Boiler Test Comparisons with PEPSE®

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Introduction

In October 1987 Central Power and Light Company (CPL), an operating company of the Central and South West Corporation, performed several boiler optimization tests on their J. L. Bates Unit 2 boiler. These tests, conducted jointly by CPL and Babcock & Wilcox (B&W) personnel, were undertaken to find ways to reduce reheat attemperation spray flow. Two methods were found effective in reducing or eliminating the need for reheat spray flow (Reference 1). One method was burner arrangement. The other method was primary superheat (PSH) damper biasing.

Burner arrangement significantly affects the reheat temperature at Bates because of the split backpass in the boiler. One side of the backpass contains the primary superheat tubes and the other the primary reheat tubes. The burner arrangement affects the temperature profile in the boiler and hence the temperature profile in the backpass. Reheat attemperation flow is affected correspondingly.

The primary superheat backpass damper position controls the split of gas flow over the primary superheat and primary reheat sides of the backpass. This impacts the amount of required reheat attemperation by increasing or decreasing the total gas flow (and thus heat transfer) over the primary reheat tubes.

Concurrent with the boiler testing, a model of the Bates boiler and turbine cycle was developed using the PEPSE computer program (Reference 2). This model was developed to verify the test results and to serve as a tool with which to make future performance predictions. The development of this PEPSE model was a joint effort of CPL and Central and South West Services (CSWS).

Background Information

Bates Unit 2 is a steam turbine unit powered by a gas-fired boiler. The unit was built in the late 1950's. It is located in Mission, Texas, in the south Rio Grande Valley, several miles from the Mexican border.

Bates Unit 2 boiler is a Riley Stoker with radiant reheat designed for pressured operation and outdoor installation. It has a design drum pressure of 1750 psig and will produce 725,000 lbm/hr (continuous rating) of steam at 1575 psig and 1005 F/1005 F when supplied with feedwater at 450 F. The furnace volume is 34,400 cubic feet. Figure 1 shows the vendor boiler schematic of this unit.

The turbine-generator is a Westinghouse tandem compound unit with a single flow HP and IP turbine, and a double flow LP turbine. The unit is rated at 100 MW. Inlet steam conditions are 1000 F/1000 F with a throttle pressure of 1450 psig. The design throttle flow is 673,000 lbm/hr. Figure 2 shows the vendor turbine cycle schematic.

The boiler was designed to operate without reheat spray flow. Reheat temperature was to be controlled by varying the amount of gas passing over the primary superheater surface and primary reheater surface, each equipped with a set of gas flow control dampers. At low loads the reheat damper would be wide open and the superheat damper would be in a partially closed position. As load increased, the superheat damper would open, allowing more flow to pass over the primary superheat section and reducing the amount of flow passing over the primary reheat section. When the superheat damper reached a wide open position, temperature was controlled by throttling the reheat damper.

This temperature control scheme was used for several years, but by 1965 it became apparent that the reheat temperature was not being adequately controlled. Above 60 MW, the reheat and superheat dampers were not able to properly control the reheat temperature. To remedy the situation, the reheat damper was fixed in the wide open position, the superheat damper was allowed to throttle with load, and reheat attemperation spray was added to control the reheat temperature above 60 MW.

Recently a test was performed by Babcock and Wilcox and Central Power and Light personnel to maximize the performance of the Bates Unit 2 boiler. In an effort to reduce or eliminate reheat spray flow, various burner patterns and reheat damper positions were tested. Results showed that reheat spray flow could be eliminated with proper burner patterns and primary superheat backpass damper positions.

PEPSE Model Development

The PEPSE boiler model schematic appears in Figure 3, and the PEPSE turbine cycle schematic is shown in Figure 4. This is a combined boiler/turbine cycle model, not two stand-alone models. The apparent split is for drafting and illustrative convenience and is not intended to suggest two separate models. Interface components and streams connecting the boiler with the turbine cycle are shown in the two figures.

Combustion air enters through a demand source component (300). The air proceeds through the forced draft fan (305) and the air preheater (310) to the boiler (320) where it mixes with natural gas from a source component (315). Hot furnace exhaust gases exit the furnace and pass over the secondary superheater (330) and secondary reheater (335) before splitting (through splitter 350) into the two sides of the backpass. The superheat side of the backpass has the flue gas flowing over the first primary superheat component (390), a component representing the backpass waterwalls (395), and then over the second primary superheater component (400). The gas then passes over two stages of economizer (405 and 410) before mixing with flue gas from the other side of the backpass (415). On the reheat side of the backpass, the flue gas passes over the first primary reheat component (365), a component representing the backpass water walls on the reheat side (370), and then over the second primary reheater component (375). Then, after passing over two stages of economizer (380 and 385), the flue gas mixes with the superheat pass flue gas in a mixer component (415). The combined flue gas passes through the air preheater (310) and exits through the stack (425).

On the H2O side of the boiler, feedwater enters the boiler from a double-ended sink component (240) and proceeds through four stages of the economizer (405, 380, 410, and 385). Exiting the economizer, the water enters the boiler waterwalls (325) by mixing with the drum downcomer in a mixer component (455). The water may go directly to the boiler waterwalls (325) or be diverted to the backpass waterwalls (370 and 395) through a splitter component (460). Through either path, the fluid eventually enters the drum (450). Steam exits the drum and goes to the primary superheat components (400 and 390). It then mixes with superheat attemperation flow, if present, from a component in the turbine cycle (229) through a mixer component (355). Finally the steam is heated in the secondary superheater (330) and enters the turbine cycle through a double-ended source component (5).

Cold reheat steam enters the boiler from the turbine cycle at a mixer component (435). This mixer combines the cold reheat with the reheat attemperation flow, if present, from a turbine cycle feedwater train component (228). The cold reheat (and reheat attemperation flow, if present) is then heated in the primary reheater components (375 and 365) and the secondary reheater component (335) before returning to the IP turbine through the intercept valve component (85).

Main steam is introduced into the turbine cycle through a double-ended source component (5). The steam then enters the high pressure (HP) turbine through the throttle valve component (10). After passing through various valve stem leakage splitters (15, 20, and 25), the steam enters the governing stage (30). The steam then passes through a splitter (35) representing the N2 packing leakage and enters the HP turbine stage component (40). After exiting the HP turbine, the steam passes through several shaft splitters (45, 50, and 55) and is mixed with various valve packing leakages through mixer components (60, 65, and 70). A portion of the steam is then extracted for feedwater heating through a splitter component (75). The resulting steam (cold reheat) is returned to the boiler for heating. Upon returning from the boiler, the steam passes through the intercept valve (85), is mixed with the N2 packing leakage through a mixer component (105), and then passes through the intermediate pressure (IP) turbine stages (110, 115, 120). Between the IP turbine exhaust and the low pressure (LP) turbine inlet, packing steam is leaked through two splitters (125 and 130). Sealing steam from the HP exhaust is introduced through a splitter (135) prior to entering the parallel LP turbine stages (145, 150, 165, and 170). The steam exits the LP turbine and enters the condenser (175). After the condenser, the condensed steam (condensate) travels through the feedwater heaters (200, 215, 220, 230, and 235) and back to the boiler through a sink component (240).

All of the boiler components were modeled in the design mode. This mode, although more complicated to set-up than the performance mode, provides greater modeling flexibility. This flexibility was needed for this study which centered on the boiler. In addition, a larger set of parametric studies may be made using design boiler components. The turbine cycle components were modeled in the performance mode. They were modeled this way because the modeling flexibility of the design mode was not required for the turbine cycle in this study.

Appendix A contains the PEPSE input listing file for the Bates Unit 2 model. Input data for constructing the model were obtained from information supplied by the boiler and turbine manufacturer. For the boiler, data from drawings, operations manuals, and the contract manual were helpful. For the turbine, data from the vendor thermal kit, especially the heat balance diagrams, were useful in constructing the model.

Originally the boiler and turbine cycle were modeled separately to make debugging and checkout simpler. The turbine cycle model was verified by comparing it to the turbine manufacturers guarantee heat balance. Key parameters which were checked included:

(1) Turbine extraction and exhaust pressures,

(2) Turbine extraction and exhaust enthalpies,

(3) Extraction flows,

(4) Leakage flows, and

(5) Condensate/feedwater temperatures.

Boiler parameters which were used for model verification included:

(1) Main steam temperature,

(2) Hot reheat temperature,

(3) Air preheater flue side and air side inlet and outlet temperatures,

(4) Furnace exit temperature,

(5) Stack temperature,

(6) Water wall outlet quality entering drum, and

(7) Drum outlet quality to superheaters.

The boiler model and turbine cycle model were combined after they were independently checked. The combined model was then verified against the same parameters.

Boiler modeling is more complicated and more time consuming than turbine cycle modeling for several reasons. One reason is that the information required for the boiler model is not as readily available as is the turbine cycle information. Nearly all of the turbine cycle data can be taken from a single heat balance diagram. The boiler information must be obtained from several sources. In addition, the boiler is usually modeled in the design mode whereas the turbine cycle is usually modeled in the performance mode.

Design mode models are more complicated to set up and debug than performance mode models. Finally, the counterflow nature of the boiler (i.e. flue gas moving counter to the steam path) makes tuning and convergence more difficult. These and other boiler modeling considerations have been reported in a paper presented at the 1987 Performance Software User's Group Meeting (Reference 3).

Calculations and Results

A series of PEPSE cases were performed for loads ranging from 60 MW to 117 MW. First a series of cases with reheat spray flow were performed. Reheat spray flow values from the boiler test were used in these cases. In the PEPSE model, the main steam flow was adjusted to achieve the desired load, followed by an adjustment of the fuel and excess air flow to achieve superheat and reheat temperatures around 1000 F. When the superheat and reheat temperatures were within 10 degrees F to 15 degrees F of 1000 F, final adjustment was accomplished using damper biasing. This was done by varying the flow split in splitter component 350. For this method to work successfully, the superheat temperature and reheat temperature had to be on opposite sides of 1000 F by approximately the same amount.

A similar series of PEPSE cases were then performed, but without reheat spray flow. Tuning of the model to achieve superheat and reheat temperatures of 1000 F was done in the same way as with reheat spray flow.

Figure 5 presents the savings calculated by PEPSE by eliminating reheat spray flow and controlling superheat and reheat temperatures using backpass damper biasing. This figure also shows the test results. Comparing the PEPSE results with the test results shows that the PEPSE results are conservative. However, the heat rate savings trends are the same. It should be noted that PEPSE does not have a feature which allows different burner positions. If it had this feature, the PEPSE results would probably match the test results more closely.

Conclusions

A PEPSE model of a complete cycle can be very useful in verifying test data and making future performance predictions. A model that is properly constructed and checked will trend cycle response with a certain degree of accuracy. This adds credibility that the model is able to reliably predict future performance.

The results of this study were not unexpected. Reducing or eliminating reheat spray flow will always reduce heat rate and improve efficiency. Although the PEPSE results did not match the test results exactly, the conservative nature of the PEPSE results provide confidence that any predictions that are made with the program will not overpredict performance.

BIBLIOGRAPHY

1. Hieu Pham and Dan Lee, Performance Optimization Test, J. L. Bates Power Station, Unit #2, Babcock & Wilcox Report, October 29, 1987.

2. W. C. Kettenacker, G. L. Minner, E. J. Hansen, P. H. Klink, PEPSE Manual: User Input Description, Vol I, Energy Incorporated, Revision 12, December 24, 1986.

3. W. C. Kettenacker and Terry L. Hesseltine, Using PEPSE to Evaluate Boiler Performance, Proceedings of the Fourth Performance User's Group Meeting, Charleston, South Carolina, June 17-19, 1987.

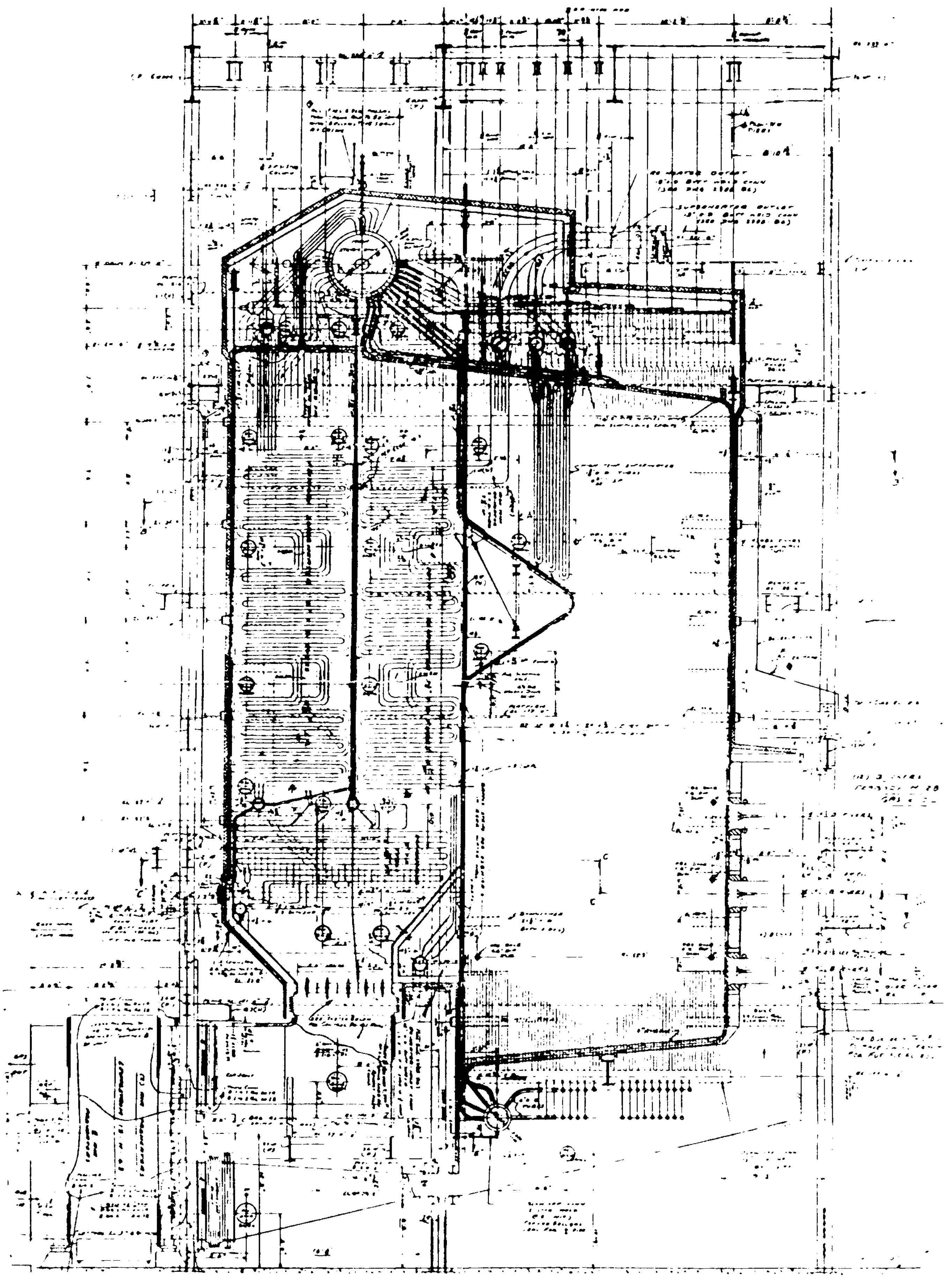

FIGURE 1 - VENDOR BOILER SCHEMATIC, J. L. BATES UNIT 2

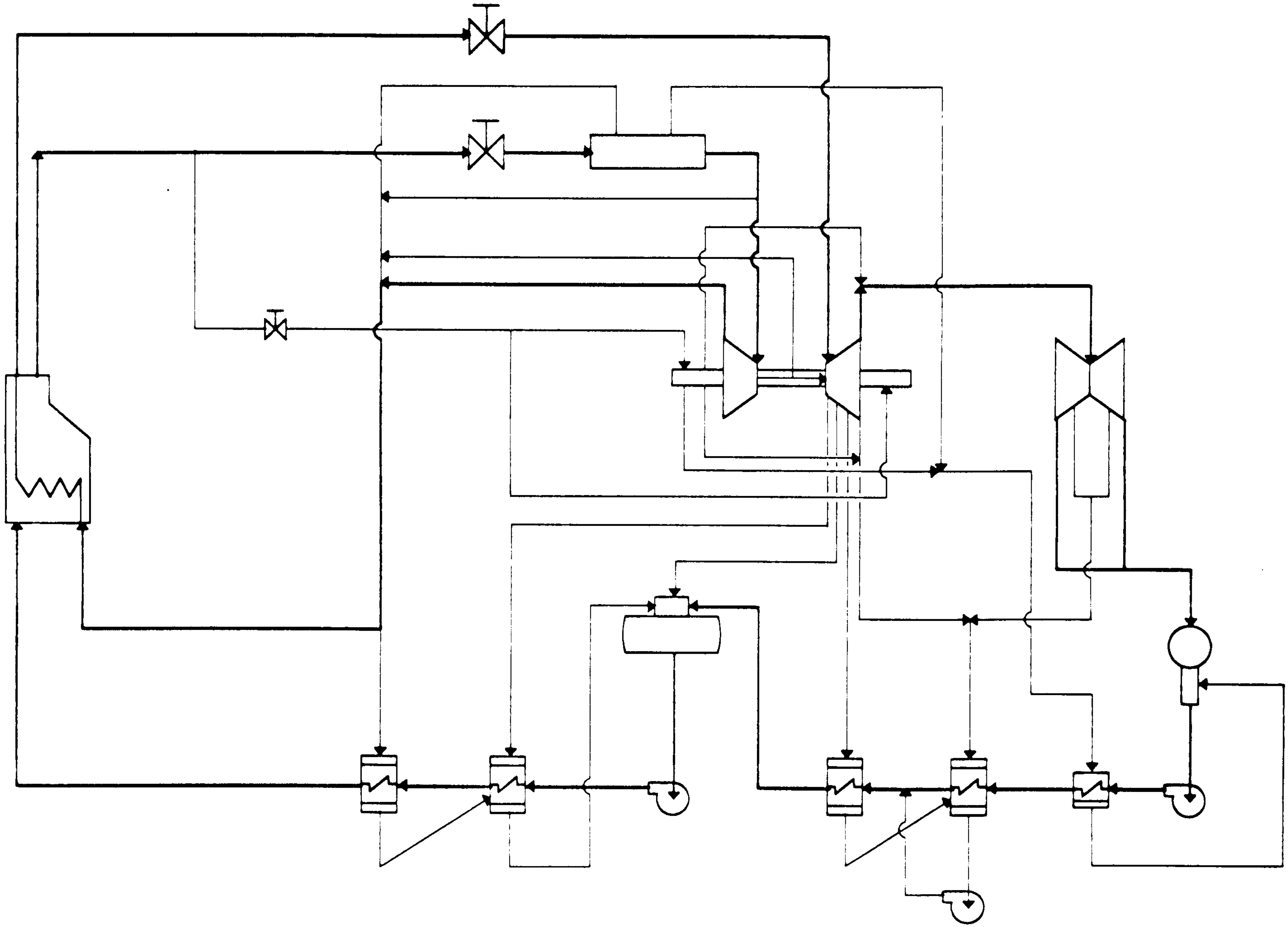

FIGURE 2 - VENDOR TURBINE CYCLE SCHEMATIC, J. L. BATES UNIT 2

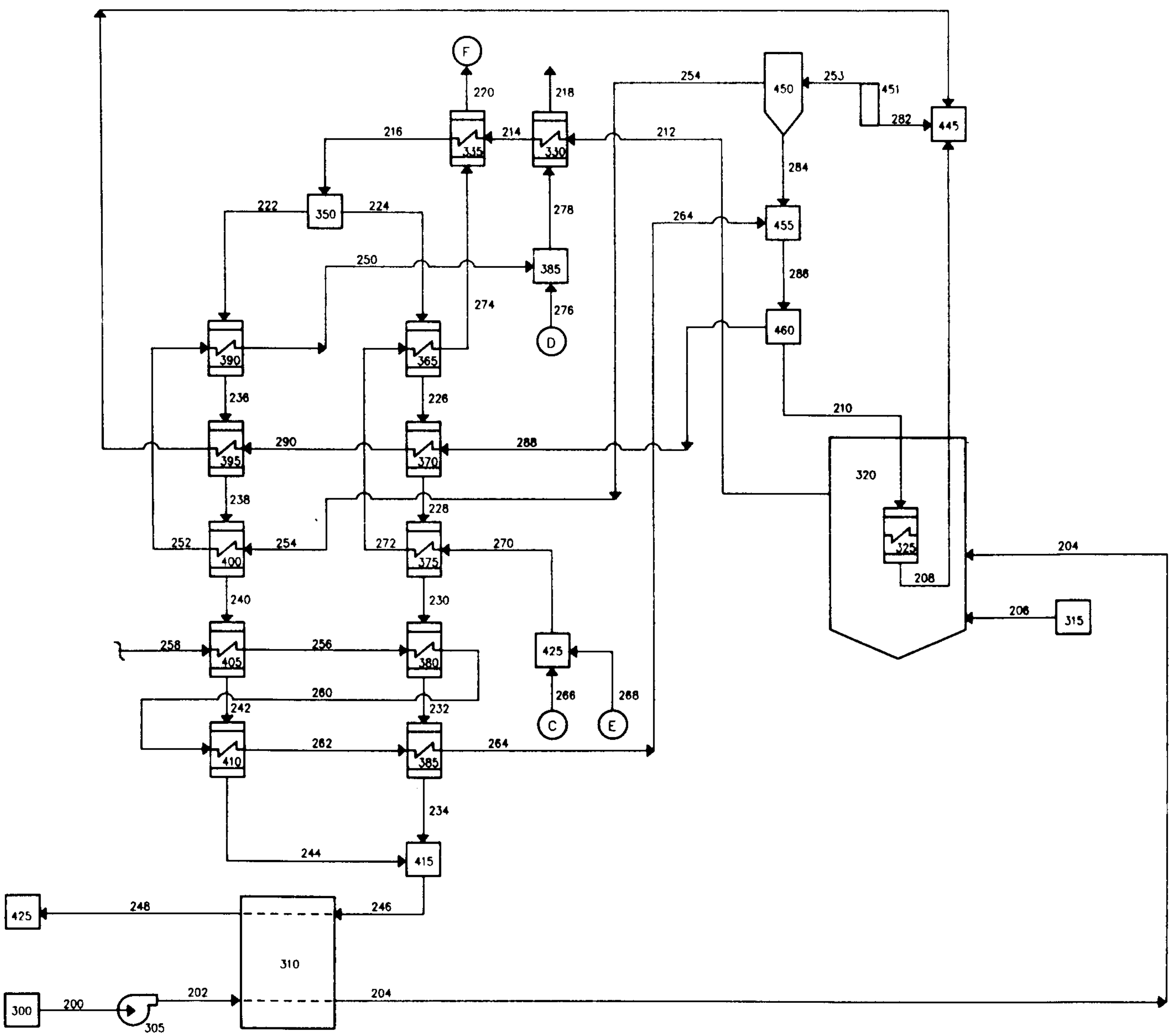

FIGURE 3 - PEPSE BOILER MODEL, J. L. BATES UNIT 2

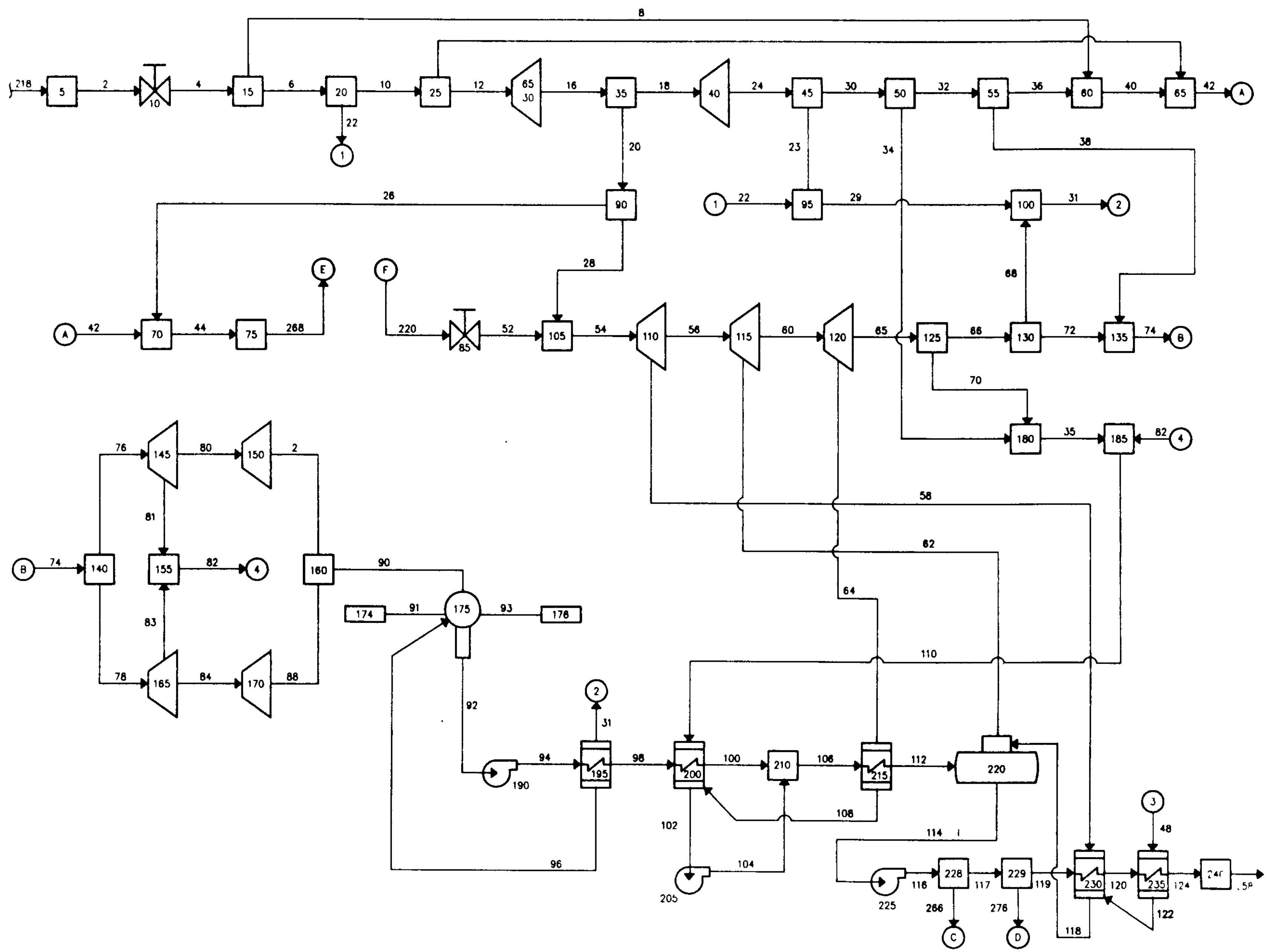

FIGURE 4 - PEPSE TURBINE MODEL, J. L. BATES UNIT 2

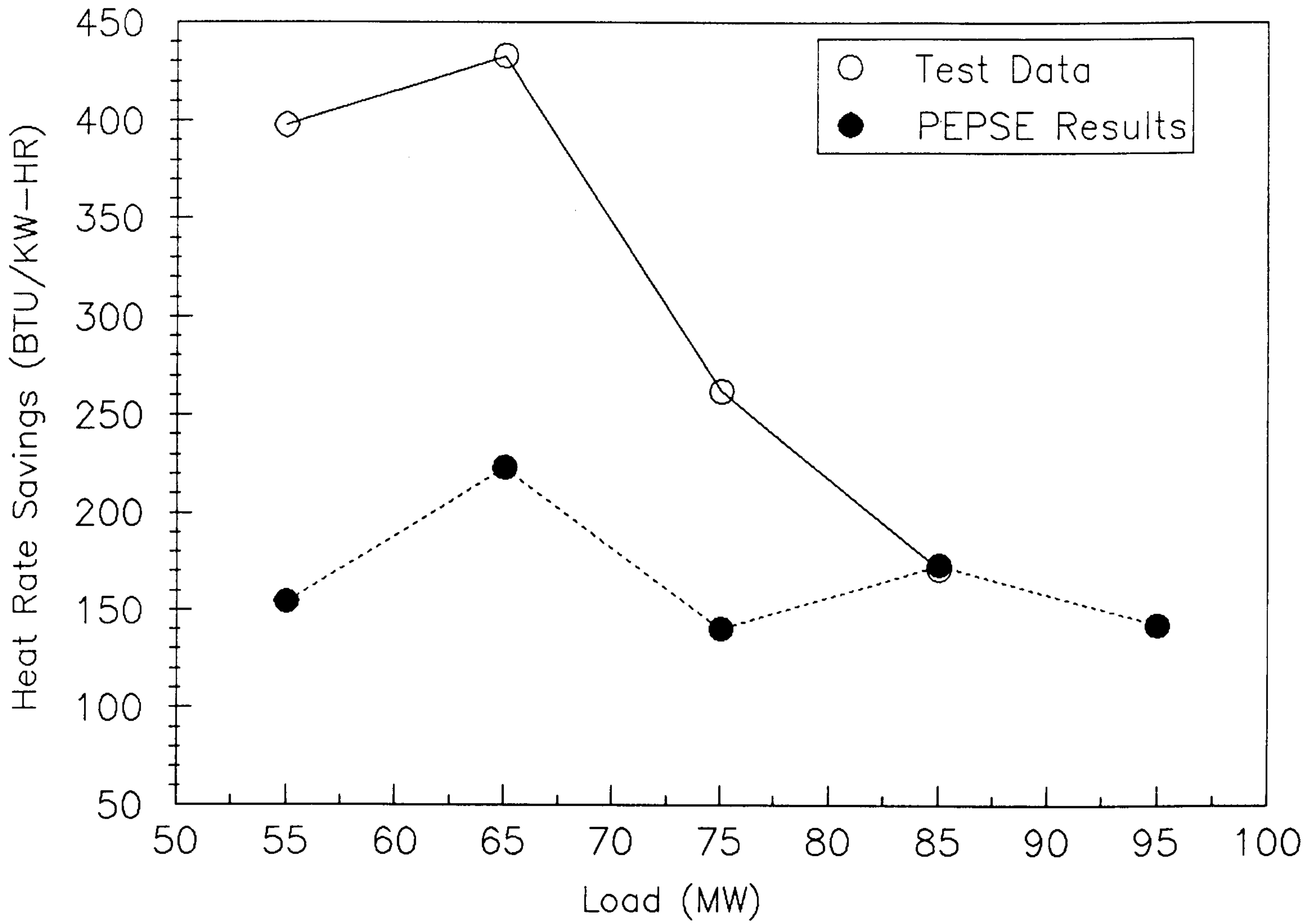

FIGURE 5 – Comparison of PEPSE and Test Results, Savings in Net Heat Rate without Reheat Attemperation

APPENDIX A

J. L. Bates Unit 2 PEPSE Input Listing

```
FILE: BATES2CD PEPSE    A   CENTRAL & SOUTH WEST  -  DALLAS, TX

= BATES UNIT 2, COMBINED BOILER AND TURBINE CYCLE MODEL
*
* GENERIC INPUT DATA
*
010000 ENGLISH,ENGLISH
010200 2,3,1,1,1,0,0.0
010201 2
011010 1,2,1,0,3600,111000.0,0.9,30.0,30.0
012000 35,2000.,2000.,0.,0.,0.,0.,2.0E6
012001 5,2,5
020002 NOPRNT
020004 NOPRNT
020021 NOPRNT
020022 NOPRNT
020023 NOPRNT
020026 NOPRNT
050000 EFF
*
*GEOMETRY
*
500020 5,U,10,I
500040 10,U,15,I
500060 15,U,20,I
500080 15,B,60,IB
500100 20,U,25,I
500120 25,U,30,I
500140 25,B,65,IB
500160 30,U,35,I
500180 35,U,40,I
500200 35,B,90,I
500220 20,B,95,IA
500230 45,B,95,IB
500240 40,U,45,I
500260 90,U,70,IB
500280 90,B,105,IB
500290 95,U,100,IA
500300 45,U,50,I
500310 100,U,195,S
500320 50,U,55,I
500340 50,B,160,IB
500350 180,U,185,IB
500360 55,U,60,IA
500380 55,B,135,IB
500400 60,U,65,IA
500420 65,U,70,IA
500440 70,U,75,I
500480 75,B,235,S
500520 85,U,105,IA
500540 105,U,110,I
500560 110,U,115,I
500580 110,E,230,S
500600 115,U,120,I
500620 115,E,220,S
500640 120,E,215,S
500650 120,U,125,I
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500660 125,U,130,I
500690 130,B,100,IB
500700 125,B,180,IA
500720 130,U,135,IA
500740 135,U,140,I
500760 140,U,145,I
500780 140,B,165,I
500800 145,U,150,I
500810 145,E,155,IA
500820 155,U,185,IA
500830 165,E,155,IB
500840 165,U,170,I
500860 150,U,160,IA
500880 170,U,160,IB
500900 160,U,175,S
500920 175,D,190,I
500940 190,U,195,T
500960 195,D,175,D
500980 195,T,200,T
500910 174,U,175,T
500930 175,T,176,I
501000 200,T,210,IA
501020 200,D,205,I
501040 205,U,210,IB
501060 210,U,215,T
501080 215,D,200,D
501100 185,U,200,S
501120 215,T,220,FW
501140 220,D,225,I
501160 225,U,228,I
501170 228,U,229,I
501180 230,D,220,D
501190 229,U,230,T
501200 230,T,235,T
501220 235,D,230,D
501240 235,T,240,I
*
*SPECIAL STREAM SPECS
*EXTR. LINES & INTER. TO TURB.
*
600580 2,.049
600620 2,.050
600640 2,.048
600620 2,.050
600540 2,.02
600480 2,.05
*
*COMPONENT SPECS
*
*TURBINES
*
*GOVERNING STAGES
*
700300 4,1,2,1,1,0,6,0,25.0
700308 1.0
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700308 1.0655
700400 5,1,1,0,1,0.0
700401 1305.0,1491.2,753280.0,481.0,712090.0
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*I.P.TURBINES
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701100 6,1,0,1,2,1,0.0
701101 424.0,1520.9,675020.0,204.0,36070.0
701108 1.0,650.0
701108 0.9788,1.0E5
701150 6,1,1,1,2,1,0.0
701151 204.0,1441.0,638950.0,83.5,37840.0
701158 1.0,650.0
701158 1.0,515.0
701200 6,1,3,1,2,1,0.0
701201 83.5,1336.0,601110.0,31.0,34280.0
701208 1.0,650.0
701208 1.0,460.0
*
*L.P.TURBINES
*
701450 7,1,0,1,3,1,0.0
701451 31.0,1245.1,287970.0,10.2,23095.0
701458 1.0,650.0
701458 1.0,450.0
701650 7,1,0,1,3,1,0.0
701651 31.0,1245.1,287970.0,10.2,23095.0
701658 1.0,650.0
701658 1.0,450.0
701500 7,1,3,0,3,1,0.0
701501 10.2,1162.0,264875.0,0.73,0.0,55.0
701700 7,1,3,0,3,1,0.0
701701 10.2,1162.0,264875.0,0.73,0.0,55.0
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*CONDENSER
*
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701800 50
*
*FEEDWATER HEATER
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702000 17,1,155,2,0.0,5.0
702150 14,0,120,2,0.0,5.20
702200 15,1,115,0.0,0.0
702300 18,1,110,2,0.0,5.0,5.05
702350 18,0,75,2,0.0,5.0,0.0
*
*REHEATER & GLAND STEAM COND.
*
701950 20,210.3
*
*COOLING TOWER
*
701760 30
701740 31,70.0,25.0,3.2E7
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700100 35,-2.0,-2.0,-2.0,.3,1450.0,1491.2,753280.0
*
*PUMPS
*
701900 41,177.0
702050 41,225.0
702250 41,1770.0
*
*MIXERS
*
700600 50,1
700650 50,1
700700 50,1
700850 34,0.0
700950 50
701000 50
701050 50,1
701350 50,1
701550 52,145,165
701600 50
701850 50,1
702100 50,1
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*SPLITTER
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700150 61,0.0,1500.0            * B  GUESS
700200 63,0.0,0.001             * A
700250 63,0.0,0.01              * C
700350 63,0.0,0.029             * D + E
700450 61,0.0,110.0             * L
700500 61,0.0,100.0             * K
700550 63,0.0,0.0135            * F
700750 60,0.0,67730.0
700900 63,0.0,0.3333            * E
701250 61,0.0,50.0              * H
701300 61,0.0,190.0             * G
701400 63,0.0,0.50
702280 61,0.0,0.0
702290 61,0.0,27200.
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*INPUT COMPONENT
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700050 33,1000.0,1450.0,725000.
*
*OUTPUT COMPONENT
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702400 32
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* FLOW FROM SPLITTER 15
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870500   2650.       * CONSTANT
880200   OPVB,50,SUB,WW,22,WWFIXB,15
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* BOILER INPUT DATA
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* GEOMETRY
502000   300,   U,   305,   I
502020   305,   U,   310,   T
502040   310,   T,   320,   IA
502060   315,   U,   320,   IF
502080   325,   T,   445,   IA
502100   460,   U,   325,   T
502120   320,   U,   330,   S
502140   330,   D,   335,   S
502160   335,   D,   350,   I
502180   330,   T,     5,   I
502200   335,   T,    85,   I
502220   350,   U,   390,   S
502240   350,   B,   365,   S
502260   365,   D,   370,   S
502280   370,   D,   375,   S
502300   375,   D,   380,   S
502320   380,   D,   385,   S
502340   385,   D,   415,   IB
502360   390,   D,   395,   S
502380   395,   D,   400,   S
502400   400,   D,   405,   S
502420   405,   D,   410,   S
502440   410,   D,   415,   IA
502460   415,   U,   310,   S
502480   310,   D,   425,   I
502500   390,   T,   355,   IA
502520   400,   T,   390,   T
502540   450,   U,   400,   T
502560   405,   T,   380,   T
502580   240,   U,   405,   T
502600   380,   T,   410,   T
502620   410,   T,   385,   T
502640   385,   T,   455,   IB
502660   228,   B,   435,   IB
502680    75,   U,   435,   IA
502700   435,   U,   375,   T
502720   375,   T,   365,   T
502740   365,   T,   335,   T
502760   229,   B,   355,   IB
502780   355,   U,   330,   T
502800   395,   T,   445,   IB
502820   445,   U,   450,   I
502840   450,   B,   455,   IA
502860   455,   U,   460,   I
502880   460,   B,   370,   T
502900   370,   T,   395,   T
* STREAM DATA
602820   5   1668.            * DRUM PRESSURE
* BOUNDARY STREAMS
602180   6   2   1   1000.   1450.   753280.
602200   6   2   1   1000.    400.   700000.
```

FILE: BATES2CD PEPSE   A   CENTRAL & SOUTH WEST - DALLAS, TX

```
602580   6  1  2  441.5   1770.   750000.
602660   6  1  2  300.0   1850.        0.
602680   6  1  2  723.0    430.   700000.
602760   6  1  2  300.0   1850.    27200.
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703000   31  100.0  14.7  1.5E6
703003   AIR,  0.0
703050   43  15.4
703100   21  1
703103   .114
703104   0.  0.  1  0.35  0.0386  225.0  225.0  75.0  5.25  3.0E5  .1  1.9
703150   31  60.  25.  45930.
703153   FUEL,  22500.,  C,  .745,  O2,  .0020,  N2,  .0080,  H2,  .245
703200   70  0  2  300  .19
703250   29  1  320
703254   0  3  74.5  358.  1.0  2.69  3.25  3.3125  0.0  74.5  23.0
703255   0.  0.  0.  22080.
703300   28  1  8.0E5  1450.  900.
703304   2  1  3  23.0  31.75  20.0  6.0  120.0  6.0  1.19  1.75  4.9688
703305   4.9688  0.0  20.0  0.2  23.0  0.  0.  0.  0.  6600.
703350   28  1  7.5E5  500.0  900.
703354   2  0  3  13.0  31.75  13.0  6.0  68.00  6.0  1.70  2.00  4.9688
703355   4.9375  0.0  13.0  0.2  23.0  0.  0.  0.  0.  2780.
703500   63  0.0  0.5
703550   50  1
703650   28  1  7.5E5  500.  500.
703654   2  0  3  9.33  31.75  9.33  32.  73.00  32.  2.17  2.50  4.9688
703655   4.9688  0.0  15.0  0.2  23.0  0.  0.  0.  0.  14265.
703700   28  1  1.5E6  1700.  -0.1
703704   2  0  2  59.0  31.75  59.0  2.0  16.00  1.0  2.69  3.25  6.6250
703705   6.6250  0.0  74.5  0.2  23.0  0.  0.  0.  0.  1600.
703750   28  1  7.5E5  500.  500.
703754   2  0  3  9.33  31.75  9.33  32.  73.00  32.  2.17  2.50  4.9688
703755   4.9688  0.0  15.0  0.2  23.0  0.  0.  0.  0.  14265.
703800   28  1  7.5E5  1800.  475.
703804   2  0  3  9.33  31.75  9.33  5.0  109.0  5.0  1.60  2.00  3.3125
703805   3.3125  0.0  3.25  0.2  23.0  0.  0.  0.  0.  2877.
703850   28  1  7.5E5  1800.  500.
703854   2  0  3  9.33  31.75  9.33  5.0  109.0  5.0  1.60  2.00  3.3125
703855   3.3125  0.0  3.25  0.2  23.0  0.  0.  0.  0.  2877.
703900   28  1  7.5E5  1500.  900.
703904   2  0  3  10.75 31.75  10.75 33.  73.00  33.  1.6075 2.0  4.9688
703905   4.9688  0.0  15.0  0.2  23.0  0.  0.  0.  0.  13560.
703950   28  1  1.5E6  1700.  -0.1
703954   2  0  2  59.0  31.75  59.0  2.0  16.00  1.0  2.69  3.25  6.6250
703955   6.6250  0.0  74.5  0.2  23.0  0.  0.  0.  0.  1600.
704000   28  1  7.5E5  1500.  800.
704004   2  0  3  10.75 31.75  10.75 33.  73.00  33.  1.6075 2.0  4.9688
704005   4.9688  0.0  15.0  0.2  23.0  0.  0.  0.  0.  13560.
704050   28  1  7.5E5  1800.  470.
704054   2  0  3  10.75 31.75  10.75 5.0  109.0  5.0  1.60  2.00  3.3125
704055   3.3125  0.0  3.25  0.2  23.0  0.  0.  0.  0.  2877.
704100   28  1  7.5E5  1800.  490.
704104   2  0  3  10.75 31.75  10.75 5.0  109.0  5.0  1.60  2.00  3.3125
704105   3.3125  0.0  3.25  0.2  23.0  0.  0.  0.  0.  2877.
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704150   50
704250   30
704350   50   1
704450   50
704500   62   1.0
704550   50   1
704600   63   0.0   0.25
*
* PERFORMANCE TYPE PRESSURE DROPS
*
703356   .016    * REHEATER
703656   .016    * REHEATER
703756   .016    * REHEATER
703306   .016    * SUPERHEATER
703906   .016    * SUPERHEATER
704006   .016    * SUPERHEATER
703806   .0027   * ECONOMIZER
703856   .0027   * ECONOMIZER
704056   .0027   * ECONOMIZER
704106   .0027   * ECONOMIZER
* QUICK FIX FOR DRUM
502530   451,   U,   450,   I
502820   445,   U,   451,   I
704510   31   .20   1750.   5047800.* (7 X MAIN STEAM FLOW) - SHAF (GUESS)
704510   31   .20   1550.   5047800.* (7 X MAIN STEAM FLOW) - SHAF (GUESS)
*
* SOURCE/SINK ENVELOPE SPECIFICATION
*
700052   10 1
701742   0   1
702402   1            * OUTPUT COMPONENT
703002   0   2
703152   0   2
704512   10 2
*
* CALCULATE GAS DENSITY, HEATING VALUE, MASS FLOW RATE
*
***870010   0.08071      * DENSITY OF AIR, LBM/FT3
***870020   0.60         * SPECIFIC GRAVITY OF NATURAL GAS
***870030   993680.      * NATURAL GAS FLOW RATE, FT3/HR
***870040   1040.        * NATURAL GAS HEATING VALUE, BTU/FT3
***880010   OPVB,1,MUL,OPVB,2,OPVB,10,        * GAS DENSITY, LBM/FT3
***880020   OPVB,4,DIV,OPVB,10,OPVB,11,       * GAS HEATING VALUE, BTU/LBM
***880030   OPVB,3,MUL,OPVB,10,WWVSC,315,     * GAS FLOW RATE, LBM/HR
*
* CALCULATE BOILER EFFICIENCY
*
870110   22500.     * DESIGN GAS HEATING VALUE, BTU/LBM
880040   WWVSC,315,MUL,OPVB,11,OPVB,12,    * HEAT IN FROM FUEL
880050   BBSTRM,218,ADD,BBSTRM,220,OPVB,13
880060   OPVB,13,SUB,BBSTRM,258,OPVB,13
880070   OPVB,13,SUB,BBSTRM,268,OPVB,13
880080   OPVB,13,SUB,BBSTRM,266,OPVB,13
880090   OPVB,13,SUB,BBSTRM,276,OPVB,13
880100   OPVB,13,DIV,OPVB,12,OPVB,14,     * BOILER EFFICIENCY
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*
* CALCULATE BACK PASS AIR SPLIT
*
880110  WW,224,DIV,WW,216,OPVB,15
*
* CALCULATE CIRCULATION LOOP FLOW
*
870050  7.0         * CONSTANT
870060  6.0         * RECIRCULATION LOOP FLOW RATIO
880130  WWVSC,5,MUL,OPVB,6,WWFIXB,450      * CIRCULATION LOOP FLOW
880140  WWVSC,5,MUL,OPVB,5,WWVSC,451
880150  WWVSC,451,SUB,WW,276,WWVSC,451     * SPECIAL SOURCE FLOW
*
* CALCULATE IP BOWL FLOW FACTOR
*
870510    0.5       * CONSTANT
870520  46389.      * IP BOWL FLOW FACTOR - DESIGN
880210  PP,54,DIV,VV,54,OPVB,53
880220  OPVB,53,TO,OPVB,51,OPVB,53
880230  WW,54,DIV,OPVB,53,OPVB,53
*
* CALCULATE CYCLE HEAT RATE
*
870540  1000.       * CONSTANT
880240  BKGROS,0,MUL,OPVB,54,OPVB,55
880250  OPVB,12,DIV,OPVB,55,OPVB,55,    * GROSS PLANT HR
880260  BKGROS,0,SUB,OPVB,60,OPVB,56
880270  OPVB,56,MUL,OPVB,54,OPVB,56
880280  OPVB,12,DIV,OPVB,56,OPVB,56     * NET PLANT HR
*
* OUTPUT VARIABLES
*
890010  'BOILER EFFICIENCY'
890011  OPVB,14
890020  'MAIN STEAM TEMPERATURE - F'
890021  TT,218
890030  'MAIN STEAM PRESSURE - PSIA'
890031  PP,218
890040  'HOT REHEAT TEMPERATURE - F'
890041  TT,220
890050  'HOT REHEAT PRESSURE - PSIA'
890051  PP,220
890060  'FURNACE INLET AIR TEMPERATURE - F'
890061  TT,204
890070  'FURNACE EXIT TEMPERATURE - F'
890071  TT,212
890080  'STACK TEMPERATURE - F'
890081  TT,248
890090  'DRUM OUTLET QUALITY'
890091  XX,254
890100  'BACK PASS AIR SPLIT, RH/TOTAL'
890101  OPVB,15
890110  'SUPERHEAT ATTEMP FLOW - LBM/HR'
890111  WW,276
890120  'REHEAT ATTEMP FLOW - LBM/HR'
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890121   WW,266
890130   'IP BOWL FLOW FACTOR - DESIGN'
890131   OPVB,52
890140   'IP BOWL FLOW FACTOR - ACTUAL'
890141   OPVB,53
890150   'AUXILIARY POWER, MWE'
890151   OPVB,60
890160   'GROSS PLANT HEAT RATE - BTU/KW-HR'
890161   OPVB,55
890170   'NET PLANT HEAT RATE - BTU/KW-HR'
890171   OPVB,56
*
* SCHEDULES
*
800100   'RADIANT WATER WALLS HTC VS NTIMES'
810100         0.0     6.0     7.0    100.0
810110   0.0   0.0     0.0     7.5      7.5
810110   0.0   0.0     0.0     5.5      5.5     * CHANGE TO TUNE TO TEST DATA
830100   1,  HTTIRH,  325,  NTIMES,  0
800200   ' HP EXHAUST PRESSURE VS FLOW TO IP BOWL'
810200         171140. 295770. 438060. 605200. 675020. 742750.
810210   0.0      126.     210.     310.     431.     481.     531.
830200   2,  PPXHP,  30,  WW,  54
*
* SPECIAL INPUT
*
890200   'AIR HEATER AIR HTC MULTIPLIER'
890201   HOAA,310,-6.00,I
890210   'AIR HEATER FLUE HTC MULTIPLIER'
890211   HOAF,310,-6.00,I
890220   'HOT SUPERHEATER HTC MULTIPLIER'
890221   HTTIRH,330,-1.70,I
890230   'HOT REHEATER HTC MULTIPLIER'
890231   HTTIRH,335,-.250,I
890240   'HP EXHAUST PRESSURE'
890241   PPXHP,30,481.0,I
*
* TEST DATA
*
******   MAIN STEAM TEMPERATURE
600020   5  0.0  1000.
******   HOT REHEAT TEMPERATURE
600520   5  0.0  1000.
890300   'MAIN STEAM FLOW, LBM/HR'
890301   WWVSC,5,395000.,I
890310   'GAS FLOW, LBM/HR'
890311   WWVSC,315,26800.,I
890320   'EXCESS AIR FRACTION'
890321   EXAIR,320,.015,I
890330   'THROTTLE PRESSURE, PSIA'
890331   PPVSC,5,1464.7,I
890340   'DRUM PRESSURE, PSIA'
890341   PPSTRU,282,1515.0,I
890350   'SUPERHEAT ATTEMPERATION FLOW, LBM/HR'
890351   WWFIXB,229,80000.,I
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890360  'REHEAT ATTEMPERATION FLOW, LBM/HR'
890361  WWFIXB,228,0.0,I
890370  'AMBIENT AIR TEMPERATURE, F'
890371  TTVSC,300,90.00,I
890380  'BACK PASS FLOW SPLIT, FRACTION'
890381  FRSPL,350,1.00,I
******  'AUXILIARY POWER, MWE'
870600  5.00
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