PEPSE® Modeling Through Complete Load Range of a Unit

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ABSTRACT

All fossil units on the Philadelphia Electric Co. system have been modeled for full load operating conditions. With the availability of lower cost generation from nuclear units and other power pools, the fossil units began operating under more cyclic conditions. Testing and heat rate analysis at low loads became necessary.

Calculation of low load heat rates by the PEPSE computer code required the modeling to be revised. Each model had to accurately represent a unit's operation over the entire load range.

The purpose of this report is to discuss the modeling techniques used and the problems encountered.

INTRODUCTION

In the utility industry today, many units that once were supplying base load electrical service are now providing electricity under cyclic operating conditions. Availability of lower cost generation from nuclear units and other power pools dictate this change in operation. Philadelphia Electric Co. (PECo) began to experience the effects of this scenario last year.

There are nine fossil units on the PECo system. All of the units are modeled at full load conditions with the PEPSE computer code. Heat rate tests have been performed at full load operating conditions. PEPSE was used to analyze the results of the heat rate test data. Any change in the operating conditions of a unit such as a heater being removed from service or excessive BFP seal flows would be studied at full load conditions to determine their effect on heat rate.

As all of our units began operating under cyclic conditions, studying unit performance under these conditions was desired. This required all full load PEPSE models to be revised to include complete load range operation. Schedules and efficiency multipliers were among the techniques employed to achieve this goal.

MODEL DEVELOPMENT

The units to be discussed for this paper are Eddystone 3 and 4. They are Westinghouse units rated at 380 MW. The full load design heat balance is shown in Figure 1. The units are "mirror images" of each other. So, by modeling one unit, two units are actually completed. The PEPSE model of the units is shown in Figure 2. Both units have steam driven boiler feed pumps. Type 8 turbines were used in the full load modeling.

Scheduling the leak off flows was the first revision completed. This proved to be very easy for these units because their design is fairly uncomplicated. The vendor heat balance leak off flows are lettered making it less confusing.

Feedwater heater TTD's and DCA's did not have to be scheduled. They are constant over the entire load range for the units.

The major revision involved the turbines. As previously stated, they were modeled using type 8 turbines. The vendor exhaust loss curve had to be scheduled in the full load heat balance because the General Electric procedures did not match the vendor turbine end conditions.

It was decided to use General Electric turbines for the multi-load revision. The full load vendor heat balance was run first. The PEPSE heat balance run did not match the vendor heat balance. It was not expected to match since the units have Westinghouse turbines.

It was obvious that efficiency multipliers and shapers were necessary to accurately define the Westinghouse turbines. Controls were employed to calculate the efficiency multipliers and shapers that were needed.

For the full load case, controls were written for calculating the efficiency multipliers for stage groups 10 and 30. They are the governing stage and the IP inlet stage group, respectively. Turbine component numbering can be referred to as shown on Figure 2. Controls for the shape factors were written for turbines 30, 40, and 41. An example of the controls for the efficiency multipliers and shapers is shown in Figure 3. The HP stage group is defined in PEPSE as the last stage group and does not require a shaper.

The results of the PEPSE run at full load with the controls proved interesting. The shapers for turbine stage groups 40 and 41 yielded results that matched the default values as defined by the PEPSE computer code. Therefore, shapers were not needed for these turbines. The controls were removed and were replaced by the values of the efficiency multipliers and shapers determined by PEPSE. The PEPSE full load heat balance was run. This compared accurately with the vendor heat balance.

The procedure as just described was repeated for five additional load levels and verified. The results obtained from the PEPSE run compared well with the vendor heat balances. It was found after completing all of the runs that shapers for turbines 40 and 41 were not required at any load level. This just made the job easier.

To reduce the amount of computer space and make the procedure easier, the efficiency multipliers and shapers were scheduled. This allowed for elimination of the controls and the optional input card for the values of the efficiency multipliers and shapers. The schedules used for complete load range operation are shown in Figures 4, 5 and 6.

The use of Volumes II and III proved to be a very valuable aid in completing this particular section of the revision.

RESULTS

The fact that the units discussed in this paper were the most simplified on our system, the project was easy to initiate. We have not been concerned about the computer time as so many other users have been. However, we are concerned with computer space. Scheduling the leak off flows, TTD's, DCA's, and the necessary turbine data significantly reduced the space required.

In addition to the two units discussed in this paper, there are five other units which have been scheduled for multi-load range operation. The two units not completed are super-critical, double reheat units.

With complete load range operation, flexibility to analyze unit operation at any load exists. At the present time, heat rates at less than full load conditions have not been performed. However, studies concerning the effects of excessive BFP flows and heaters out of service have been performed at low loads. The analysis using the PEPSE computer code has proven to be a significant improvement in our existing performance program.

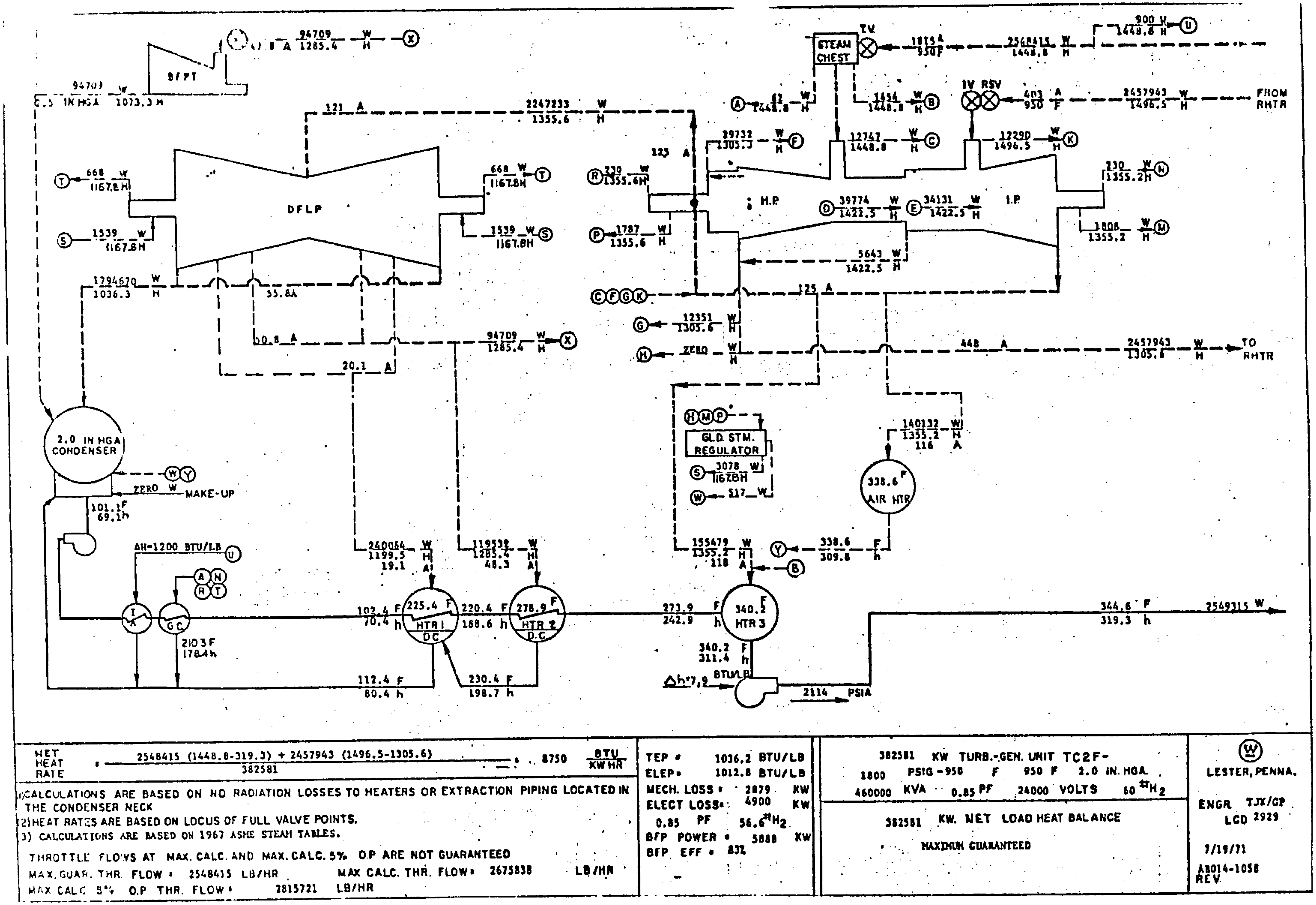

FIGURE 1: EDDYSTONE 3 AND 4
FULL LOAD DESIGN
HEAT BALANCE

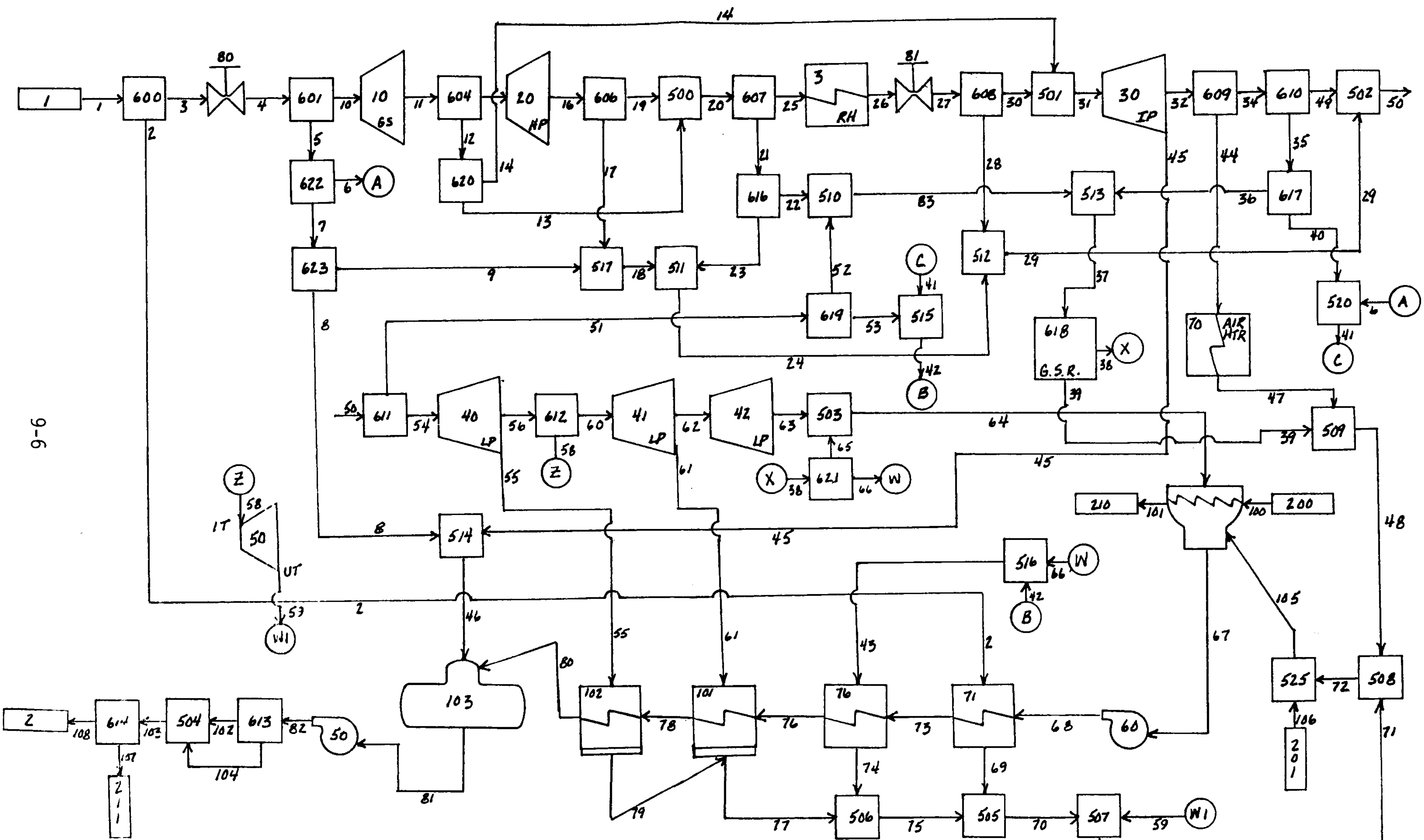

FIGURE 2: PEPSE MODEL OF
EDDYSTONE 3 AND 4

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EDIT ---- T413RWC.PEPSE.DATA(F07HHXX) - 01.02 ------------------ COLUMNS 001 072
COMMAND ===> _                                                    SCROLL ===> PAGE
****** ***************************** TOP OF DATA ******************************
***
***CONTROLS USED TO CALCULATE EFFICIENCY MULTIPLIERS AND SHAPERS
***
=THROTTLE FLOW = 688290.
*700010 33 950.,1815.,688290.
*891001 EXUSLS,42,15.0,1
*840100 EFMULT,10,1283.5,0.0001,1.,HH,16
*840200 EFMULT,30,1102.9,0.0001,1.,HH,63
*
*840300 SHAPER,20,1283.5,0.001,1.,HH,16
*840400 SHAPER,30,1358.20,0.001,1.,HH,32
*840700 SHAPER,40,1290.8,0.001,1.,HH,56
*840800 SHAPER,41,1209.6,0.001,1.,HH,62
*
*840109 .8,1.2
*840209 .8,1.2
*840309 300.,25000.
*840409 300.,2500.
*840709 300.,22000.
*840809 300.,10000.
*
700108 1.06878
700208 0.0,0.00
700308 .993211,574.
700408 0.0,553.7
700418 0.0,550.3
.
****** ***************************** BOTTOM OF DATA ****************************
```

FIGURE 3

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***
***EDDYSTONE 3 AND 4 REVISIONS FOR MULTIPLE LOAD DESIGN HEAT BALANCES
***
*
* SCHEDULES
*
* GEN ELEC LOSS
*
800100 'GENERATOR ELECTRICAL LOSS'
810100      0.,95.957,191.939,287.976,382.581,398.797,418.476
810110 0.0,0.,2001.,2492.,3342.,4900.,4976.,4746.
830100 1,BKELEI,1,BKGRO,1
*
*
800200 'LEAKAGE A,B,C'
*
810201 00.00000,1.8000,1.8000001,2.1000,2.1000001,2.4000,2.4000001,
810211 0.,6.064,15.064,12.030000,13.532,12.774000,14.274,13.516000,
810202 2.6800,2.6800001,3.
810212 14.916,13.400000,15.000
820200 1000.,1000000.
830200 2,WWFIXB,601,WW,3
*
800300 'LEAKAGE A'
*
810301 0.,1.8,1.8000001,2.1,2.1000001,2.4,2.4000001,2.68,2.6800001,3.
810311 0.,0.,168.,84.,100.,75.,90.,60.,66.,0.,0.
820300 1.,1000000.
830300 3,WWFIXB,622,WW,3
*
800400 'LEAKAGE C'
*
810401 0.,3.
810411 0.,0.,15.
820400 1000.,1000000.
830400 4,WWFIXB,623,WW,3
*
800500 'LEAKAGE D'
*
810501 0.,.688951,1.258016,1.855463,2.548415,2.675638
810511 0.,0.,10.663,19.568,28.964,39.774,41.773
820500 1000.,1000000.
830500 5,WWFIXB,604,WW,3
*
800600 'LEAKAGE E PRIME'
*
810601 0.,.688951,1.258016,1.855463,2.548415,2.675638
810611 0.,0.,1.333,2.329,3.567,5.643,6.075
820600 1000.,1000000.
830600 6,WWFIXB,620,WW,3
*
800700 'LEAKAGE F'
*
810701 0.,.688951,1.258016,1.855463,2.548415,2.675638
```

FIGURE 4

```
810711 0.,0.,8.138,14.978,22.074,29.732,31.109
820700 1000.,1000000.
830700 7,WWFIXB,606,WW,3
*
800800 'LEAKAGE G,H'
*
810801 0.,.688951,1.258016,1.855463,2.548415,2.675638
810811 0.,0.,5.946,7.612,9.551,12.351,12.978
820800 1000.,1000000.
830800 8,WWFIXB,607,WW,3
*
800900 'LEAKAGE G'
*
810901 0.,.688951,1.258016,1.855463.2.548415,2.675638
810911 0.,0.,3.31,6.067,8.978,12.351,12.978
820900 1000..1000000.
830900 9,WWFIXB,616,WW,3
*
801100 'LEAKAGE M,N'
*
811101 0...688951.1.258016.1.855463.2.548415.2.675638
811111 0.,0.,4.53,10.,14.89,20.38,21.37
821100 100.,1000000.
831100 11,WWFIXB,610,WW,3
*
801300 'LEAKAGE P,R'
*
811300 0..6.88951E5,12.58016E5,18.55463E5,25.48415E5,26.75638E5
811310 0.,0.,.447E3,.989E3,1.474E3,2.017E3,2.115E3
831300 13.WWFIXB.611,WW.1
*
801500 'EXTRACTION TO AIR HTR'
*
811501 0.,.688951,1.258016,1.855463,2.548415,2.675638
811511 0.,0.,32.462,67.185,102.602,140.132,146.569
821500 1000..1000000.
831500 15.WWFIXB.609.WW.3
*
801700 'ENTHALPY RISE ACROSS HPBFP'
**
811701 .4,.6..8,1.,1.2,1.4,1.6,1.8,2..2.2.2.4.2.6.2.8.3.00
811711 0.,16.6,14.6,12.8,11.1,9.8,9.1,8.6,8.3,8.1,8.0,7.9,7.9,8.3,9.6
821700 1.,1000000.
*831700 17,HDPUM,50,WW,3
*
*
801800 'EXHAUST LOSS'
*
811801 .8,1.2,1.6,2.,2.4,2.8,3.,3.2,3.6,4.,4.4.6.,8.4,9.6,12.
*811801 .4,.6,.8,1.,1.2,1.4,1.5,1.6,1.8,2.,2.2,3.,4.2,4.8,6.
811811 0.,36.,22.8,15.8,11.8.9.5,8.2,8..8.2,9.1,11.2.14.1,29.7,47..
811812 54.3,64.7
821800 1.,1.E8
831800 18,EXUSLS,42,OPVB,101
```

FIGURE 5

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*
*EXHAUST ENTHALPY OF BFPT EXHAUST
*
*811901 .4,.6,.8,1.,1.2,1.4,1.6,1.8,2.,2.2,2.4,2.6,2.8,3.00
*811911 0.,1.278,1.226,1.171,1.135,1.114,1.103,1.095,1.089,1.084,1.080,
*811912 1.076,1.073,1.069,1.069
*821900 1000.,1000000.
*831900 19,HHPTGX,50,WW,3
*
801200 '6TH PCK. LEAK TO U.T.'
811200 6.88951E5,12.58016E5,18.55463E5,25.48415E5
811210 0.,6.1195E4,6.6023E4,7.5891E4,9.4709E4
*831200 12,WWFIXB,612,WW,1
***
802000 'BOILER FEED PUMP EFF'
812000 688951. 1258016.,1855463.,2548415.
812010 0.,.426,.6470,.7360,.8327
832000 20,EFFPMP,50,WW,3
***
802100 'BOILER FEED PUMP TURBINE EFF'
812100 688951.,1258016.,1853463.,2548415.
812110 0.,.710,.7852,.7900,.7900
832100 21,EFFMAC,50,WW,3
***
802200 'GOV STAGE EFF CORR FACTOR'
812200 1258016.,1855463.,2548415.
812210 0.,.968,1.012,1.012
832200 22,EFMULT,10,WW,3
***
802300 'BOILER FEED PUMP DISC PRESS'
812301 688951.,1258016.,1855463.,2548415.,2675838.,2815721.
812310 0.,1900.,1945.,2010.,2114.,2134.,2265.,
832300 23,PMPDIS,50,WW,3
***
802400 'EFFICIENCY MULTIPLIER'
812401 688951.,1258016.,2815721.
812410 0.,.998,1.0029,1.0029
832400 24,EFMULT,30,WW,3
***
802500 'SHAPER'
812501 688951.,1258016.,2815721.
812510 0.,1.E5,547.36,547.36
832500 25 SHAPER,30,WW,3
870210 .982
***
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*/
=THROTTLE FLOW = 1856363#/HR
700010 33,950.,1815.,1856363.
*/
*=THROTTLE FLOW = 1258916#/HR
*700010 33,950.,1815.,1258916.
*/
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FIGURE 6