance modelling program in 1985. This modelling program is called PMAX and is used to monitor boiler, turbine, and feedwater heater performance while a unit is on-line. As of this date, PMAX is being utilized at each of our coal-fired units.

In July '90 discussion began concerning the need to model and predict changes in operating parameters before they actually occurred. We wanted a way to study the effect of verifying operating conditions on the unit and to assess the impact of equipment changes on plant efficiency. PEPSE was chosen as the modelling tool to accomplish this. Initially, the PEPSE turbine model was developed for each plant. These are very useful but it was felt that a boiler model for each of KCPL's units would provide a much more useful and predictive tool. In May of 1991, a PEPSE boiler model class was given to the Performance Engineers at each station. Each engineer was charged with developing a working model of their respective boilers.

The boiler at Hawthorn was originally designed to burn a high Btu (11,000 Btu/lb.) Illinois bituminous coal. This type of coal was never burned at this station. Presently, Hawthorn is burning several Powder River Basin coals on the unit. Heating values are in the range of 8500 - 8800 Btu's/lb. with a very low sulfur content of 0.5% or less. The original equipment manufacturer provided a "Predicted Performance Sheet" based on the use of the Illinois coal. This sheet contained many of the operating temperatures and pressures that the unit could be expected to produce while burning the Illinois coal. Since Hawthorn has never burned this type of fuel, this performance sheet was rather useless. Comparisons to actual data were virtually impossible. Thus, the need was recognized to utilize the Pepse boiler model to develop a new "Predicted Performance Sheet" for the unit based on the burning of western fuels. This would allow some comparisons to be made with the expected and actual performance parameters.

In addition to developing a new predictive performance sheet for the unit, the PEPSE boiler model was asked to predict the performance of burning various fuel types in Hawthorn Unit 5. Hawthorn has had the opportunity in the past to take advantage of low cost spot fuel purchases. These purchases have usually resulted in poor performance of the unit or increased shutdowns of the unit due to various reasons. Hawthorn Station wanted a predictive modelling tool(s) to aid in the selection of the fuel types before purchasing them. Currently, Hawthorn conducts "test burns" of the fuel types in the boiler, usually with poor results. It is hoped that the PEPSE boiler model (along with other models being developed, i.e., CQIM, etc.) can eliminate the need to run test burns of coals and predict which coals may best be utilized in the unit.

KCPL & Hawthorn Station Background

KCPL's capacity is about 70% coal-fired and 14% natural gas burning combustion turbines used for peaking. The remaining is nuclear capacity from the Wolf Creek Plant which began operation in 1985. Hawthorn operates as part of KCPL's five-plant 3,028 MW generating system. These power facilities produce electricity for over 400,000 customers in KCPL's 4,700 square mile service territory. Hawthorn represents almost 15% of the Company's total production capacity. Hawthorn Units 1-4 were completed between 1951 and 1955 and are on permanent shutdown. The last Hawthorn addition - Unit 5 in 1969 - was KCPL's first large-scale, modern generating unit, providing significant economies of scale. Its current rated capacity is 477 megawatts but has a generator rating of 514 megawatts.

The steam generator is a Combustion Engineering forced flow, tangentially fired unit. (Fig. 1) There are six type 803 RPS pulverizers on the unit with a mill flow rate of 42 tons/hour each. The design steam capacity at the maximum continuous rating load is 3,500,000 lb/hr. The tubing geometry in the boiler includes radiant and convective superheat and reheat assemblies. A continuous finned, staggered economizer (a source for pluggage to occur) was also designed into the unit. The unit was also originally designed and operated as a forced draft unit. The change to a balance draft unit occurred in 1978.

Boiler Model Construction

The construction of the boiler model for Hawthorn Unit 5 began with the developed boiler model example in the PEPSE boiler modelling class. This model was developed by Gene L. Minner of Halliburton/NUS. The model geometries of the boiler example in the class and that of Hawthorn Unit 5 are exactly the same. This simplified much of the boiler modelling. Many of the same assumptions were used as in the class example. Information required to construct the boiler model came from several sources including plant drawings, design information, contract data and construction memos. A simplified boiler model was first constructed to test the boundary conditions. (Fig. 2) Once this model converged and the output matched the vendor's predicted temperatures and pressures, the detailed boiler model was then constructed. The detailed boiler model incorporated all the separate components for each of the major boiler sections. (Fig. 3) The tube geometry and passage dimensions were identified and entered into the component sections. The detailed boiler model was then run and the output checked against the design load data. Fine tuning of the Hawthorn 5 model was difficult due to the lack of data for the various boiler stages. It appears that the original equipment manufacturer was becoming aware that other organizations could develop a computerized performance

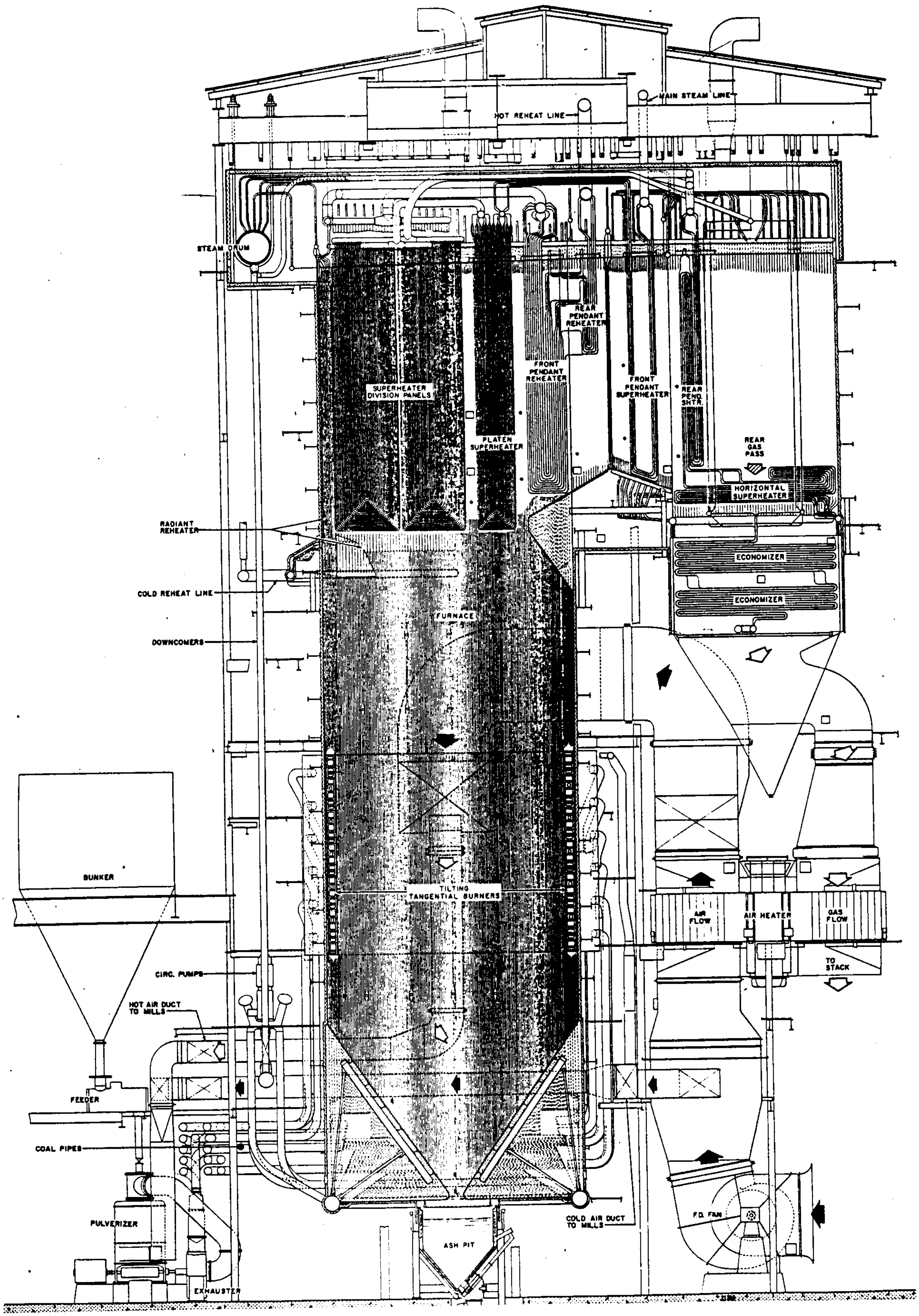
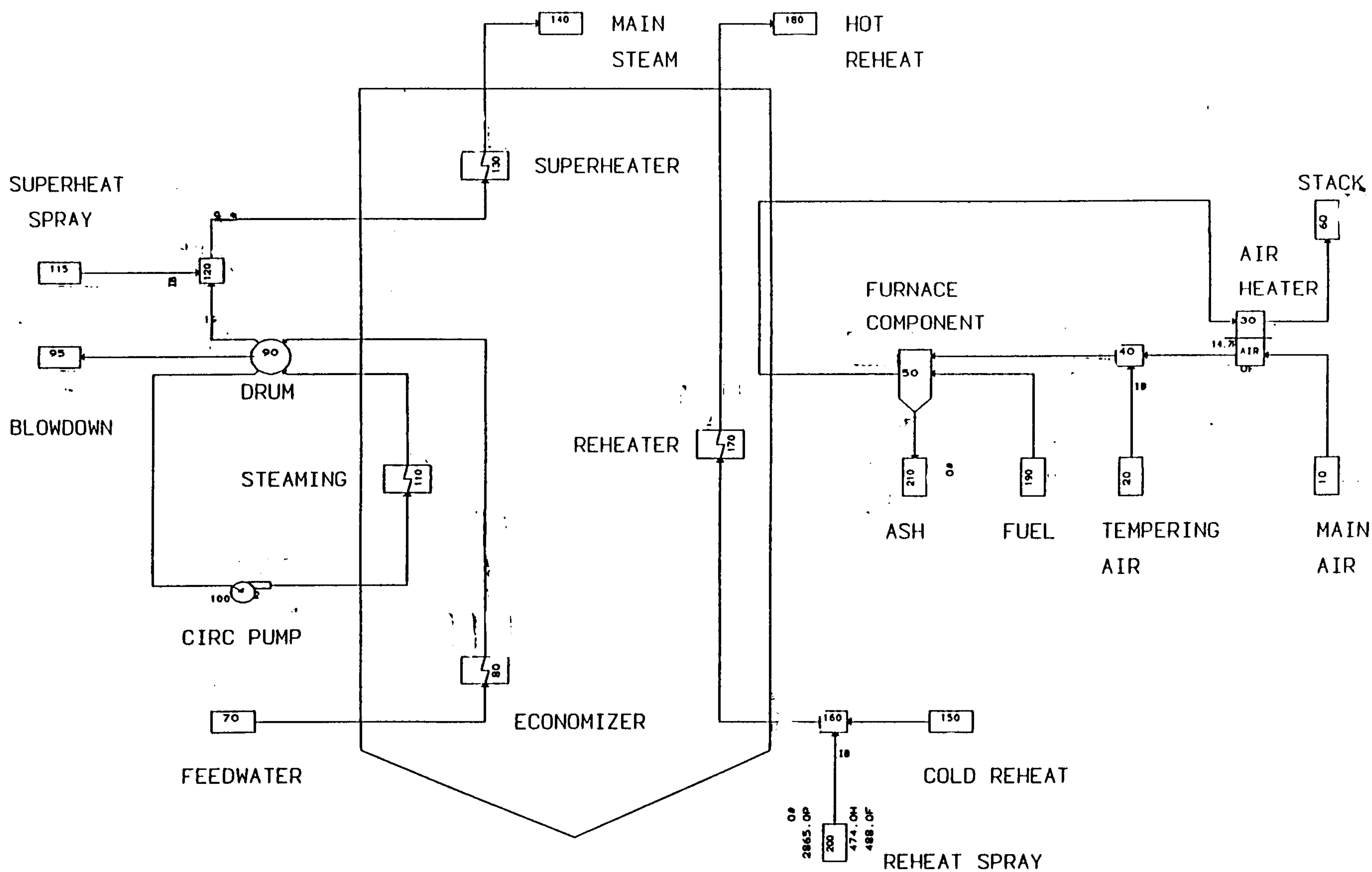


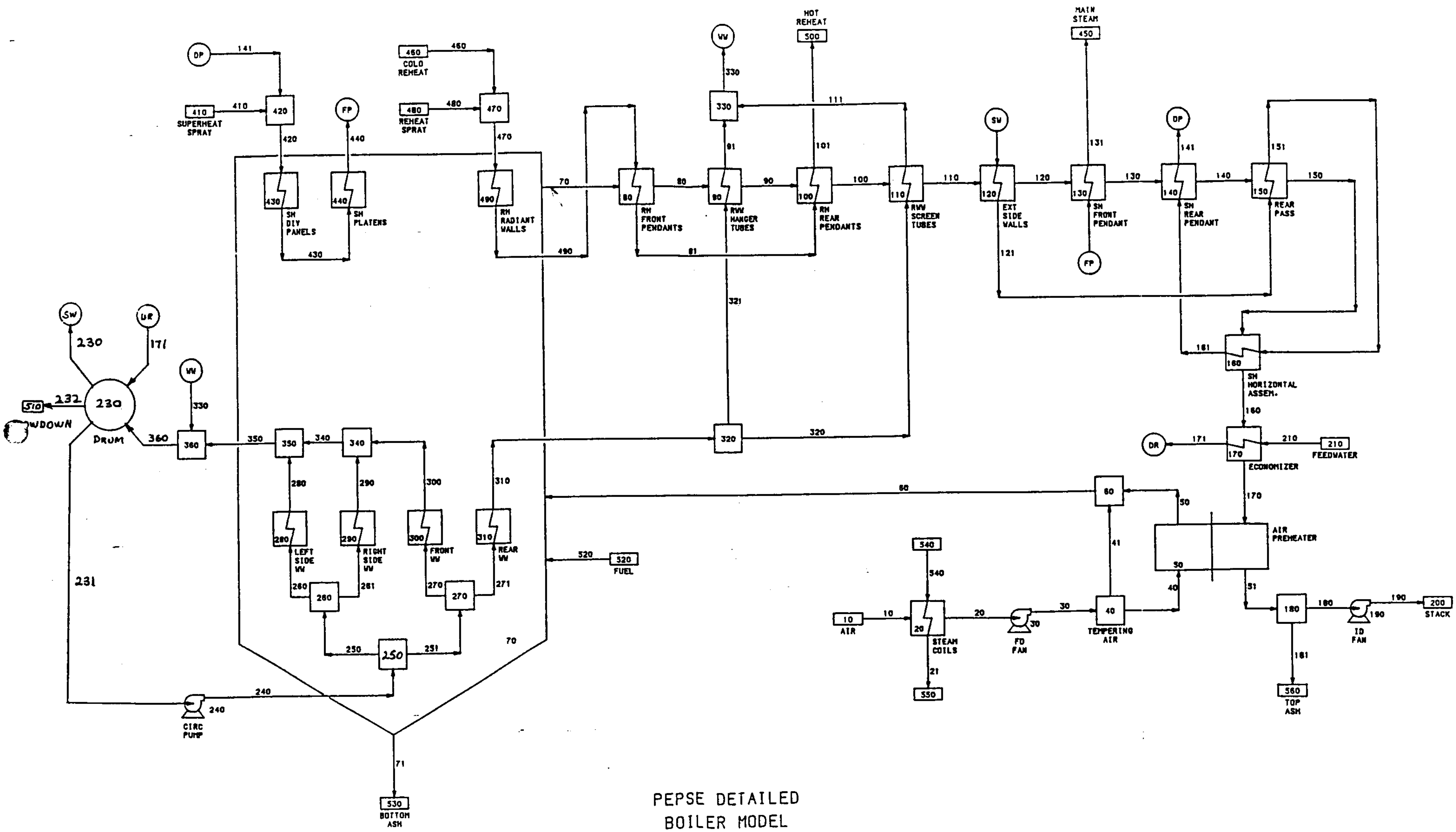
Fig. 1

Hawthorn Unit 5
Combustion Engineering, Inc.



PEPSE SIMPLIFIED BOILER MODEL

Fig. 2
Hawthorn Unit 5, 9/91



PEPSE DETAILED
BOILER MODEL

Fig. 3
Hawthorn Unit 5, 10/91

model. They reduced dramatically the amount of information on their predicted performance sheet. Our Montrose units, built in the late 50's, contain much more thermal data on their data sheets, making fine tuning much easier. HTC multipliers, fouling factors and form loss coefficients were determined where information was available. If operating parameters were unavailable, preliminary values given in the boiler model training handbook were used. Once the detailed boiler model converged, a check against the vendor's predicted performance values validated the model. The fine tuned detailed boiler model was developed for operating conditions at the maximum continuous rating (MCR) and the control load point.

For comparing the desired values with the actual values and adjusting the levels of fuel, air, and water to match the desired values, a "control system" had to be incorporated into the model. Four PEPSE controls were used to simulate the boiler "control system"[1]:

Desired Value	Controlled Value
Steam Pressure	Drum Pressure
Steam Temperature	Attemperation Flow
Drum Exit Quality	Feedwater Flow
Hot Reheat Temperature	Furnace Exit Temperature

With the control system in place, the boiler model was completed and ready to do some preliminary analyses. The complete boiler model input is included as an appendix to the paper.

Boiler Model Utilization

A. New Predicted Performance Data Sheet

Hawthorn Unit 5 was built in 1969. The design of the unit was

[1] PEPSE Boiler Modelling Seminar Notebook, Halliburton/NUS.

developed by Combustion Engineering. With the development of the boiler design, C.E. provided in the boiler instruction manual, a data sheet that indicated the predicted performance of the boiler. (Fig. 4) Since 1969, this was the only gauge operating personnel used to judge the performance of the boiler and the values used were based on a coal type that was never used in the boiler. The high cost of this Illinois bituminous coal made it uneconomical to burn at Hawthorn. Coal from Oklahoma was burned from 1969 - 1985.

Hawthorn switched to burning a western Powder River Basin coal in 1986. This was in response to environmental concerns and the favorable fuel prices of western fuels. With this new type of fuel being burned in the unit, a new data sheet needed to be developed.

After matching Combustion Engineering's predicted performance values at the control load and MCR for the design coal, the representative western coal (Black Thunder) ultimate analysis was entered as the fuel source (component 520) and the evaporation flow, temperature, and pressure utilized as the independent variable or output desired. An estimate was made on the quantity of air flow entered into the boiler. The results of the PEPSE runs can be seen in Fig. 5. The most interesting result was seen in the amount of fuel that is required to meet the steam demand. At a rated steam flow of 3,500,000 lb/hr., the western fuel required was 134,145 lb/hr. more than the original design fuel. The required mill flow rate was 3 tons/hr. higher than what the mills were designed to deliver. Boiler efficiency also decreased by 2-3% at the two load points. After looking at these results, it was decided to try and let PEPSE tell us how much steam flow (or megawatt load) the unit could generate with the western fuels. The results indicated the unit could supply 3,124,803 lb/hr of steam. This is 89.2% of the rated design steam flow. The rated megawatt loading at full steam flow is 515 megawatts. The new predicted steam flow coordinates to a loading of 460 megawatts. The unit is presently rated at 477

KANSAS CITY POWER & LIGHT COMPANY
HAWTHORNE STEAM ELECTRIC STATION
UNIT NO. 5

ORIGINAL C-E CONTRACT NO. 21765 – CCRRP
POWER SYSTEM SERVICES CONTRACT 59776

PREDICTED PERFORMANCE*

		Control Load	Max. Cont. Load	Max. Cont. Load
Fuel		COAL		GAS
Evaporation	lb/hr	1,667,000	3,500,000	3,500,000
Feedwater Temperature	F	413	483	483
Superheater Outlet Temperature	F	1,005	1,005	1,005
Superheater Outlet Pressure	psig	2,500	2,625	2,625
Superheater Pressure Drop	psi	55	200	200
Reheater Flow	lb/hr	1,507,000	3,120,000	3,120,000
Reheater Inlet Temperature	F	536	627	627
Reheater Inlet Pressure	psig	275	581	581
Reheater Outlet Temperature	F	1,005	1,005	1,005
Reheater Pressure Drop	psi	16	31	31
Economizer Pressure Drop	psi	4	20	20
Air Drop Cold Air Duct to A.H. Outlet	"wg	1.10	4.10	3.5
Air Drop Hot Air Duct to Windbox	"wg	0.35	1.30	1.10
Air Drop through Windbox **	"wg	2.0-5.0	3.5-5.0	3.5-5.0
Furnace Pressure	"wg	–0.10	–0.10	–0.10
Gas Drop, Furnace to Econ. Outlet	"wg	2.00	7.65	6.05
Gas Drop, Econ. Outlet to A.H. Outlet	"wg	1.80	5.60	5.00
Gas Temp. Entering Air Heater	F	565	670	665
Gas Temp. Leaving Air Heater, Uncorr.	F	236	268	251
Gas Temp. Leaving Air Heater, Corr.	F	246	258	241
Air Temp. ~~Leaving~~ Ent. Air Heater	F	125	102	90
Air Temp. Leaving Air Heater	F	527	601	599
Ambient Air Temperature	F	80	80	80
Excess Air Leaving Economizer	%	20	20	10
Fuel Fired	lb/hr	211,900	409,700	
	CFH			4,960,000
Efficiency	%	90.07	89.08	85.44

*NOTE: These performance figures are predicted only and are not to be construed as being guaranteed except where the points coincide with the guarantees.

Superheat steam temperature control range is from 1,667,000 to 3,500,000 lb/hr.
Reheat steam temperature control range is from 1,507,000 to 3,120,000 lb/hr.

**Adjustable for favorable firing conditions.

The fuel specifications on which the guarantees are based are as follows:

Mid-West Bit.		
F.C.	44.35%	HHV = 11,315 BTU/LB
Vol.	34.92	
Ash	8.86	
Moist.	11.87	
Total	100.00%	

Fig. 4

KANSAS CITY POWER & LIGHT COMPANY
HAWTHORN UNIT NO. 5 STEAM ELECTRIC STATION
ORIGINAL C.E. CONTRACT NO. 21765

PREDICTED PERFORMANCE* FUEL	CONTROL LOAD		MAX. CONT. LOAD		LOAD WITH MILL DESIGN FLOW RATE
	DESIGN COAL	WESTERN COAL	DESIGN COAL	WESTERN COAL	WESTERN COAL
Evaporation lb/hr	1,667,000	1,667,000	3,500,000	3,500,000	3,124,803
Feedwater Inlet Temp. °F	413	413	483	483	483
Feedwater Outlet Temp. °F	544	547	607	613	619
Economizer Press. Drop psi	4	4	20	20	16.5
Furnace Exit Temp. °F	2,207	2,174	2,416	2,375	2,483
Superheater Outlet Temp.°F	1,005	1,005	1,005	1,005	1,005
Superheater Outlet Press.psig	2,500	2,500	2,625	2,625	2,604
Superheater Spray Flow lb/hr	89,944	91,982	84,615	108,213	179,401
Superheat Temp. Aftr Spray Flow °F	765	766	792	795	795
Reheater Flow lb/hr	1,507,000	1,507,000	3,120,000	3,120,000	2,888,096
Reheater Inlet Temp. °F	536	536	627	627	572
Reheater Inlet Press. psig	275	275	581	581	555.4
Reheater Outlet Temp.°F	1,005	1,005	1,005	1,005	1,005
Reheater Pressure Drop	16	16	31	31	23
Air Flow lb/hr	2,768,183	2,740,506	4,694,500	4,745,203	4,412,524
Gas Flow lb/hr	2,379,835	2,420,298	4,603,955	4,788,802	4,413,523
Gas Temp. Enter. A.H.°F	564	567	668	675	669
Gas Temp. Exit. A.H.(Corr.) °F	240	252	258	274	271
Gas Temp. Exit. A.H.(Uncor.)°F	268	281	275	290	289
Air Temp. Enter. A.H.°F	125	125	102	102	102
Air Temp. Exit. A.H. °F	538	546	604	617	614
Ambient Air Temp. °F	80	80	80	80	80
Excess Air Leaving Econ. %	20	20	20	20	20
Fuel Fired lb/hr	211,652	279,792	409,455	543,600	501,000
Mill Flow Rate Tons/hr	17.64	23.32	34.12	45.30**	41.75
Boiler Efficiency %	89.50	87.10	88.90	86.05	86.11

The fuel specs. on which the predicted performance is based on are as follows:		Mid-West Bit.	Black Thunder
HHV	Btu/lb	11315	8800
Moisture	%	11.87	28.00
Ash	%	8.86	4.90
Sulfur	%	3.38	0.34
Volatile	%	34.92	32.09
Fixed Carbon	%	44.35	35.40

*The predicted performance values were generated by PEPSE Performance Modelling System.

**Beyond Mill Design Flow Rate

Fig. 5

megawatts but recently have only been able to load up to around 455 megawatts. This gives credence to PEPSE's output. The new predicted performance sheet will be placed in the Boiler Instruction Manuals. After the Spring 1992 overhaul, Hawthorn is planning to run tests to compare the PEPSE results with the actual performance parameters. Thermowells are being installed in the inlet and outlet headers of the boiler sections. This information will help define the tuning factors that are required to more accurately model the system. Once completed, this new Predictive Performance Data Sheet will be the basis for comparison of the Hawthorn Unit 5 performance.

B. Fuel Type Predicted Performance

The Hawthorn 5 PEPSE boiler model was asked to predict the performance of the boiler with various fuel types. Hawthorn was preparing to perform some actual "test burns" of several coal types. These tests required the burning of approximately 30,000 - 60,000 tons of each coal type. Without knowing how the boiler would react to the fuel, the station was at risk of having deratings of the unit or increased forced outages if the fuel was incapable of burning. In addition to the potential for increased operating and maintenance expenses, there was a substantial amount of data that must be gathered by the various departments at the station (i.e., Fuel, Operations, Results, and Engineering departments). The need for a boiler model that could predict the performance was needed at Hawthorn Station.

Two PEPSE runs were made of the three coal types Hawthorn was planning to burn at the station. The first run was to predict the fuel usage and boiler efficiency at the maximum continuous rating (MCR). This, for Unit 5, was a steam flow of 3,500,000 lb/hr. The other PEPSE run was made with the same fuel flow at the time the Central Testing Crew was performing boiler efficiency tests on the test fuels. The results from this run would tell us the maximum steam flow and boiler efficiency for the same amount of fuel during the performance tests. The run results could then be compared with the test results to see how well the boiler model matched the actual test results.

Following is a table of the PEPSE projected results and the results taken by KCPL's Central Testing Group:

	Coal Type A			Coal Type B			Coal Type C		
	PEPSE @ MCR	Actual Results	PEPSE w/ Same Fuel Amount	PEPSE @ MCR	Actual Results	PEPSE w/ Same Fuel Amount	PEPSE @ MCR	Actual Results	PEPSE w/ Same Fuel Amount
Firing Rate (lb/hr)	569023	527200	527200	569662	521800	521800	532953	532000	532000
Boiler Efficiency (%)	85.6	84.10	85.9	85.4	83.1	85.1	86.5	84.0	86.1
Exit Gas Temperature (°F)	678	761	665	680	770	663	669	761	666
Superheat Spray Flow (lb/hr)	122566	186270	90530	126521	272560	101719	93591	165120	63227
Main Steam Flow (Klb/hr)	3,500	2,975	3,375	3,500	2,998	3,211	3,500	2,980	3,519

The results from both the PEPSE runs and the tested parameters show some discrepancies and similarities.

Boiler efficiency, although the tested amounts were lower, still showed the same trend as what was predicted by PEPSE. (See Fig. 6).

The other parameters that could be compared, including boiler efficiency, all differ from the PEPSE results. This may be due to several reasons:

1. The boiler at the time of the tests was beginning to plug severely in the backpass of the boiler. This will cause exit gas temperatures to rise, O_2 levels to rise and heat transfer to decrease thereby reducing the tested boiler efficiency.
2. The tested results are averaged over a 2 hour period. During this time frame,

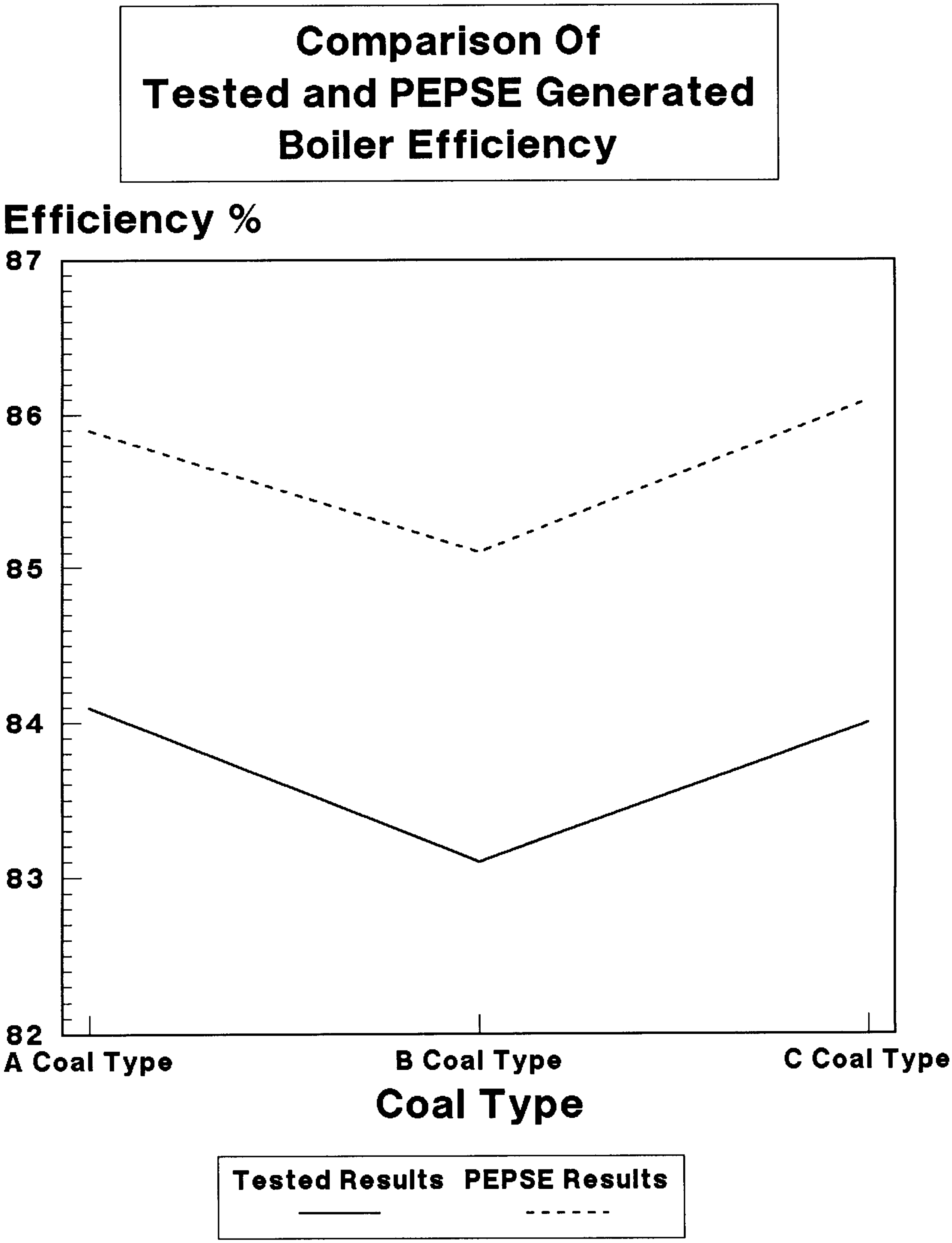

Comparison Of
Tested and PEPSE Generated
Boiler Efficiency
Efficiency %
87
86
85
84
83
82
A Coal Type
B Coal Type
C Coal Type
Coal Type
Tested Results
PEPSE Results

Fig. 6

boiler upsets may occur thus affecting the final results.

3. The heat transfer coefficient multipliers originally developed could be incorrect and more data input is required to correctly predict these multipliers.

4. The two lowest pressure feedwater heaters were out of service at the time of the test. This causes the boiler to utilize more fuel to raise the feedwater temperature thereby reducing boiler efficiency.

In conclusion, it appears that several areas need to be addressed before the developed PEPSE boiler model can be used to make final economic decisions on the coal type to burn at Hawthorn Unit 5. Testing procedures and boiler conditions must be standardized for comparison; the heat transfer coefficient multipliers must be further fine tuned in the model to more accurately model the heat transfer occurring in the various sections; and operating parameters (O_2, air heater exit gas temperature, etc.) that are more indicative of actual conditions occurring in the boiler must be utilized in the model.

It should be stated that the present model does indicate trends that occur between various coal types and thus the initial objectives in developing the model have been met. These initial trial runs of the PEPSE boiler model will serve as a basis for further refinement.

<u>Future Uses of the Boiler Model</u>

The advantages of having a working boiler model are clearly defined for Hawthorn and KCPL. Specifically at Hawthorn, there are several areas in which the PEPSE boiler model will be utilized in the near future.

1. Presently, the economizer on Unit 5 is of the continuous finned, staggered tube design. This design is very susceptible to pluggage. There are several tubing geometry alternatives available; some requiring more heat transfer surface. PEPSE will be asked to determine what the change in tubing geometry will do to boiler operation, construction requirements (more tubes needed) and boiler efficiency.
2. The boiler on Unit 5 has a tendency to foul in certain sections of the boiler. Heat transfer coefficient multipliers may be manipulated to simulate the fouling in these areas and determine how and to what degree this affects the performance of the unit. This can help Hawthorn concentrate their maintenance and construction efforts in areas that have the most impact.
3. Operating parameters such as excess air, spray flows and combustion air conditions will be manipulated in the boiler model to investigate the effects on overall performance.
4. The Central Testing Group at KCPL has interest in using the PEPSE boiler model to assess their testing results. Presently, no comparison except to past data can be made.
5. Several plant operating problems (low reheat temperatures, high exit gas

temperatures, etc.) need to be analyzed and corrected. Before initiating actual changes in the boiler, PEPSE can show the effects on the boiler performance and aid in the decision making process.

Summary

Kansas City Power & Light Company recognized the need to develop working predicted performance boiler models at their generating stations. A preliminary model was developed for Hawthorn Unit 5. This model has been used to develop a new predicted performance data sheet for the unit based on the current coal type the unit is burning. The past data sheet was for a design coal that never was burned at the station. The new predicted data sheet will be fine tuned as data instruments are installed in the boiler.

The second use of the model has been to compare the predicted performance of several coal types for making economical fuel choices. Although further refinement is needed, the model does produce preliminary results that can aid in the selection of fuel types prior to performing costly test burns.

In the future, the PEPSE Boiler Model will be fine tuned to perform tube geometry predictions, assess test data, and to eliminate operating problems.

REFERENCES

1. PEPSE Boiler Modelling Seminar Notebook, Halliburton/NUS Energy Group, P. O. Box 50736, Idaho Falls, Idaho, 5/1/91.

2. Hawthorn Steam Electric Station Unit 5 Boiler Instruction Manual:, Vol. 1, Combustion Engineering, Inc., 1000 Prospect Hill Road, Windsor, Connecticut, 10/68.

3. Hawthorn Station Information Guide, Kansas City, Power & Light Company, P. O. Box 418679, Kansas City, MO 64141-9679.

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*
*         PEPSE USER : ADMIN
*               DATE : 04/28/92
*               TIME : 12:13
*      MODEL FILE ID : H5MCR1
*        JOB FILE ID : \EASEPLUS\DEMO\H5MCRT1.JOB
*    RESULTS FILE ID : \EASEPLUS\DEMO\H5MCRT1.OUT
*
= (DPW) HAWTHORN UNIT 5 BOILER MODEL (NO FRILLS, DESIGN MODE COMPONS)
*
*  THE TYPE 1 STREAMS ACCOUNT FOR ELEVATION, FRIC, FORM IN CIRC LOOP.
*  SINGLE DOWNCOMER STREAM REPRESENTS 9 PARALLEL PIPES.  CAN MATCH ONLY
*  VELOCITY AND L/D, BUT NOT REYNOLDS NUMBER.
*
*
**************************************************************
*       GENERIC INPUT DATA
**************************************************************
*
*  CYCLE FLAGS
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*
*  CYCLE CONVERGENCE DATA
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*  SPECIAL FEATURES INITIATION DATA
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*  SPECIAL FEATURES CALCULATIONAL ORDER DATA
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020002  NOPRNT
020004  NOPRNT
020005  NOPRNT
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020015  NOPRNT
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020028  NOPRNT
020029  NOPRNT
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020037  NOPRNT
020038  NOPRNT
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020050  NOPRNT
*
*** MODEL GEOMETRY
*
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500210   20,  T, 550,  I
500300   30,  U,  40,  I
500400   40,  U,  50,  T
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500600	60,	U,	70,	IA
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500710	70,	B,	530,	I
500800	80,	D,	90,	S
500810	80,	T,	100,	T
500900	90,	D,	100,	S
500910	90,	T,	330,	IB
501000	100,	D,	110,	S
501010	100,	T,	500,	I
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501500	150,	D,	160,	S
501510	150,	T,	160,	T
501600	160,	D,	170,	S
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501700	170,	D,	50,	S
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501800	180,	U,	190,	I
501810	180,	B,	560,	I
501900	190,	U,	200,	I
502100	210,	U,	170,	T
502400	240,	U,	250,	I
502500	250,	U,	260,	I
502510	250,	B,	270,	I
502600	260,	U,	280,	T
502610	260,	B,	290,	T
502700	270,	U,	300,	T
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502800	280,	T,	350,	IB
502900	290,	T,	340,	IB
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503100	310,	T,	320,	I
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505200	520,	U,	70,	IF
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*
****************************************************************
*      COMPONENT DATA
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*
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700201    0.     0.     0.     0.     0.     0.     0.
*  REHEATER FRONT PENDANT
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700804    3      1       1    50.   52.25     42.    20.
700805   65.     2.   2.17   2.5    4.5    9.5      0.
700806    0.  0.9     20.     0.   9.22e-5       0.
700807    0.     0.     0.     0.     0.     0.
700808    0.     0.    0.0     0.     0.     0.     0.
*  REAR WATERWALL HANGER TUBES
700900   28      1    2059000.  2859.699951   0.2
700904    3      0       3    42.700001    52.25    42.700001      1.
700905   61.     1.   1.57   2.25   2.25   9.5      0.
700906    0.  0.9     20.     0.   0.000127      0.
700907    0.     0.     0.     0.     0.     0.
700908    0.     0.    0.0     0.     0.     0.     0.
*  REHEATER REAR PENDANT
701000   28      1    3120000.  595.700012  552.
701004    3      0       1    43.   52.25     18.    10.
701005  131.     2.   2.2    2.5    4.375    4.75     0.
701006    0.  0.9     20.     0.   9.091e-5     0.
701007    0.     0.     0.     0.     0.  564.700012
701008    0.     0.    0.0     0.     0.     0.     0.
*  REAR WATERWALL SCREEN TUBES
701100   28      1    5040000.  2859.699951   0.2
701104    3      0       3    40.   52.25     40.     3.
701105  162.     1.   1.855    2.375    3.25   3.847      0.
701106    0.  0.9     20.     0.   0.000108      0.
701107    0.     0.     0.     0.     0.     0.
701108    0.     0.    0.0     0.     0.     0.     0.
*  EXTENDED SIDE WALLS
701200   28      2    1219200.  2859.699951      1.     1.
701201    0.     0.     0.     0.     0.     0.
701202    0.     0.    0.0     0.     0.
*  SUPERHEATER FRONT PENDANT
701300   28      1    3500000.  2859.699951   909.
701304    3      0       1    43.   52.25     42.     8.
701305  131.     2.   1.405    2.125     4.   4.75     0.
701306    0.  0.9     20.     0.   0.000142     0.
701307    0.  22532.     0.     0.     0.     0.
701308    0.     0.    0.0     0.     0.     0.     0.
*  SUPERHEATER REAR PENDANT
701400   28      1    3500000.  2859.699951   909.
701404    3      0       2    43.   52.25     39.    12.
701405  156.     3.   1.4      2.     4.     4.     0.
701406    0.  0.9     20.     0.   0.000143     0.
701407    0.  49192.     0.     0.     0.     0.
701408    0.     0.    0.0     0.     0.     0.     0.
*  REAR PASS
701500   28      2    4876800.  2859.699951      1.     1.
701501    0.     0.     0.     0.     0.     0.
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701502     0.     0.    0.0     0.     0.
*  SUPERHEATER HORIZONTAL ASSEMBLIES
701600    28      1    3500000.  2859.699951   909.
701604     3      0      2   31.75   52.25   31.25    20.
701605  156.     5.   1.48    2.     4.     4.     0.
701606     0.   0.9    20.     0.   0.000135    0.
701607     0.   62738.     0.     0.     0.     0.
701608     0.     0.    0.0     0.     0.     0.     0.
*  ECONOMIZER
701700    28      1    3360000.  2859.699951   483.
701704     3      0      2   31.75   52.25   31.25    30.
701705  178.    15.   1.6     2.     5.   3.5    861.75
701706  882.5   0.9    20.     0.   0.000125    0.
701707     0.  143705.     0.     0.     0.     0.
701708     0.     0.    0.0     0.     0.     0.     0.
*  AIR HEATER
700500    21      2    601.     0.     0.     0.
700501     0.     0.     0.     0.     0.
700502     0.     0.     0.     0.     0.
700503     0.  311000.     0.     0.     0.     0.     0.     0.     0.     0.
*  LEFT SIDE WATERWALL
702800    29      1     70
702804  0.2       1    171.5   208.     1.
702805  1.56     2.   2.375     0.     0.    20.
702806  0.000125    0.     0.  6970.     0.
702807     0.     0.     0.     0.     0.     0.
*  RIGHT SIDE WATERWALL
702900    29      1     70
702904  0.2       1    171.5   208.     1.
702905  1.56     2.   2.375     0.     0.    20.
702906  0.000125    0.     0.  6970.     0.
702907     0.     0.     0.     0.     0.     0.
*  FRONT WATERWALL
703000    29      1     70
703004  0.2       1    171.5   307.     1.
703005  1.56     2.   2.375     0.     0.    20.
703006  0.000125    0.     0.  8934.     0.
703007     0.     0.     0.     0.     0.     0.
*  REAR WATERWALL
703100    29      1     70
703104  0.2       1    171.5   307.     1.
703105  1.56     2.   2.375     0.     0.    20.
703106  0.000125    0.     0.  8934.     0.
703107     0.     0.     0.     0.     0.     0.
*  SUPHTR DIV PANELS
704300    29      1     70
704304  931.      1     50.   804.     2.
704305  1.344   1.75  2.125     0.     0.    20.
704306  0.000149    0.     0.  13950.    0.
704307     0.     0.     0.     0.     0.   0.4
*  SUPHTR PLATEN
704400    29      1     70
704404  925.      1     50.   714.     2.
704405  1.594     2.  2.375     0.     0.    20.
704406  0.000123    0.     0.  13715.    0.
704407     0.     0.     0.     0.     0.   0.4
*  RHTR RAD WALLS
704900    29      1     70
704904  680.      1    50.25   458.     1.
704905  2.025   2.355   2.375     0.     0.    20.
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704906  9.87e-5     0.     0.  5104.     0.
704907    0.    0.    0.    0.    0.  0.4
*
*************** SOURCES, SINKS, AND VALVES
*
*  AIR
700100   31    80.  14.7  4400000.    0.    0.
700103   AIR, -0.013
*  FEEDWATER
702100   33   483.  2859.699951   3360000.    0.    0.
*  SUPERHEAT SPRAY
704100   31   483.  2859.699951   140000.     0.    0.
*  COLD REHEAT
704600   31   627.  595.700012  3120000.    0.    0.
*  REHEAT SPRAY
704800   31   483.  2859.699951     0.    0.    0.
*  DESIGN FUEL
705200   31    80.  2500.   409700.     0.    0.
705203  FUEL, 11315., SSVL, 0., CO2, 0., H2O, 0.1187
705204   SO2, 0.,   O2, 0.0867,  N2, 0.0073,  CO, 0.
705205    H2, 0.0451,    C, 0.6198,   S, 0.0338, ASH, 0.0886
*  STEAM COIL INLET
705400   31   1.05  14.7  30000.    0.    0.
*  STACK OUTLET
702000  30
*  MAIN STEAM OUT
704500  32
*  HOT REHEAT
705000  30
*  BLOWDOWN
705100  30
*  BOTTOM ASH
705300  30
*  STEAM COIL OUTLET
705500  30
*  TOP ASH
705600  30
*
*************** PUMPS, COMPRESSORS, AND FANS
*
*  MAIN CIRC PUMP - SET PUMP HEAD
702400   41     0.    1.    1.  0.82
702401    0.    0.    0.    0.    0.  223.
*  F.D. FAN (80% EFFICIENCY ASSUMED)
700300   43   14.7    1.    1.  0.8
*  I.D. FAN (80% EFFICIENCY ASSUMED)
701900   43   14.7    1.    1.  0.8
*
*************** MIXERS
*
*
703600   50     1     0.
*  SUPERHEAT SPRAY + MAIN STEAM
704200   50     1     0.
*  REHEAT SPRAY + COLD REHEAT
704700   50     1     0.
*  PREHEATED AIR + TEMPERING AIR
700600   50     1     0.
*  REAR WW HANGER TUBES + RWW SCREEN TUBES
703300   50     0     0.
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*  WATER WALL MIXERS
703400   50      1     0.
*
703500   50      1     0.
*
*************** SPLITTERS
*
*  TEMPERING AIR
700400   61      0.  383300.
*  R WW SCREEN TUBES, SPLIT PER FLOW AREA
703200   63      0.  0.29
*  TOP ASH
701800   69      0.    0.    0.
701801    RCO2, 0., RH2O, 0., RSO2, 0.,  RO2, 0.
701802     RN2, 0.,  RCO, 0.,  RH2, 0.,   RC, 0.995
701803      RS, 0., RASH, 0.995
*  F,R WALL (SPLIT PER FLOW AREA FRACTIONS)
702500   63      0.  0.725
*  SIDE WALL
702600   63      0.  0.5
*  REAR WALL
702700   63      0.  0.5
*
*************** CLASS 7 COMPONENTS
*
*  FURNACE/COMBUSTOR
700700   70      1     3    10   0.2
700701    0.     0.    0.  0.0018  0.0025    0.
700702    1.  100.     0.    0.     0.     0.  0.015
*  BOILER DRUM
702300   73      1   520   2839.699951     0.     0.     0.
702301    5.     0.    0.    0.
702309    5      0     0.    0.    0.
*
*
**************************************************************
*      SPECIAL FEATURES
**************************************************************
*
*************** CONTROL BLOCKS
*
*
*  SET CONTROL BLOCK ON ALL CONTROLS PRESENT
845100      1     2     3     4     0
846101      0.      0.     0.     0.     0.
846104      0.      0.     0.     0.     0.
*
*************** OPERATIONAL VARIABLES
*
* FRACTION OF CONV. PASS HEAT TRANS. AREA, EXT. SIDE WALL
870030   0.006
* FRACTION OF CONV. PASS HEAT TRANS. AREA, REAR PASS
870040   0.044
*
*************** OPERATIONS
*
* SET BOILER EFF. FLUE GAS TEMPERATURE
880010     TTUNCT     50         EQL        ETTFG      1
* SET FURNACE COMPONENT INPUT WORD FOR HEAT LOSSES
880020     ELUNSP     1          EQL        UFUNL      70
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* SET FURNACE INPUT WORD FOR FRACTIONAL UNACC. HEAT LOSS
880030    OPVB        6       SUB       WWVSC    410       WWVSC    210
* SET FEEDWATER FLOW
880040    WWVSC     210       ADD       WW       232       WWVSC    210
* SET COLD REHEAT FLOW
880050    OPVB        7       SUB       WWVSC    480       WWVSC    460
* HEAT OUTPUT
880100    BBSTRM    131       ADD       BBSTRM   101       OPVB      10
*
880110    OPVB       10       ADD       BBSTRM   232       OPVB      10
*
880120    OPVB       10       SUB       BBSTRM   210       OPVB      10
*
880130    OPVB       10       SUB       BBSTRM   410       OPVB      10
*
880140    OPVB       10       SUB       BBSTRM   460       OPVB      10
*
880150    OPVB       10       SUB       BBSTRM   480       OPVB      10
* ENERGY INPUT
880300    QHHVFL      0       ADD       QHBAE      0       OPVB      20
*
880310    OPVB       20       ADD       QHBZE      0       OPVB      20
*
880320    OPVB       20       ADD       QHBFE      0       OPVB      20
*
880330    OPVB       20       ADD       QHBX       0       OPVB      20
*
880340    OPVB       20       ADD       QHBMAE     0       OPVB      20
*
880350    OPVB       20       ADD       QHBMIS     0       OPVB      20
* CALCULATE I/O EFF.
880400    OPVB       10       DIV       OPVB      20       OPVB      40
* CALC. TOTAL HEAT TO CONVECTIVE STAGES
881000    BBHXTS     80       EQL       OPVB     100
*
881010    BBHXTS     90       ADD       OPVB     100       OPVB     100
*
881020    BBHXTS    100       ADD       OPVB     100       OPVB     100
*
881030    BBHXTS    110       ADD       OPVB     100       OPVB     100
*
881040    BBHXTS    130       ADD       OPVB     100       OPVB     100
*
881050    BBHXTS    140       ADD       OPVB     100       OPVB     100
*
881060    BBHXTS    160       ADD       OPVB     100       OPVB     100
*
881070    BBHXTS    170       ADD       OPVB     100       OPVB     100
* CALC. EXT. SIDE WALL HEAT DUTY
881090    OPVB      100       MUL       OPVB       3       BBHXGR   120
881095      8
* CALC. REAR PASS HEAT DUTY
881100    OPVB      100       MUL       OPVB       4       BBHXGR   150
881105      8
*
*************** SPECIAL INPUT/OUTPUT
*
890020      'MAIN STEAM (EVAPORATION) FLOW'
890021      OPVB          6     3500000.               I
890030      'HOT REHEAT FLOW'
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890031       OPVB            7       3120000.                  I
890040       'SUPERHEAT SPRAY FLOW'
890041       WWVSC         410       140000.                   I
890050       'REHEAT SPRAY FLOW       '
890051       WWVSC         200         0.                      I
890060       'FUEL FIRING RATE'
890061       WWVSC         520       409700.                   I
891010       'UNCORRECTED GAS EXIT TEMP.        '
891011       TTUNCT         50
891020       'BOILER EFF BY I/O METHOD'
891021       OPVB           40
891030       'BOILER EFF BY HT LOSS METHOD      '
891031       EFBLRD          0
*
*************** BOILER EFFICIENCY CALCULATION
*
900000      1  100.  14.7
* FLUE GAS DESCRIPTION
900110   170    0.    0.    0.    0.    0.    0.
900111     0.    0.    0.    0.    0.    0.
* COMBUSTION AIR
900210    40    0.    0.    0.    0.
* FUEL DESCRIPTION
900310   520    0.    0.    0.    0.    0.
900311     0.    0.    0.    0.    0.    0.
* TEMPERING AIR
900510    41    0.    0.    0.    0.    0.
* AUXILIARY DRIVE HEAT CREDIT - CIRC. PUMP
900610   240    0.
* UNBURNED CARBON IN STACK
901110    70    0.    0.
* UNBURNED CARBON IN REFUSE
901120    71    0.    0.
* RADIATION LOSS
901610    70    0.
* UNACCOUNTED HEAT LOSS
901910   0.0155
*
*
*
= (DPW) CONTROL SYSTEM BOILER MODEL
*
*  CONTAINS THE TUNING FACTORS, BUT NOT THE CONTROLS, FROM THE FINE-TUNE
*  STEP.  NOW THE BOILER CONTROLS TO ACHIEVE EVAPORATION, AND MAIN
*  STEAM AND REHEAT SET POINTS ARE INCLUDED.  THE ROTARY AIR HEATER IS
*  IN THE REFERENCE-BASED PREDICTIVE HEAT TRANSFER CALC MODE.
*
*
**************************************************************
*      GENERIC INPUT DATA
**************************************************************
*
*  CYCLE CONVERGENCE DATA
012000  150     0.    0.    0.    0.    0.   10   500000.
*
*  SPECIAL FEATURES INITIATION DATA
012001    5     2    10     0     0     0
*
*  SPECIAL FEATURES CALCULATIONAL ORDER DATA
012002    0     0     0
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*
****************************************************************
*      COMPONENT DATA
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*
*************** HEAT EXCHANGERS
*
*  AIR HEATER - REF-BASED PRED, HT MODE
700500   21      3
700503    0.  600000.     0.     0.     0.     0.     0.     0.     0.     0.
700504  102.  601.  670.  268.  3819000.  4612000.
700506    0.     0.     0.     0.     0.     0.
*
*************** SOURCES, SINKS, AND VALVES
*
*  DESIGN FUEL
705200   31     80.  2500.   409700.     0.     0.
*
*************** CLASS 7 COMPONENTS
*
*  FURNACE/COMBUSTOR
700700   70      1      3     10   0.2
700701  2000.     0.     0.  0.0018  0.0025    0.
700702    1.  100.     0.     0.     0.     0.  0.015
*  BOILER DRUM - ZERO DEMAND REF
702300   73      1      0   2839.699951     0.     0.     0.
702301    5.     0.     0.     0.
702309    5      0      0.     0.     0.
*
*
****************************************************************
*      SPECIAL FEATURES
****************************************************************
*
*************** CONTROLS
*
*
*  CONTROL FIRING FOR DRUM ENERGY IMBALANCE
840100   WWVSC    520     1.  100000.     1.  BBEIBC  230
840109   200000.  900000.
*
*  CONTROL FURNACE EXIT T FOR HOT REHEAT
840200   TEXF      70   1005.   1e-4    1.  TT      101
840209   1200.  2700.
*
*  CONTROL SH SPRAY FOR MAIN STEAM T
840300   WWVSC     410   1005.   1e-4    1.  TT      131
840309     0.   1200000.
*
*  CONTROL DRUM P FOR MAIN STEAM P
840400   PPDRUM   230   2639.699951   1e-4    1.  PP      131
840409   2000.  3000.
*
*************** CONTROL BLOCKS
*
*
*  SET CONTROL BLOCK ON ALL CONTROLS PRESENT
845100     1     2     3     4     0
845108   KEEP
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846101     0.     0.     0.     0.     0.
846104     0.     0.     0.     0.     0.
*
*************** SPECIAL INPUT/OUTPUT
*
890060     'FUEL FIRING RATE'
890061     WWVSC       520     575000.          I
891510     ''
891511     TEXF         70     2629.800049      I
891520     ''
891521     RSVF        430     0.4              I
891530     ''
891531     RSVF        440     0.4              I
891540     ''
891541     RSVF        490     0.4              I
891550     ''
891551     HTTIRH       80     -0.3             I
891560     ''
891561     HTTIRH      100     -0.31            I
891570     ''
891571     HTTIRH      130     -0.73            I
891580     ''
891581     HTTIRH      140     -0.85            I
891590     ''
891591     HTTIRH      160     -0.85            I
891600     ''
891601     HTTIRH      170     -0.75            I
891610     ''
891611     TUFORM       80      -1.             I
891620     ''
891621     TUFORM      100     -8.75            I
891630     ''
891631     PDHXTU      150     0.01             I
891640     ''
891641     TUFORM      130     -6.875           I
891650     ''
891651     TUFORM      140      -1.             I
891660     ''
891661     TUFORM      160      -1.             I
891670     ''
891671     TUFORM      170      -5.             I
891680     ''
891681     TUFORM      430      -1.             I
891690     ''
891691     TUFORM      440      -1.             I
891700     ''
891701     FRMLS       490      -1.             I
891710     ''
891711     TUFORM      280      -1.             I
891720     ''
891721     TUFORM      290      -1.             I
891730     ''
891731     TUFORM      300      -1.             I
891740     ''
891741     TUFORM       90      -1.             I
891750     ''
891751     TUFORM      110      -1.             I
891760     ''
891761     PDHXTU      120     0.01             I
891770     ''
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891771      TUFORM       310        -1.                      I
891780      ''
891781      HTTIRH        90        -0.85                    I
891790      ''
891791      HTTIRH       110        -0.85                    I
*
*
*
*
**************************************************************
*      COMPONENT DATA
**************************************************************
*
*************** SOURCES, SINKS, AND VALVES
*
*  BLACK THUNDER
705200   31    80.  2500.   575000.     0.     0.
705203  FUEL, 8800., SSVL, 0., CO2, 0., H2O, 0.28
705204   SO2, 0.,   O2, 0.1252,  N2, 0.0069,  CO, 0.
705205    H2, 0.0354,    C, 0.5,   S, 0.0034, ASH, 0.049
*
*
**************************************************************
*      SPECIAL FEATURES
**************************************************************
*
*************** SPECIAL INPUT/OUTPUT
*
890010      'FUEL FIRING RATE'
890011      WWVSC        520       575000.                   I
*
*
*
*
******************************************
*   END OF BASE DECK
******************************************
*
*
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