Simplified Design Mode Boiler Modeling

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ABSTRACT

Santee Cooper has three basic objectives in boiler modeling. These are: (1) to develop a detailed program to analyze boiler test results, (2) to establish the capability to analyze proposed design changes to the boiler and/or its auxillaries, and (3) to establish the capability to analyze various operating conditions to evaluate effects on boiler performance. The PEPSE program presents two basic options for boiler modeling. These are: (1) a performance mode boiler model, and (2) a full design mode boiler model. After some research into the input description for the full design mode model, we found there are actually two options within this option. These are the full design specification and what we will refer to as the simplified design specification. The simplified design specification requires the overall heat transfer coefficients, the effective areas for heat transfer, and pressure drop description for the convective stages. For the radiant stages, the thermal conductivity of the tubing, and the inside and outside tube diameters are specified instead of the overall heat transfer coefficients. This simplified design mode model satisfies our present boiler modeling objectives. We developed a simplified design mode model for our 3,900,000 lb/hr C.E. boiler. Controls were used to calculate actual heat transfer coefficients and effective areas based on measured temperatures leaving the tubing sections. A detailed test is necessary to obtain the data to build this type of model. The details of this type test are included in this paper.

INTRODUCTION

Santee Cooper's Performance Services has begun work on developing PEPSE models for all of their coal fired boilers. These include eight Riley Stoker boilers of various sizes and designs and one Combustion Engineering boiler. The C.E. boiler is the largest of the group rated at 3,900,000 lb/hr steam flow. This boiler supplies steam to a General Electric turbine rated at 530 MW capacity. The C.E. boiler is the only model completed at the present. Therefore, it is the basis for much of the information in this paper.

OBJECTIVES

The main objective of Santee Cooper's Performance Services group is to improve operating efficiency of the units. In boiler modeling this basically breaks down into three main objectives. They are: (1) To develop a detailed program to analyze boiler test results. (2) To establish capability to analyze and evaluate proposed design changes to the boiler and/or its auxiliaries. (3) To have the capability to analyze the effects of various operating conditions on boiler performance. The first objective involves analyzing the data from the routine performance tests conducted by Performance Services. This includes evaluating the boiler's present condition and determining how that condition differs from the last test conducted on that unit. Often there are proposals by the boiler manufacturer and sometimes by other vendors for changes to the steam generating unit to improve performance. Achievement of the second objective will allow

Performance Services to evaluate these changes to quantify their effectiveness. The third objective is mainly to aid operations personnel in operating the units as efficiently as possible under various conditions. Specifically using the PEPSE boiler models to do predictive studies assuming various changes in operating parameters. For example, observing the results of the model while varying the excess air from 20 % to 40 %.

OPTIONS

There are several options available when developing a boiler model. The first is a performance mode model. The second is a full design mode model. The third is what I will refer to as a simplified design mode model. The performance mode model is built based on test data or contract data only. It is a very basic approach to boiler modeling. The full design mode model is built from design data of the boiler. It is a very detailed approach in which all of the tubing sections are specified by the number of tubes, distance between tubes, tube lengths, tube materials, etc. The third option is a somewhat less rigorous approach to a design mode boiler model. In this approach, effective area for heat transfer, overall heat transfer coefficient, and pressure drop description are input for each section of tubing in the convective stages. For the radiant stages, the thermal conductivity of the tubing, and the inside and outside tube diameter are specified instead of the overall heat transfer coefficients. A detailed test on the unit is required for this approach to acquire pressure drop data for the gas and the steam, temperatures of the steam leaving each tubing section, and gas temperatures at various locations in the boiler. The data necessary for the simplified ASME boiler efficiency calculation is also required. In this model the heat transfer coefficients are assumed for the convective stages since the coefficients are generally in a fairly narrow range. For the radiant stages the thermal conductivity of the tubing is assumed since it should also be in a fairly narrow range. Controls are used to calculate effective areas for all stages to achieve correct steam enthalpies exiting the sections.

ADVANTAGES AND DISADVANTAGES

The performance mode model has several advantages. Most significantly, it provides boiler modeling capability with minimal effort. The model does not require as much breakdown of the boiler internals and does not require as much performance data to produce results. The main disadvantage of the performance mode is that the model is very limited in its predictive capability. Most predictive work with this model requires many assumptions which make the results very doubtful.

The full design mode model is a very useful model. It can be used for any type of predictive study that is possible using either of the other models. However, it is not condusive to test data analysis. The main disadvantage of this type of model is it requires very detailed design data which is often very hard to find and in many cases not available. Often in the case of older units, modifications have been made that change the performance of the boiler. This again complicates the model building process. It also increases the likelihood that the model once completed, will not accurately match the actual performance of the unit.

The advantages of the simplified design mode model are similar to those of the full design mode model. It can be used for most predictive studies. It is a better tool for test data analysis than the full design model, since it is built using test data and controls. The same process that was used to build the model from the test data can be used to analyze the data. The only difference being that the heat transfer coefficients and tubing thermal conductivities would be the controlled variable rather than the effective heat transfer area. The change in the calculated heat transfer coefficients and thermal conductivities would represent the fouling of the tubes. The disadvantages of this type of model include its reliance on test data, the uncertainty in the actual heat transfer coefficients and the actual effective areas. As discussed earlier, the model is based on test data which would require a detailed test.

MODEL SELECTION

Choosing the appropriate model is crucial to the success of a boiler modeling program. The model must satisfy the objectives of the boiler performance program. Time and effort required for each type of model is also an important consideration. In essence, the program selected must have the highest possible return on the time and effort invested. For Santee Cooper the most feasible is the simplified design mode model. This is mainly because it satisfies all three of the modeling objectives outlined earlier and also because it supports a detailed testing program which is one of the strong points of Santee Cooper's Performance Services group. The main shortcoming observed with the performance mode model is the inability to do predictive studies. The full design mode model has this capability but requires a great deal of time and effort to construct the model. Once the model is built, it is only as good as the data used to develop it. If the unit is old, it is possible that this full design mode model is not an accurate representation of the unit in its present condition. Also, this model is not a good choice for test data analysis.

MODEL DEVELOPMENT

Developing the models is the next major project in this program. There are many choices as to the detail and complexity of the model. A model can be very simple which usually implies very limited usefulness. A model can also be so complex that the effort involved in developing the model is not worth the return to be received from it. We tried to develop a model that would meet our needs but would not require an extraordinary amount of effort. This involves deciding how far to break down the tubing sections into different convective and radiant stages. This is an area in which no two engineers will probably make the exact same decision. Obviously the more breakdown there is into various sections the more accurate the model and also the more complex the model.

Santee Cooper's Performance Services group has currently developed a model for the Cross Generating Station boiler which is a 3,900,000 lb/hr boiler built in 1983. This unit was selected as the first to be modeled for several reasons. The unit is fairly new so most data needed for the model was available. The unit is Santee Cooper's largest and most complex. A third reason is we are fortunate enough to have a package of data to build the model similar to that we would obtain in the future for all units from testing. This data is similar to that discussed in the boiler modeling section in the discussion on the simplified design mode boiler.

The model schematic was developed using vendor schematics of the steam and feedwater paths, vendor drawings of the actual tube sections and their arrangement in the gas path, and with a good idea of how complex we wanted the model to be. The next step in developing the model was to reduce the steam and feedwater flow paths to the desired level of complexity. Next we had to model the gas path over the tube sections. This is a very difficult task because of the many different flow patterns the gas could have depending on fan and burner setups. Also the geometry of the tubing makes this a very subjective area. The model schematic was developed from the reduced flow paths mentioned above and the boiler outline. The resultant model and all other schematics are found in Appendix A.

The input deck for the model used to calculate heat transfer coefficients and the effective areas is shown in Appendix B. It should be noted that for the design mode cards for the radiant stages reasonable values for words 1,2,5,6,7,11,15, and 16 are required for this simplified design mode model. The rest of the variables can be input as "0.". For the convective stages, reasonable values must be used for words 1,2,3,21,22, and 23. The rest are really meaningless for the simplified design mode other than they are required for the model to run. Also worth noting are the controls to calculate the overall heat transfer coefficients and the effective areas for the stages. In the model presented in Appendix A, the heat transfer coefficients rather than the effective areas are controlled for the convective stages. Controls could be used to calculate effective areas for these stages just as well. To help these controls to converge, control interval update cards, control limiter cards, and stream specification cards were added to the model. The stream specification cards were used to specify stream end conditions for the tube side flows into the radiant and convective stages.

Next a second model was constructed from this model to do predictive studies. The input data for this model can be found in Appendix C. The main difference between this model and the first one is that the controls and "control helpers" for the effective areas and heat transfer coefficients are eliminated. The calculated heat transfer coefficients and effective areas are input on the design cards for the various stages. Controls were added to simulate actual boiler operation. The first was controling furnace exit temperature to acheive reheat temperature. This simulates the burner tilts. The second was controling firing rate to acheive steam quality entering the superheat sections. The last was controling superheat spray flow to acheive the correct superheater outlet temperature. Boiler efficiency calculations were also added.

DATA NEEDED

The following is a list of the test data necessary for the Cross boiler model:

INSTRUMENTATION LIST FOR CROSS BOILER TEST

1. Superheat section inlet temperature.
2. Superheat roof tube section outlet temperature.
3. Superheat side wall section outlet temperature.
4. Superheat rear wall section outlet temperature.
5. Superheat horizontal section outlet temperature.
6. Superheat pendant section outlet temperature.
7. Superheat spray outlet temperature.
8. Superheat panel front section outlet temperature.
9. Superheat panel rear section outlet temperature.
10. Superheat platen section outlet temperature.
11. Reheat section inlet temperature.
12. Reheat pendant front section outlet temperature.
13. Reheat pendant rear section outlet temperature.
14. Reheat wall tube section outlet temperature.
15. Reheat spray outlet temperature.
16. Economizer inlet temperature.
17. Baretube economizer outlet temperature.
18. Economizer sling tube outlet temperature.

19. FD fans discharge pressures.
20. PA fans discharge pressures.
21. Steam flows to air preheater steam coils.
22. Airheater air in temperatures.
23. Airheater air out temperatures.
24. Airheater gas in temperatures.
25. Airheater gas out temperatures.
26. Coal samples
27. Coal flow.
28. Fly ash samples.
29. Bottom ash samples.
30. Furnace gas exit temperature.
31. Reheat pendant rear gas exit temperature.
32. Superheat horizontal lower bank exit gas temperature.
33. Economizer lower bank exit gas temperature.
34. Feedwater flow.
35. Superheat spray flow.
36. Reheat spray flow.
37. Reheat steam flow.
38. Pulverizer amps.
39. Feeder rates.
40. Ambient temperature.
41. Wet bulb temperature.
42. Barometric pressure.
43. ID fans discharge pressures.
44. Airheater O_2 in (A&B).
45. Airheater O_2 out (A&B).

46. Airheater CO_2 in (A&B).

47. Airheater CO_2 out (A&B).

48. Furnace draft loss (FD Fan to Air Heater outlet).

49. Steam quality leaving steam drum.

50. Hot air damper positions (mills)

51. Cold air damper positions (mills)

52. All fuel damper positions.

53. All air damper positions.

54. Overfire air damper positions.

55. Steam drum pressure.

56. Cold reheat pressure.

57. Hot reheat pressure.

58. Feedwater @ Economizer pressure.

59. Superheater outlet pressure.

60. FD fan flows.

61. PA fan flows.

REQUIREMENTS FOR TEST

Tests to obtain the data listed above are very manpower intensive but do not require a large amount of sophisticated test equipment. There are many temperature measurements required for these tests, most of which can be obtained with standard thermocouples. There are some that cannot be obtained this way. These are the temperatures of the flue gas at the furnace exit and other various places in the boiler. These require the use of a water-cooled HVT probe. Several pressure transmitters, differential transmitters and manometers are also required. Much of the data required can be obtained from control room instrumentation or existing plant instrumentation. This is mainly reference data including: pulverizer amps, damper positions, etc. Samples of coal and ash will have to be obtained and analyzed. Probes will have to be inserted into the gas ducts before and after the airheaters to obtain the oxygen content of the gas and the gas temperature at various positions in the duct. Instrumentation to determine the oxygen content of the sample obtained from the probes is therefore required. A psychrometer will be required to obtain the wet bulb and dry bulb temperatures for humidity determination. Fan flows will have to be determined either by actual test or by design curves based on differential pressures. A data acquisition system will be very useful in recording most of this data.

MODELING DIFFICULTIES

One of the most difficult parts of building the Cross boiler model was deciding how complicated/simple to make the model. This is an area in which no two modelers would be likely to agree completely. Each modeler has to decide how much detail is needed to develop an effective model for their needs. It is safe to say that the simplest model that will satisfy the modeling objectives is the best model to use. Another difficulty we encountered was modeling the gas flow over all the individual sections. This requires a lot of "engineering judgement" in determining the flow splits of the gas. Many things can affect these flow splits in actual operations. These include fan biasing, air and fuel damper positions, etc. This is why it is important to record all of these when testing to obtain the model development data or in any subsequent testing.

Another difficulty encountered with this model was obtaining convergence. This is especially prevalent in the type of model we used for Cross Unit 2. Using controls to calculate the effective areas for heat transfer or the heat transfer coefficients substantially increases the amount of work that has to be done by PEPSE to obtain convergence as do the contols that are used to simulate actual boiler operation. PEPSE could require as many as 200 iterations plus some "control helpers" to obtain convergence.

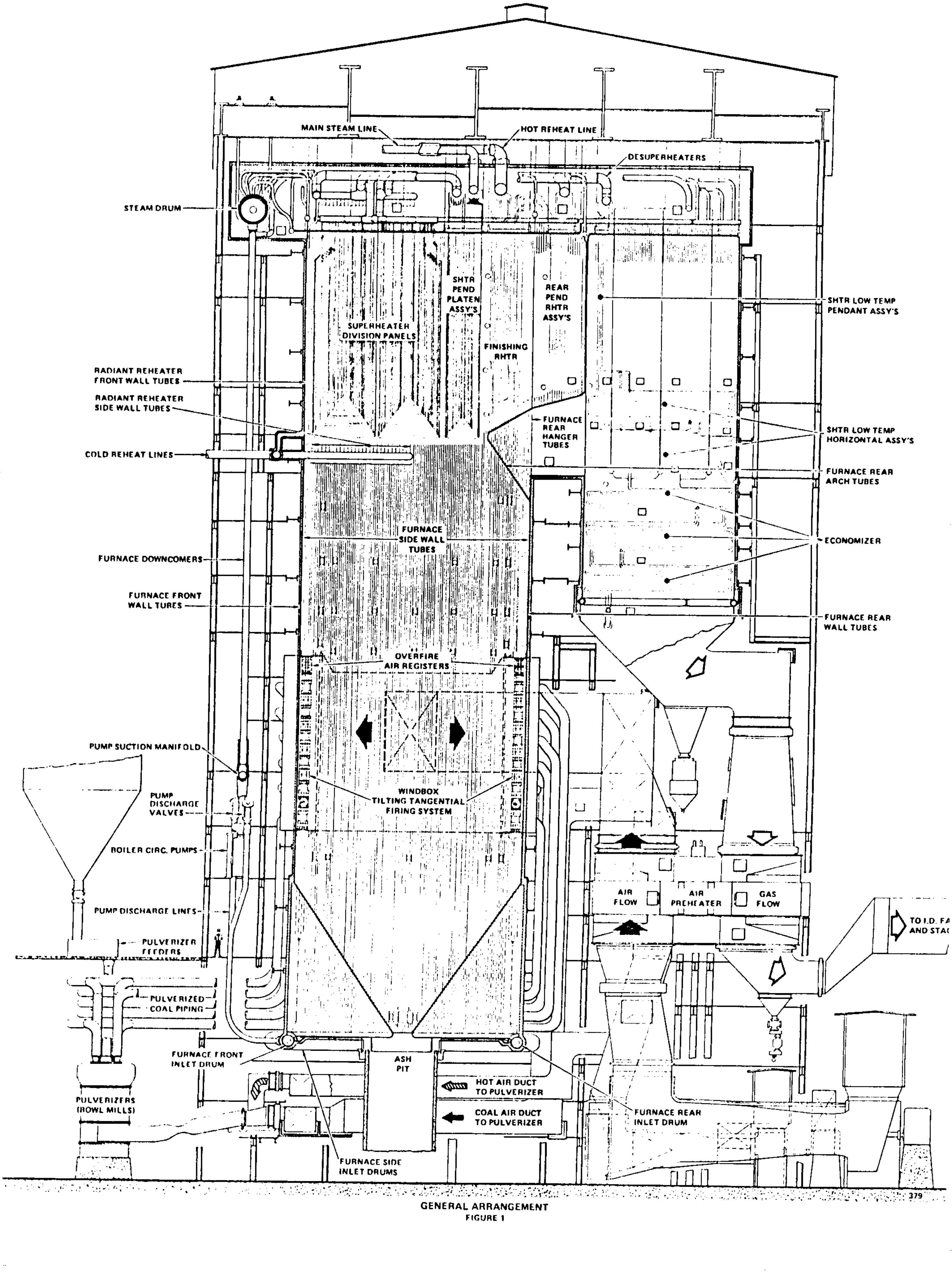
CONCLUSIONS

Boiler modeling requires many assumptions. It is not as formatted as the turbine model. There are several reasons for this including: (1) The boiler system is much more complicated and has many more degrees of freedom than the turbine system. (2) There has been considerably less work done in boiler modeling than in turbine modeling. (3) The gas flows paths in the boiler can change considerably depending on the way the boiler is operated. (4) Boiler designs can vary widely making generic type modeling difficult.

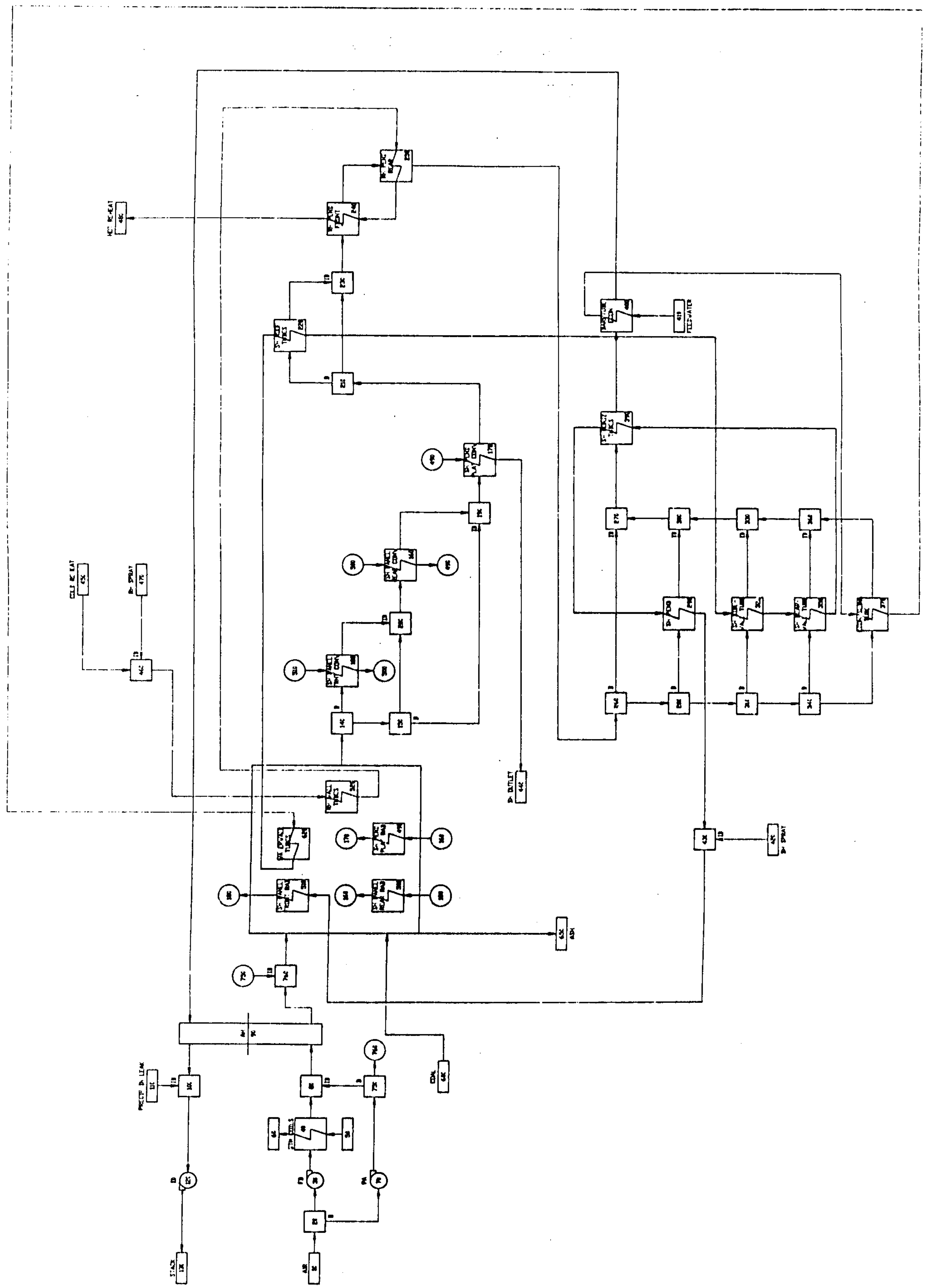
The assumptions required to build the boiler model must be considered when evaluating results from this model. In other words, the results cannot be used as freely as they can for the turbine model. However, these results are probably the most accurate that can be obtained without actual unit operation.

This simplified design model should satisfy Santee Cooper's objectives in boiler modeling and be a very useful tool in the performance program.

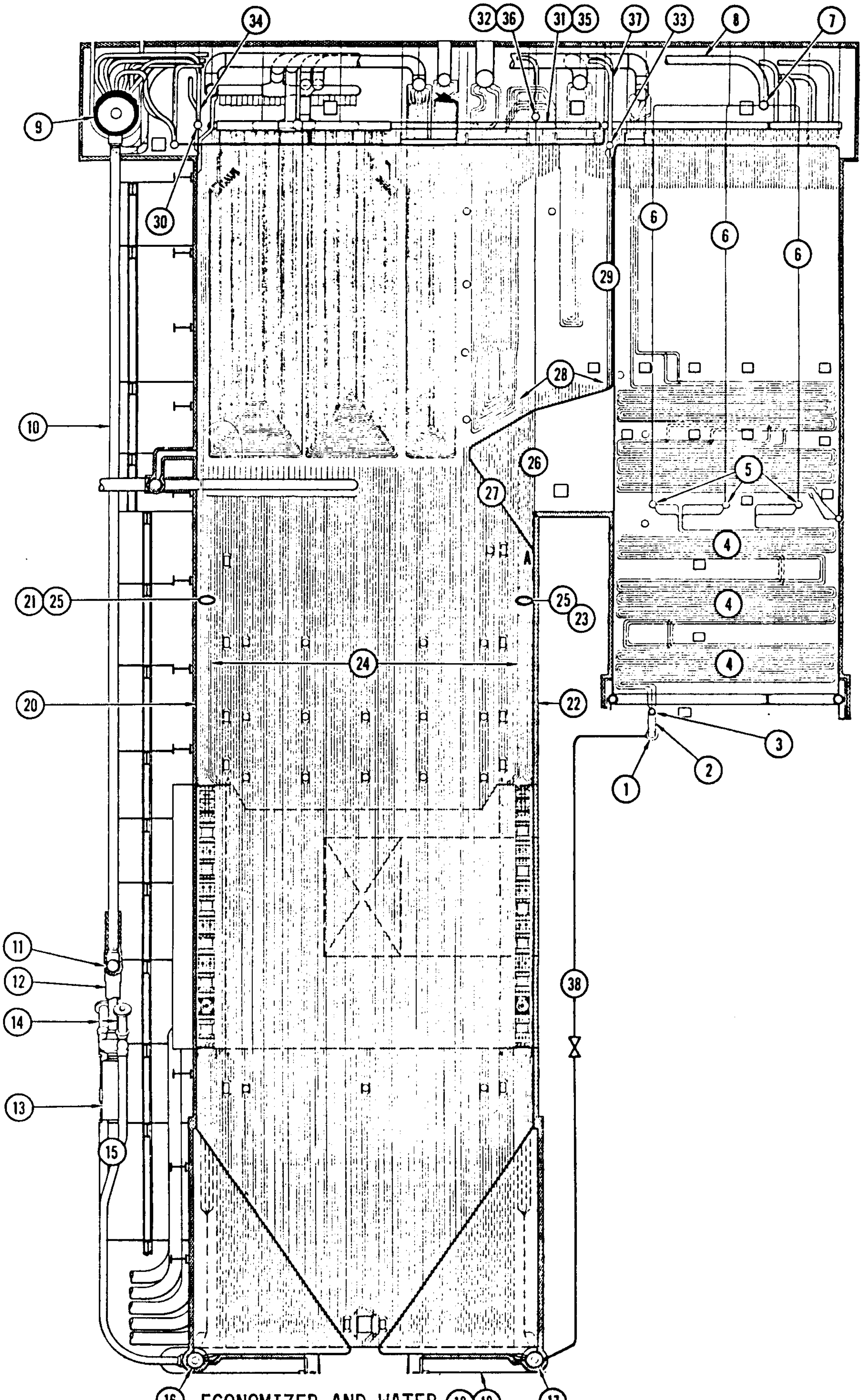
Appendix A



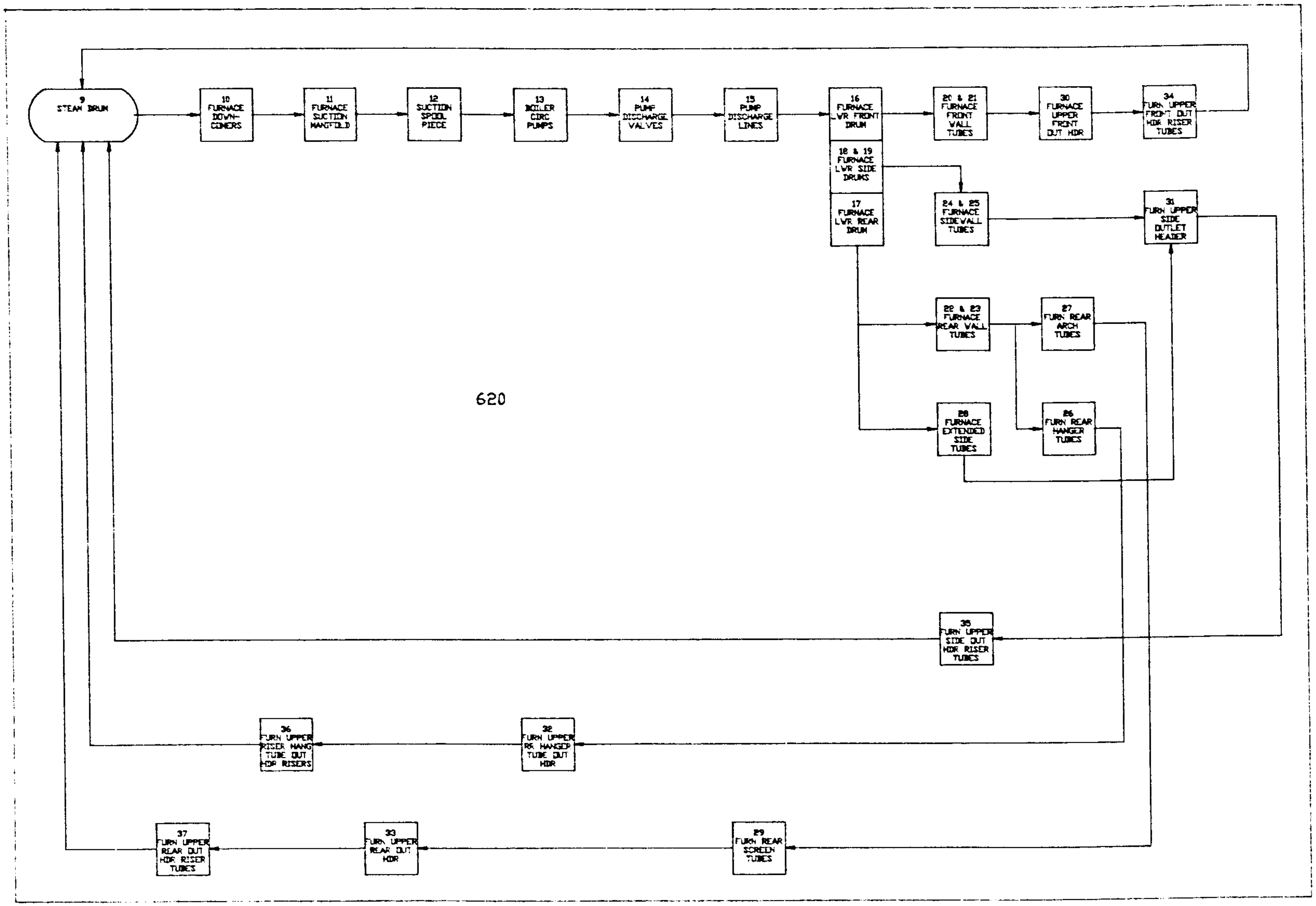
GENERAL ARRANGEMENT
FIGURE 1



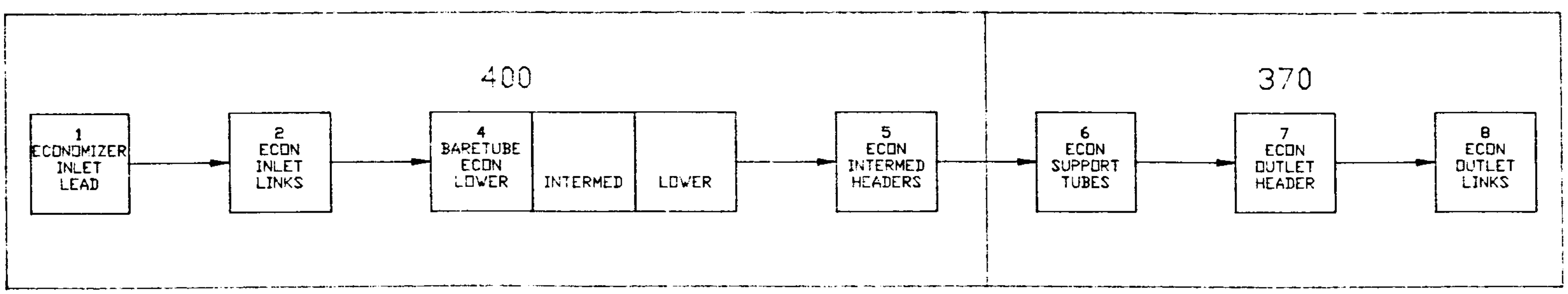
MODEL SCHEMATIC
FIGURE 2



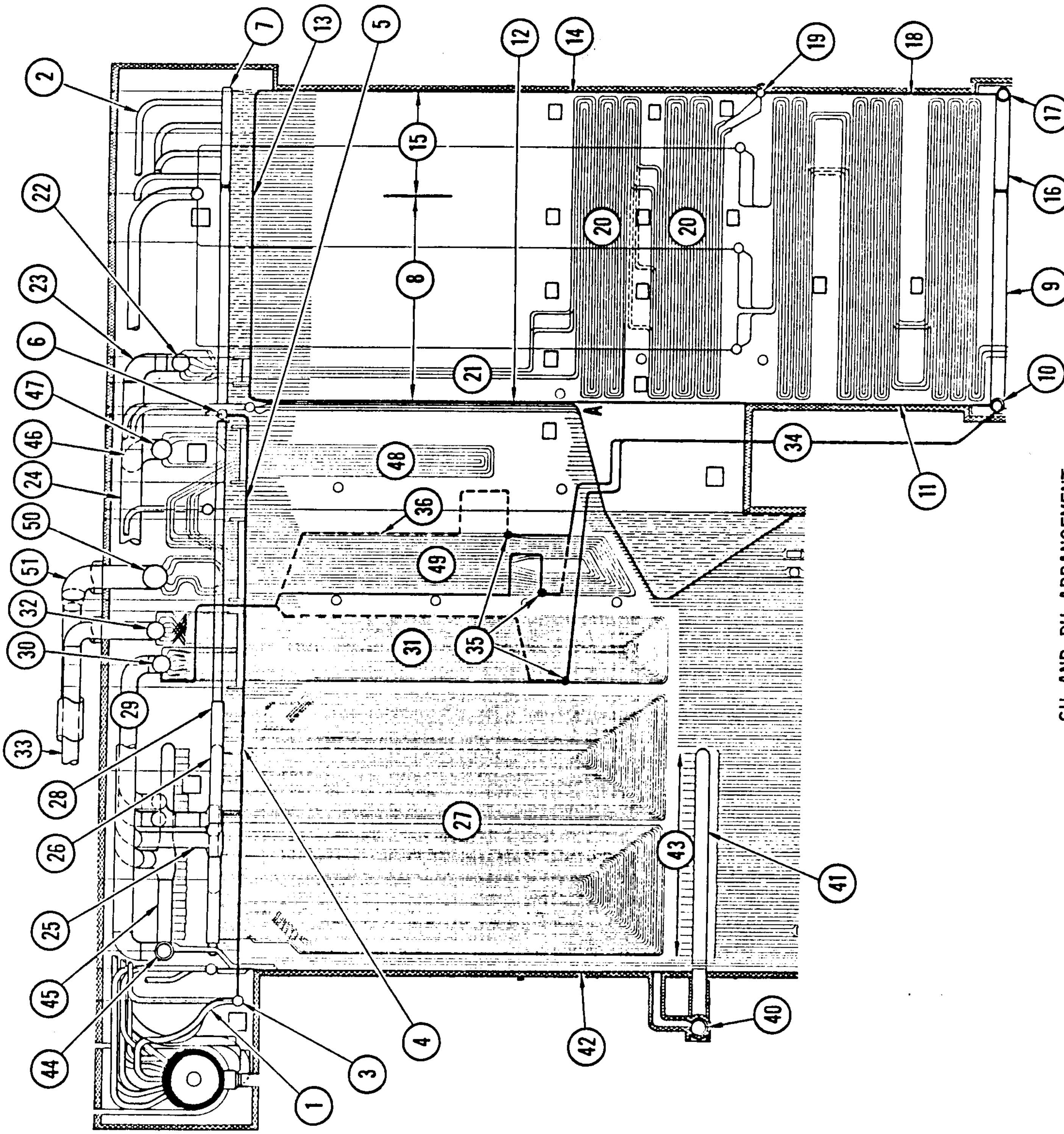
ECONOMIZER AND WATER-
WALL ARRANGEMENT
FIGURE 3



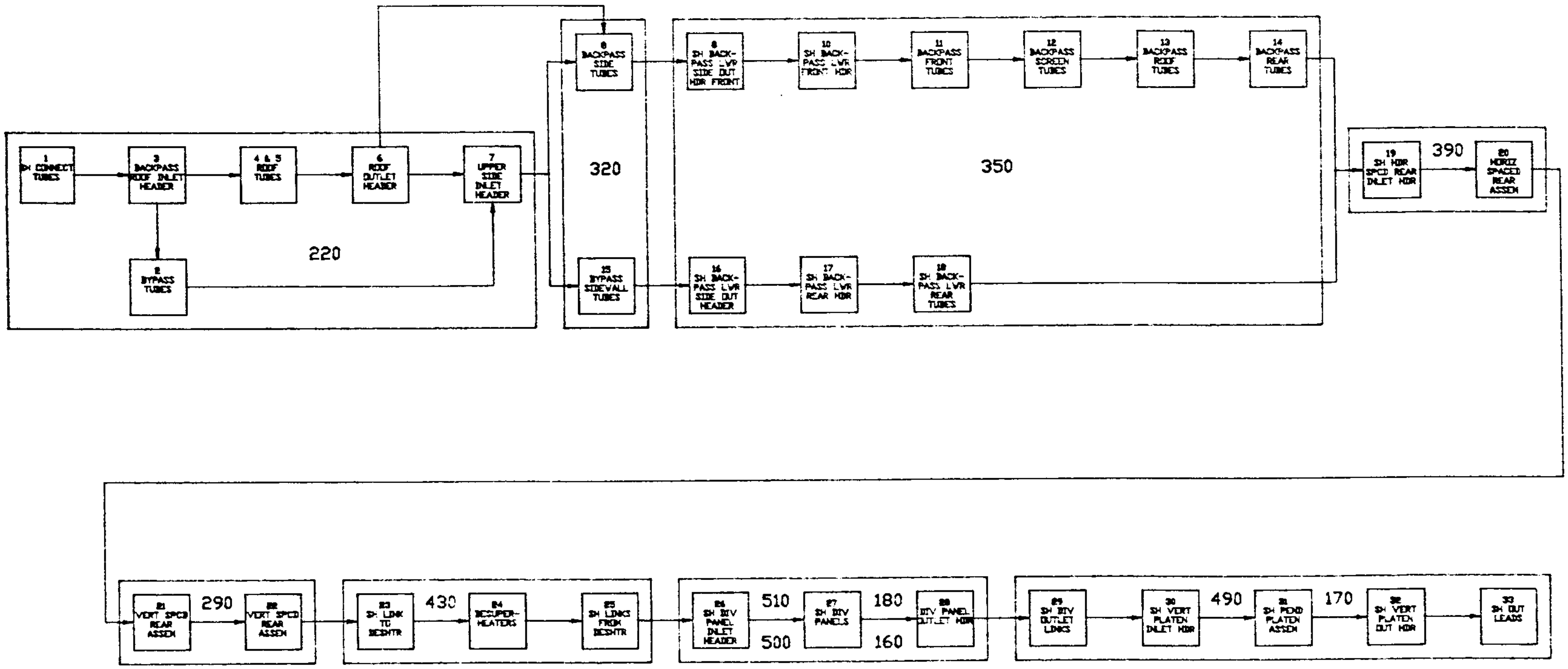
WATERWALL SCHEMATIC
FIGURE 4



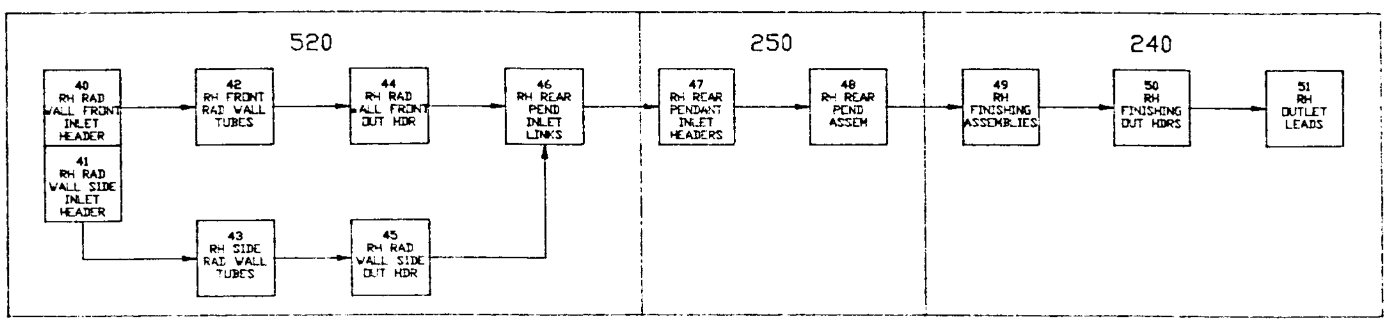
ECONOMIZER SCHEMATIC
FIGURE 5



SH AND RH ARRANGEMENT
FIGURE 6



SH SCHEMATIC
FIGURE 7



RH SCHEMATIC
FIGURE 8

Appendix B

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= CROSS DESIGN MODE BOILER MODEL
*
* GENERIC INPUT
010200 0,0,0,0,0
012000 200
*
* GEOMETRY CARDS
500150 10,U,20,I
500250 20,U,30,I
500260 20,B,70,I
500350 30,U,40,S
500450 40,T,60,I
500460 40,D,80,IA
500550 50,U,40,T
500750 70,U,750,I
500850 80,U,90,T
500950 90,T,760,IA
500960 90,D,100,IA
501050 100,U,120,I
501060 110,U,100,IB
501250 120,U,130,I
501450 140,B,180,S
501460 140,U,150,I
501550 150,U,200,IA
501560 150,B,190,IB
501650 160,T,490,T
501660 160,D,190,IA
501750 170,T,440,I
501760 170,D,210,I
501850 180,T,500,T
501860 180,D,200,IB
501950 190,U,170,S
502050 200,U,160,S
502150 210,U,230,IA
502160 210,B,220,S
502250 220,D,230,IB
502350 230,U,240,S
502450 240,T,480,I
502460 240,D,250,S
502550 250,T,240,T
502260 220,T,320,T
502560 250,D,260,I
502650 260,B,270,IB
502660 260,U,280,I
502750 270,U,390,S
502850 280,U,310,I
502860 280,B,290,S
502950 290,T,430,IA
502960 290,D,300,IB
503050 300,U,270,IA
503150 310,U,340,I
503160 310,B,320,S
503250 320,T,350,T
503260 320,D,330,IB
```

```
503350 330,U,300,IA
503450 340,U,370,S
503460 340,B,350,S
503550 350,T,390,T
503560 350,D,360,IB
503650 360,U,330,IA
503750 370,T,620,T
503760 370,D,360,IA
503950 390,T,290,T
503960 390,D,400,S
504050 400,T,370,T
504060 400,D,90,S
504150 410,U,400,T
504250 420,U,430,IB
504350 430,U,510,T
504550 450,U,460,IA
504650 460,U,520,T
504750 470,U,460,IB
504950 490,T,170,T
505050 500,T,160,T
505150 510,T,180,T
505250 520,T,250,T
506050 600,U,610,IF
506150 610,U,140,I
506160 610,B,650,I
506250 620,T,220,T
507550 750,B,760,IB
507560 750,U,80,IB
507650 760,U,610,IA
*
* STREAM SPECIFICATION
601650 5 2529.995  861.444
604350 5 2599.982  755.444
601850 5 2564.984  808.444
603750 5 2657.786  596.7
604650 5 564.000   631.0
604950 5 2529.992  888.414
603950 5 2609.900  746.544
603550 5 2651.798  688.344
602550 5 554.107   811.4
605250 5 563.999   706.8
604150 5 2695.000  484.0
604050 5 2658.078  591.6
605150 5 2599.98   765.406
605050 5 2564.981  820.464
606250 5 2651.806  1.0
602260 5 2651.803  680.344
603250 5 2651.801  684.344
*
* INPUT COMPONENTS
701100 31,80.,14.7,0.0,*PRECIPITATOR O2 IN
701103 AIR,-.013
700100 31,80.,14.7,4318248.,*AIR IN FLOW
700103 AIR,-.013
```

```
704100 31,484.,2695.,3565101.,*FW @ ECONOMIZER
704500 31,631.,564.,3209016.,*CRH IN
704700 31,300.,1500.,0.0
704200 31,365.,2750.,0.0
706000 33,80.,14.7,373803.34
706003 FUEL,12470.,
706004 C,.7023,H2,.0492,S,.0099,O2,.0664,N2,.0139,H2O,.0531,ASH,.1052
700500 31,0.,0.,0.
*
* OUTPUT COMPONENTS
701300 32
700600 30
704400 30
706500 30
704800 30
*
* RADIANT STAGES
704900 29,1,610
704904 892.72,1,0.,0.,1.,1.25 1.75 0. 0. 0. 20. 0. 0. 0.
704905 1658.95 .000001
705100 29,1,610
705104 767.44,1,0.,0.,1.,1.25 1.75 0. 0. 0. 20. 0. 0. 0.
705105 904.08   .000001
705000 29,1,610
705004 822.50,1,0.,0.,1.,1.25 1.75 0. 0. 0. 20. 0. 0. 0.
705005 849.52  .000001
706200 29,1,610
706204 679.00,1,0.,0.,1.,1.25 1.75 0. 0. 0. 20. 0. 0. 0.
706205 35097.28 .00225 0. 0. 2651.806
705200 29,1,610
705204 706.80,1,0.,0.,1.,1.25 1.75 0. 0. 0. 20. 0. 0. 0.
705205 3028.48 .000001
*
* CONVECTIVE STAGES
701700 28,1,3600000.0,2500.,1001.54
701704 3,0,1,51.,51.,1.,1.,1.,1.,1.,2.,1.,1.,1.,1.,1.,1.,0.,0.,0.,
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702900 28,1,3565101.,2610.,749.
702904 3,0,2,51.,51.,1.,1.,1.,1.,1.,2.,1.,1.,1.,1.,1.,1.,0.,0.,0.,
702905 7.9,11108.,.0038
703900 28,1,3565101.,2652.,691.
703904 3,0,3,51.,51.,1.,1.,1.,1.,1.,2.,1.,1.,1.,1.,1.,1.,0.,0.,0.,
703905 10.5,104368.,.0158
702400 28,1,3209016.,560.,811.
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702500 28,1,3209016.,570.,707.
702504 3,0,1,51.,51.,1.,1.,1.,1.,1.,2.,1.,1.,1.,1.,1.,1.,0.,0.,0.,
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701805 10.777,12155.36,.01346
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*
* MIXERS
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704600 50
701900 50
702000 50
702300 50
702700 50
703000 50
703300 50
703600 50
704300 50
701000 50
707600 50
*
* SPLITTERS
701400 63,0.0,.43088
701500 63,0.0,.32364
702100 63,0.0,.4,*GUESS
702600 63,0.0,.5,*ESTIMATE
702800 63,0.0,.25,*ESTIMATE
703100 63,0.0,.3333,*ESTIMATE
703400 63,0.0,.5,*ESTIMATE
700200 63,0.0,.33333
707500 63,0.0,.2419
*
* FANS
700300 43,15.06
700700 43,15.06,*ASSUMMED
701200 43,15.06,*ASSUMMED
*
* FURNACE
706100 70,1,3,10,.2,    .0,0.0,0.0,.0093       .002
*
* STM COILS
700400 20,80.0
*
* AIRHEATER
```

```
700903 .0750
700900 21,2,524.,0.,.001
*
* CONTROLS
* WATERWALLS
840100 AATIRH,620,1.0,1.E-4,0.,XX,-625
* SUPERHEAT
840200 HTTIRH,220,680.344,1.E-4,0.,TT,-226
840300 HTTIRH,320,684.344,1.E-4,0.,TT,-325
840400 HTTIRH,350,688.344,1.E-4,0.,TT,-355
840500 HTTIRH,390,746.544,1.E-4,0.,TT,-395
840600 HTTIRH,290,755.444,1.E-4,0.,TT,-295
840700 AATIRH,510,765.406,1.E-4,0.,TT,-515
840800 HTTIRH,180,808.444,1.E-4,0.,TT,-185
840900 AATIRH,500,820.464,1.E-4,0.,TT,-505
841000 HTTIRH,160,861.444,1.E-4,0.,TT,-165
841100 AATIRH,490,888.414,1.E-4,0.,TT,-495
841200 HTTIRH,170,1003.60,1.E-4,0.,TT,-175
* ECONOMIZER
841300 HTTIRH,400,591.600,1.E-4,0.,TT,-405
841400 HTTIRH,370,596.700,1.E-4,0.,TT,-375
* REHEATER
841500 AATIRH,520,706.800,1.E-4,0.,TT,-525
841600 HTTIRH,250,811.400,1.E-4,0.,TT,-255
841700 HTTIRH,240,1005.10,1.E-4,0.,TT,-245
*
* INTERVAL UPDATE FACTORS
840105 2
840205 3
840305 4
840405 4
840505 4
840605 4
840705 2
840805 2
840905 2
841005 2
841105 2
841205 2
841305 4
841405 4
841505 2
841605 3
841705 3
*
* LIMITERS
840109  3000.  42000.
840209 8. 12.
840309 8. 12.
840409 5. 10.
840509 8. 12.
840609 6. 14.
840709  100.  1000.
840809 8.  12.
```

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840909  100. 1000.
841009 9.  13.
841109  200.  2000.
841209 10. 14.
841309 8.  14.
841409 6.  10.
841509  300.  3200.
841609 9.  13.
841709 10. 14.
*
*
.
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Appendix C

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= CROSS DESIGN MODE BOILER MODEL
*
* GENERIC INPUT
010200 0,0,0,0,0
012000 200
*
* GEOMETRY CARDS
500150 10,U,20,I
500250 20,U,30,I
500260 20,B,70,I
500350 30,U,40,S
500450 40,T,60,I
500460 40,D,80,IA
500550 50,U,40,T
500750 70,U,750,I
500850 80,U,90,T
500950 90,T,760,IA
500960 90,D,100,IA
501050 100,U,120,I
501060 110,U,100,IB
501250 120,U,130,I
501450 140,B,180,S
501460 140,U,150,I
501550 150,U,200,IA
501560 150,B,190,IB
501650 160,T,490,T
501660 160,D,190,IA
501750 170,T,440,I
501760 170,D,210,I
501850 180,T,500,T
501860 180,D,200,IB
501950 190,U,170,S
502050 200,U,160,S
502150 210,U,230,IA
502160 210,B,220,S
502250 220,D,230,IB
502350 230,U,240,S
502450 240,T,480,I
502460 240,D,250,S
502550 250,T,240,T
502260 220,T,320,T
502560 250,D,260,I
502650 260,B,270,IB
502660 260,U,280,I
502750 270,U,390,S
502850 280,U,310,I
502860 280,B,290,S
502950 290,T,430,IA
502960 290,D,300,IB
503050 300,U,270,IA
503150 310,U,340,I
503160 310,B,320,S
503250 320,T,350,T
503260 320,D,330,IB
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503350 330,U,300,IA
503450 340,U,370,S
503460 340,B,350,S
503550 350,T,390,T
503560 350,D,360,IB
503650 360,U,330,IA
503750 370,T,620,T
503760 370,D,360,IA
503950 390,T,290,T
503960 390,D,400,S
504050 400,T,370,T
504060 400,D,90,S
504150 410,U,400,T
504250 420,U,430,IB
504350 430,U,510,T
504550 450,U,460,IA
504650 460,U,520,T
504750 470,U,460,IB
504950 490,T,170,T
505050 500,T,160,T
505150 510,T,180,T
505250 520,T,250,T
506050 600,U,610,IF
506150 610,U,140,I
506160 610,B,650,I
506250 620,T,220,T
507550 750,B,760,IB
507560 750,U,80,IB
507650 760,U,610,IA
*
*
* INPUT COMPONENTS
701100 31,80.,14.7,0.0,*PRECIPITATOR O2 IN
701103 AIR,-.013
700100 31,80.,14.7,4318248.,*AIR IN FLOW
700103 AIR,-.013
704100 31,484.,2695.,3565101.,*FW @ ECONOMIZER
704500 31,631.,564.,3209016.,*CRH IN
704700 31,300.,1500.,0.0
704200 31,365.,2750.,0.0
706000 33,80.,14.7,373803.34
706003 FUEL,12470.,
706004 C,.7023,H2,.0492,S,.0099,O2,.0664,N2,.0139,H2O,.0531,ASH,.1052
700500 31,0.,0.,0.
*
* OUTPUT COMPONENTS
701300 32
700600 30
704400 30
706500 30
704800 30
*
* RADIANT STAGES
704900 29,1,610
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704904 892.72,1,0.,0.,1.,1.25 1.75 0. 0. 0. 20. 0. 0. 0.
704905 1739.70 .000001
705100 29,1,610
705104 767.44,1,0.,0.,1.,1.25 1.75 0. 0. 0. 20. 0. 0. 0.
705105 951.38   .000001
705000 29,1,610
705004 822.50,1,0.,0.,1.,1.25 1.75 0. 0. 0. 20. 0. 0. 0.
705005 896.52  .000001
706200 29,1,610
706204 679.00,1,0.,0.,1.,1.25 1.75 0. 0. 0. 20. 0. 0. 0.
706205 36869.36 .00225 0. 0. 2651.806
705200 29,1,610
705204 706.80,1,0.,0.,1.,1.25 1.75 0. 0. 0. 20. 0. 0. 0.
705205 3182.60 .000001
*
* CONVECTIVE STAGES
701700 28,1,3600000.0,2500.,1001.54
701704 3,0,1,51.,51.,1.,1.,1.,1.,1.,2.,1.,1.,1.,1.,1.,1.,0.,0.,0.,
701705 12.643,24286.,.0079
702900 28,1,3565101.,2610.,749.
702904 3,0,2,51.,51.,1.,1.,1.,1.,1.,2.,1.,1.,1.,1.,1.,1.,0.,0.,0.,
702905 7.705,11108.,.0038
703900 28,1,3565101.,2652.,691.
703904 3,0,3,51.,51.,1.,1.,1.,1.,1.,2.,1.,1.,1.,1.,1.,1.,0.,0.,0.,
703905 10.119,104368.,.0158
702400 28,1,3209016.,560.,811.
702404 3,0,1,51.,51.,1.,1.,1.,1.,1.,2.,1.,1.,1.,1.,1.,1.,0.,0.,0.,
702405 12.345,37750.,.01786
702500 28,1,3209016.,570.,707.
702504 3,0,1,51.,51.,1.,1.,1.,1.,1.,2.,1.,1.,1.,1.,1.,1.,0.,0.,0.,
702505 11.599,23070.,.01754
704000 28,1,3565101.,2658.,484.
704004 3,0,3,51.,51.,1.,1.,1.,1.,1.,2.,1.,1.,1.,1.,1.,1.,0.,0.,0.,
704005 11.392,191849.0,.0137
703700 28,1,3565101.,2695.,592.
703704 3,0,2,51.,51.,1.,1.,1.,1.,1.,2.,1.,1.,1.,1.,1.,1.,0.,0.,0.,
703705 8.764,3860.,.00011
701800 28,1,3565101.,2600.,757.5
701804 3,1,1,51.,51.,1.,1.,1.,1.,1.,2.,1.,1.,1.,1.,1.,1.,0.,0.,0.,
701805 10.657,12155.36,.01346
701600 28,1,3565101.,2600.,810.5
701604 3,0,1,51.,51.,1.,1.,1.,1.,1.,2.,1.,1.,1.,1.,1.,1.,0.,0.,0.,
701605 11.479,9680.74,.01364
702200 28,1,3565101.,2600.,679.
702204 3,0,1,51.,51.,1.,1.,1.,1.,1.,2.,1.,1.,1.,1.,1.,1.,0.,0.,0.,
702205 10.330,5391.6,.000001
703200 28,1,3565101.,2600.,682.5
703204 3,0,1,51.,51.,1.,1.,1.,1.,1.,2.,1.,1.,1.,1.,1.,1.,0.,0.,0.,
703205 11.365,9231.,.000001
703500 28,1,3565101.,2600.,686.5
703504 3,0,2,51.,51.,1.,1.,1.,1.,1.,2.,1.,1.,1.,1.,1.,1.,0.,0.,0.,
703505 7.133,11741.,.000001
*
* MIXERS
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700800 50
704600 50
701900 50
702000 50
702300 50
702700 50
703000 50
703300 50
703600 50
704300 50
701000 50
707600 50
*
* SPLITTERS
701400 63,0.0,.43088
701500 63,0.0,.32364
702100 63,0.0,.4,*GUESS
702600 63,0.0,.5,*ESTIMATE
702800 63,0.0,.25,*ESTIMATE
703100 63,0.0,.3333,*ESTIMATE
703400 63,0.0,.5,*ESTIMATE
700200 63,0.0,.33333
707500 63,0.0,.2419
*
* FANS
700300 43,15.06
700700 43,15.06,*ASSUMMED
701200 43,15.06,*ASSUMMED
*
* FURNACE
706100 70,1,3,10,.2,0.0,0.0,0.0,.00032728,.002
*
* STM COILS
700400 20,80.0
*
* AIRHEATER
700900 21,3
700903 .0750
700904 83.704 524.000 614.487 248.370 3942400. 4652606.
*
* BOILER EFFICIENCY CALCULATION
900000 1 80.
900110 96
900210 15
900310 605 0.0
900810 .0026
901110 616
901610 0. .0019
901910 .0074
*
*
* BOILER CONTROLS
842100 TEXF,610,1005.096,1.E-3,0.,TT,-245
842200 WWVSC,600,1.0,1.E-3,0.,XX,-625
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842300 WWVSC,420,1003.604,1.E-3,0.,TT,-175
* LIMITERS
842109 2000. 2400.
842209 350000. 400000.
842309 0. 500000.
* INTERVAL UPDATE FACTORS
842105 10
842205 10
842305 10
* CONTROL INITIATION
842106 15
842206 15
842306 15
* UPDATE
842107 .60
842207 .60
842307 .60
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REFERENCES

The following references were used in the construction of this model and in the preparation of this report.

1 - PEPSE Computer Code, Energy Inc., PO Box 736, Idaho Falls, Idaho, Version 52X, and 53T.

2 - PEPSE Manual: Volume I, User Input Description, Energy Inc., PO Box 736, Idaho Falls, Idaho.

3 - C.E. Boiler Instruction Manual, Volume 1 of 6, Combustion Engineering Inc., 1000 Prospect Hill Rd., Windsor, C.T.

4 - Boiler Performance Data, Burns and Roe, Inc., Paramus, New Jersey.