Temperature Effects on Reheat when Sending Process Steam to a Wallboard Plant (Drying Gypsum) At Winyah Station

Leif Svensen P.E.

Santee Cooper

2006

Abstract

This study is to determine the impact of supplying 113,750,000 Btus/hour heat to a wallboard plant for drying Gypsum. The plant will be on a piece of land adjacent to our Winyah Generating Station and the steam will be coming from one if the units on the site. After a short review, we decided that the most feasible location for this extraction is the cold reheat line. We also considered one other location that which was a closer match for the process's desired steam conditions, the extraction just before the crossover line. This location was not selected because General Electric determined that it would require a major modification to the extraction nozzle. The cold reheat extraction point did not require major modifications. To determine the value of the steam we ran turbine models first. I then ran combined the turbine/boiler models to find the effects of taking this steam from the cold reheat line and the impact it has on superheat and hot reheat temperature.

Introduction

Winyah Generating Station is located in Georgetown, South Carolina. It has four generating units Winyah 1, 2 ,and 3 are General Electric (GE) turbines and Winyah 4 is a Westinghouse turbine. All have a gross output of 303 MW at 1,983,000 lbs./hr steam flow, 1000/1000 °F throttle/reheat inlet temperatures, 2 inches Hg condenser pressure and 2,400 psig throttle pressure. All the boilers are Riley coal fired boiler and rated at 2,100,000 lbs./hr, 1005/1005 °F superheat/ reheat temperatures and 2,475 psig superheater outlet pressure. The boiler for Winyah 1 is a wall-fired unit Winyah 2, 3, and 4 are turbo-fired units with Winyah unit #2 having a radiant reheater section. Winyah unit #1 operates at a lower than design reheat temperature. This has been since the unit's start date and it is determined that the design of the boiler is the cause.

With upgrades and the addition of new sulfur scrubbers and the station's capability to produce wallboard quality gypsum, Santee Cooper has searched for buyers to use this new "product" stream. Siting the wallboard plant on site proved to be the optimal solution. A wallboard manufacturer is now under contract to purchase the Gypsum. This plant will require approximately 113,750,000Btus/hour of heat in the drying process that is supplemented with natural gas for temperature control. One Winyah unit at a time will supply the heat for the process but all four could have the capability to supply the steam. At this point in time only Winyah units 1 and 3 are being considered to supply the steam.

This paper will concentrate on Winyah unit #1 boiler since it operates with the reheat temperature that is anywhere 20 ºF to 50 ºF deficient throughout the generation range.

PEPSE Modeling

We used two models to complete this study, a turbine model created in 1996 and a boiler model created in 2002. The turbine model was developed with the heat balances from 1995 blading change out to the aero design for the high-pressure and intermediate pressure turbine sections. See my paper from the June 11-14, 1996 users group meeting titled "Customization of GE Turbine Expansion Line Curves to Model a GE Advanced Aero Design Steam Turbine Upgrade". This model was then linked to a boiler model of Winyah Unit #1 boiler. Both of these models are also setup to run multi-load PEPSE® cases.

This boiler is a Riley unit with an in service date of 1975. It originally did not attain reheat temperature during its acceptance tests and had the reheat surface area increased in 1977. After the second addition of surface the unit operated at higher temperatures but with the installation of low NOx burners reheat temperature is a concern again. The boiler modeling was first completed using the original design data from 1975 and matched with the original test data. Next, a model with the increased surface are was constructed. I also benchmarked this model to test data from 1977. The unit was still short on reheat temperature.

At the time of boiler modeling we noticed that the as built economizer surface area square footage was less than the original specification. We ran another model with the original specified area and got increases in both superheat and reheat temperatures of about 5 ºF and 15 ºF respectively. This showed us that an increase in economizer surface area could help the temperature situation.

To link these two PEPSE® models I use special option 11. To keep the modeling simple I decided not to transfer any spray flows between models and let the superheat and reheat temperatures rise. The biggest dilemma was in how I should run the boiler model. I decided that for the base cases (no steam flow to the Wallboard plant) that to balance the drum I would use fuel flow. When running the cases in which there is steam sent to the Wallboard plant that I balance the drum in the boiler model using feedwater flow. I decided on this because I wanted to see what the effects were when the fuel flow was fixed to the amounts that are in the baseline PEPSE® runs. Each model has some unique modeling modifications to achieve the desired results.

I modified the turbine model by the addition of a heat exchanger to simulate the effect of the wall board plant.. I have modeled this heat exchanger's steam supply coming from the cold reheat line. In the model the heat exchanger drains into the inlet to the deaerator. The wallboard plant will take and condense the steam returning condensate to a point in the steam cycle close to the returning wallboard condensate. This drying process requires a fixed amount of energy, which amounts to 113,750,000 Btus/hr (see Figure 1 below).

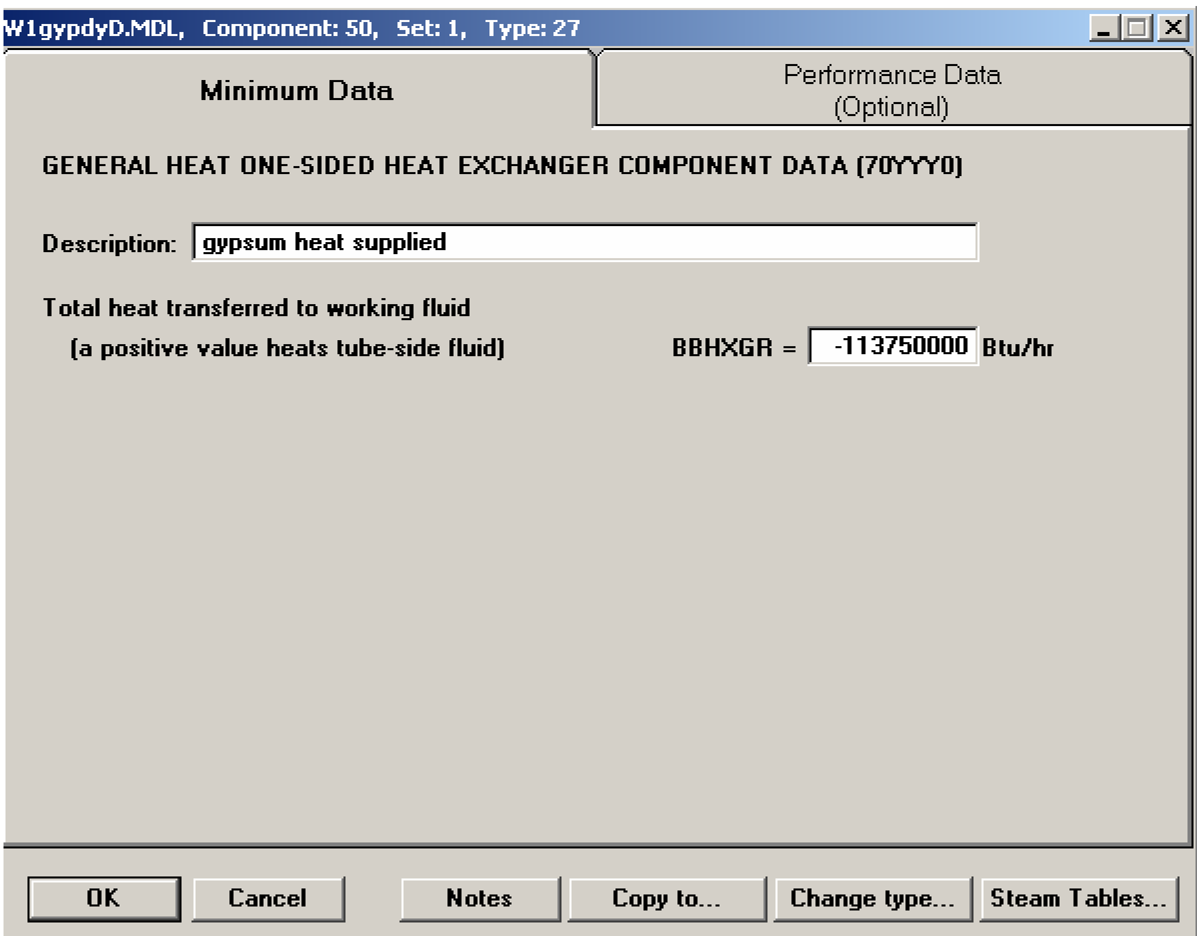


Figure 1

I also used controls for the base cases to control the steam flow in order to get the desired generation output. This was to have the base cases at set outputs. I could then compare these base cases to the cases using process steam to show the amount of generation lost that the PEPSE® runs predicted. An example of this control is shown in the figures 2 and 3.

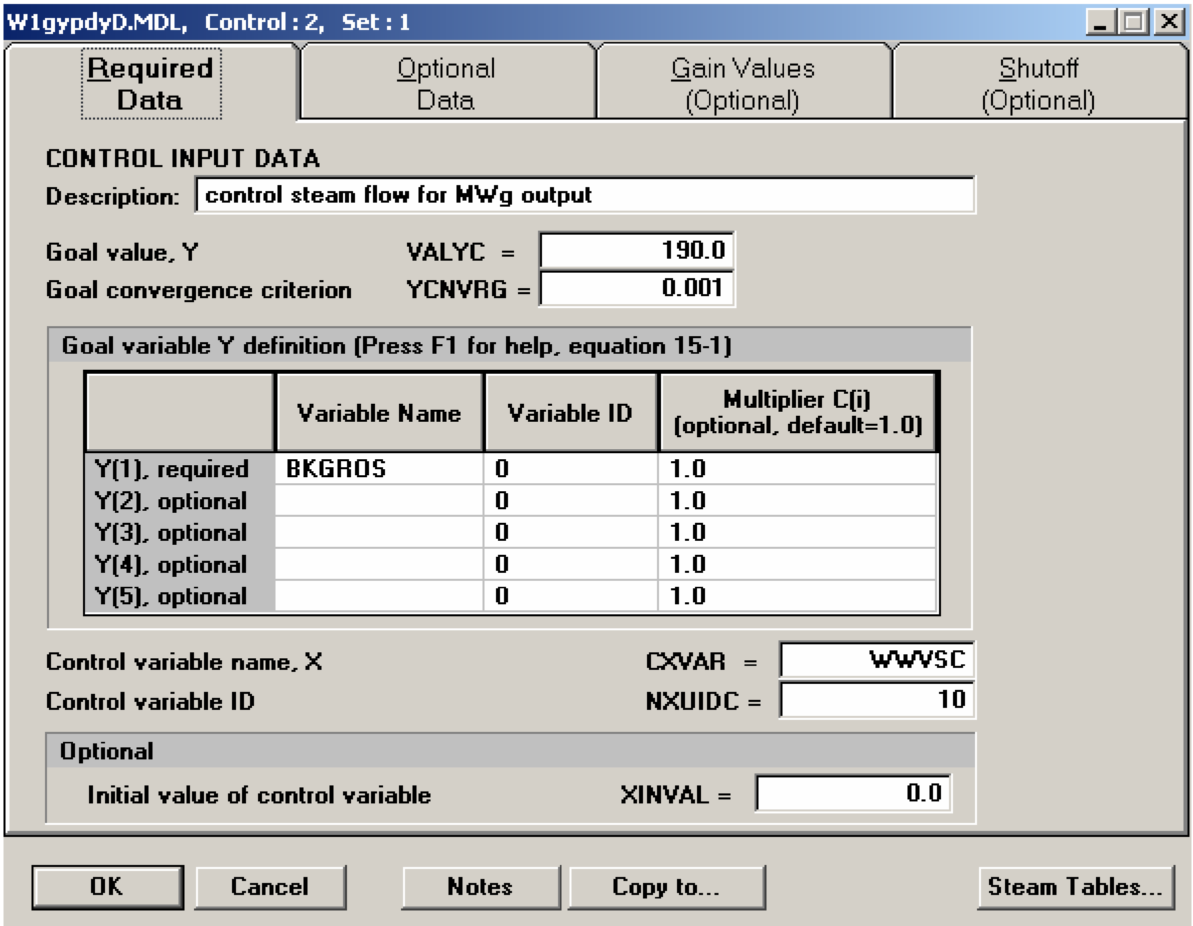


Figure 2

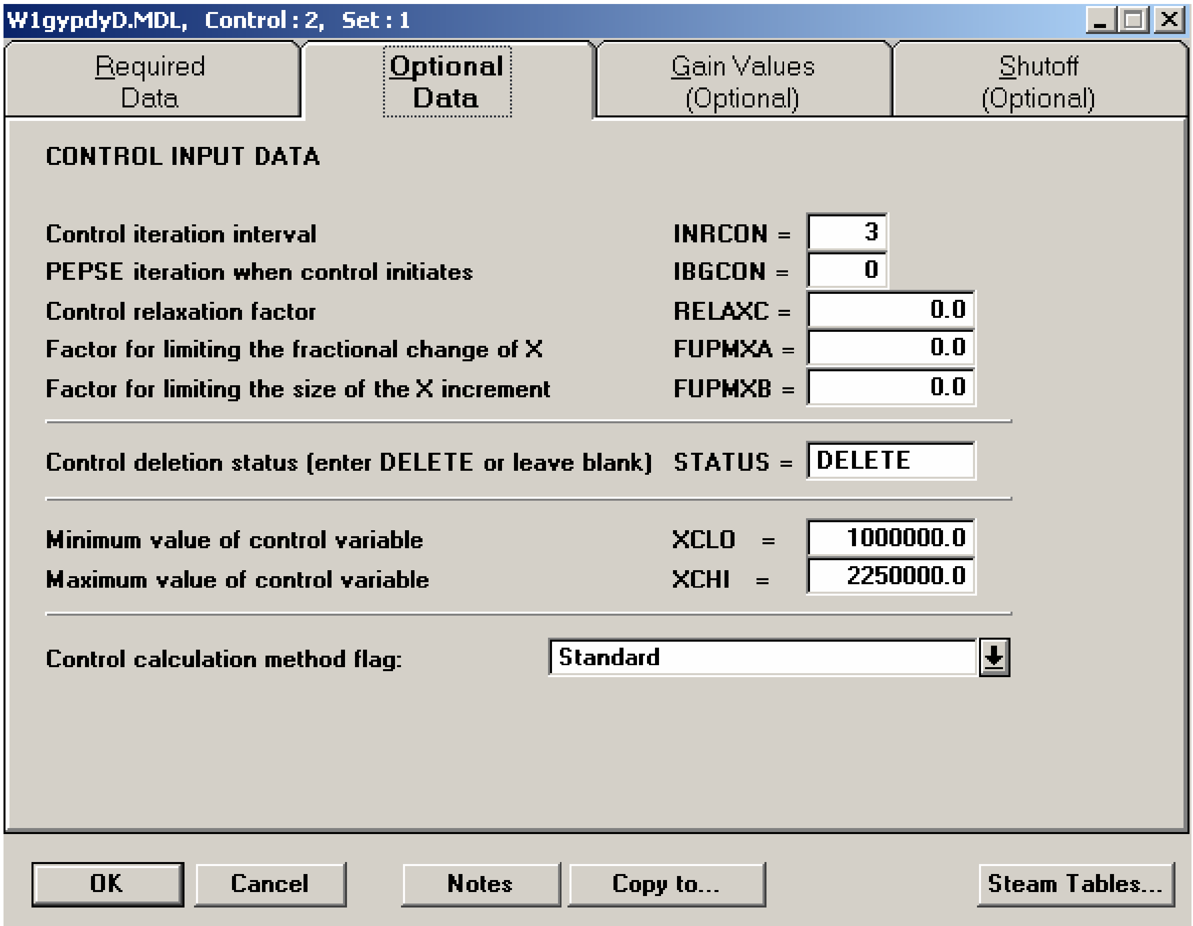

W1gypdyD.MDL, Control : 2, Set : 1
Required Data
Optional Data
Gain Values (Optional)
Shutoff (Optional)
CONTROL INPUT DATA
Control iteration interval
INRCON =
3
PEPSE iteration when control initiates
IBGCON =
0
Control relaxation factor
RELAXC =
0.0
Factor for limiting the fractional change of X
FUPMXA =
0.0
Factor for limiting the size of the X increment
FUPMXB =
0.0
Control deletion status (enter DELETE or leave blank)
STATUS =
DELETE
Minimum value of control variable
XCLO =
1000000.0
Maximum value of control variable
XCHI =
2250000.0
Control calculation method flag:
Standard
OK
Cancel
Notes
Copy to...
Steam Tables...

Figure 3

To the boiler model base cases I wrote the control for drum energy balance to use furnace exit gas temperature to balance the drum. An example of this is in Figure 4.

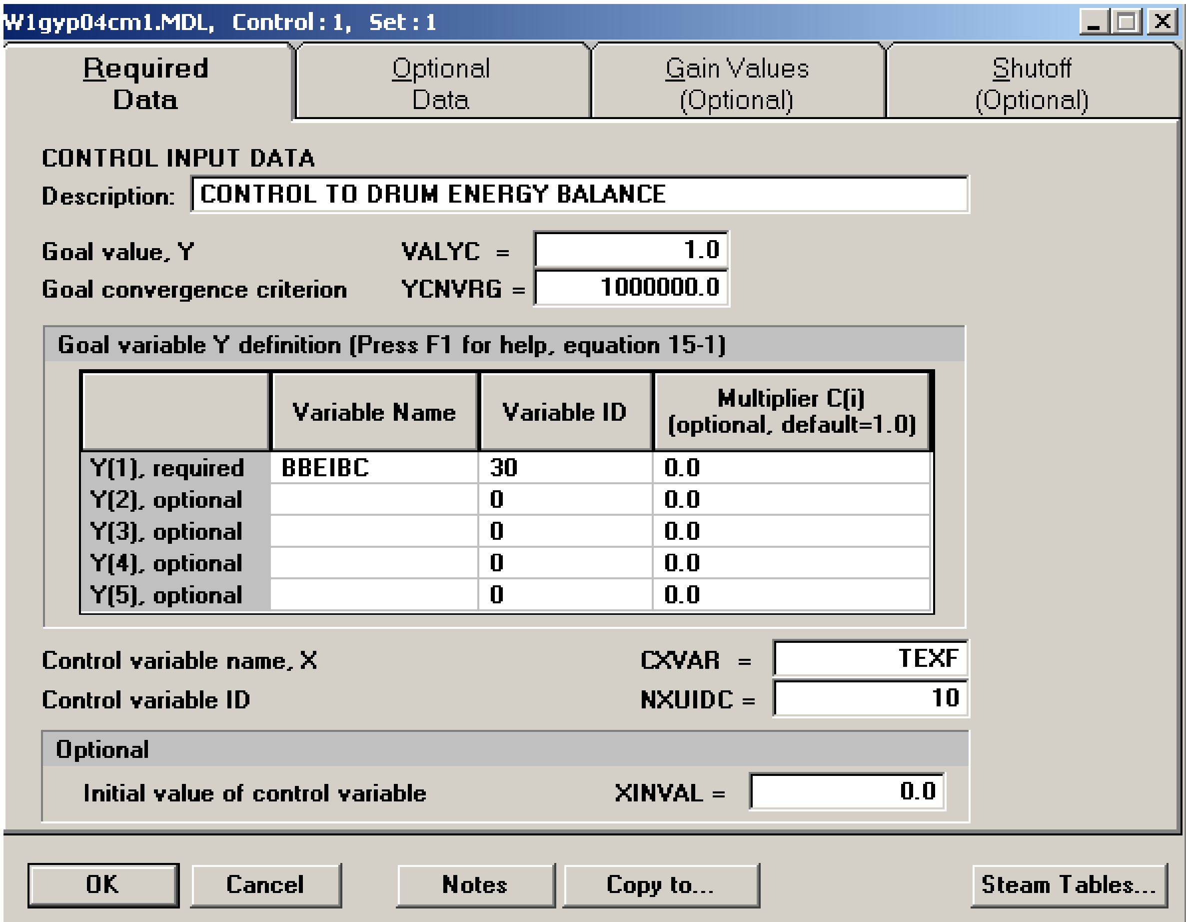
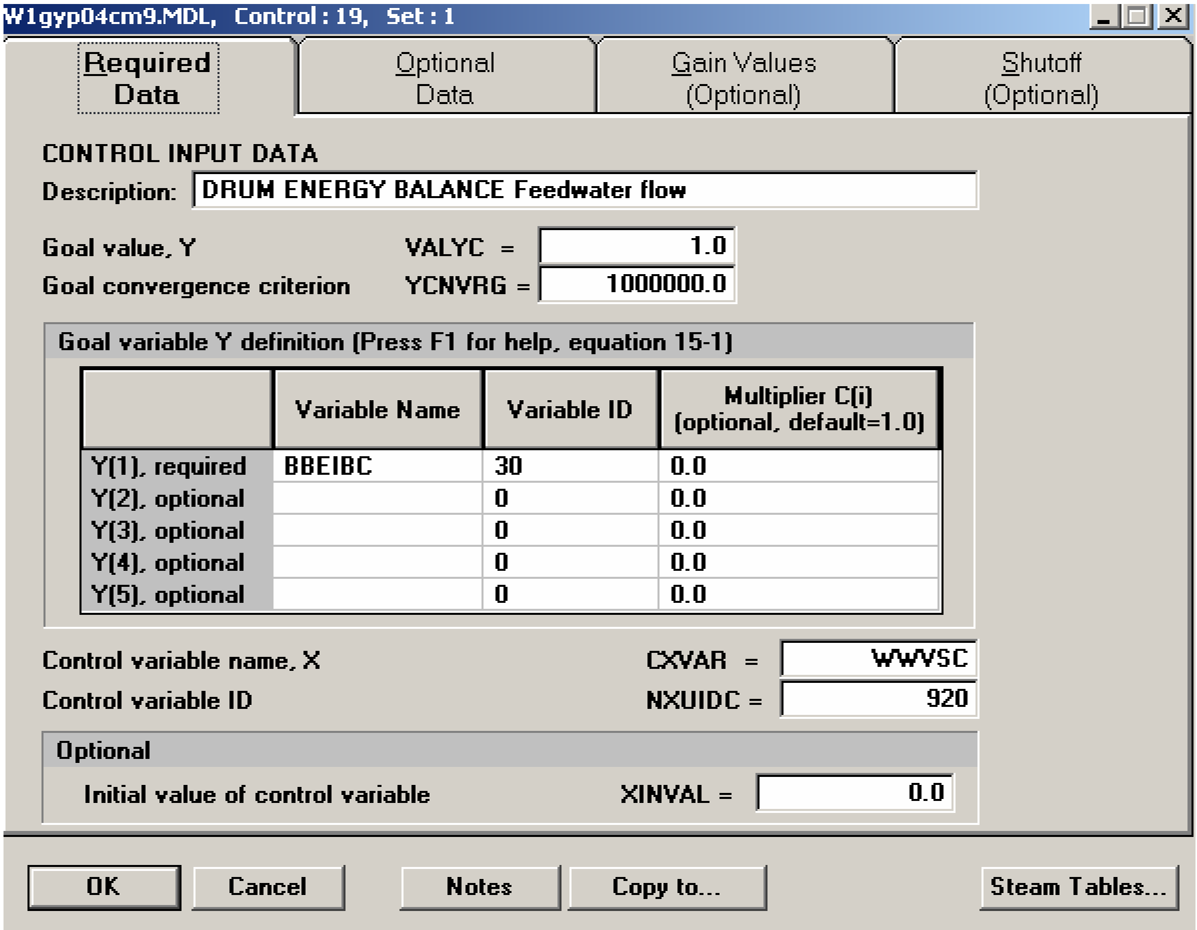


Figure 4

For the PEPSE® cases sending process steam out to the customer I used a control to balance the drum by using feedwater flow. This is because in these cases I have the fuel flow fixed at the base cases amount and this turned out to be one of the better options for insuring the model converged. Figure 5 is what this control looked like.


W1gyp04cm9.MDL, Control : 19, Set : 1
Required Data
Optional Data
Gain Values (Optional)
Shutoff (Optional)
CONTROL INPUT DATA
Description: DRUM ENERGY BALANCE Feedwater flow
Goal value, Y VALYC = 1.0
Goal convergence criterion YCNVRG = 1000000.0
Goal variable Y definition (Press F1 for help, equation 15-1)
Variable Name
Variable ID
Multiplier C(i) (optional, default=1.0)
Y(1), required BBEIBC 30 0.0
Y(2), optional 0 0.0
Y(3), optional 0 0.0
Y(4), optional 0 0.0
Y(5), optional 0 0.0
Control variable name, X CXVAR = WWVSC
Control variable ID NXUIDC = 920
Optional
Initial value of control variable XINVAL = 0.0
OK
Cancel
Notes
Copy to...
Steam Tables...
Figure 5

The two models were linked using special option 11. Note that the boiler is moving feedwater flow to balance the drum energy. To insure that this feedwater flow is transferred back to the turbine model from the boiler model you do not apply the negative sign in front of the steam flow component receiving flow from the boiler model (figure 7). In this case the component receiving the feedwater flow is component number 10. The next two figures (6 and 7) illustrate how to link the two models.

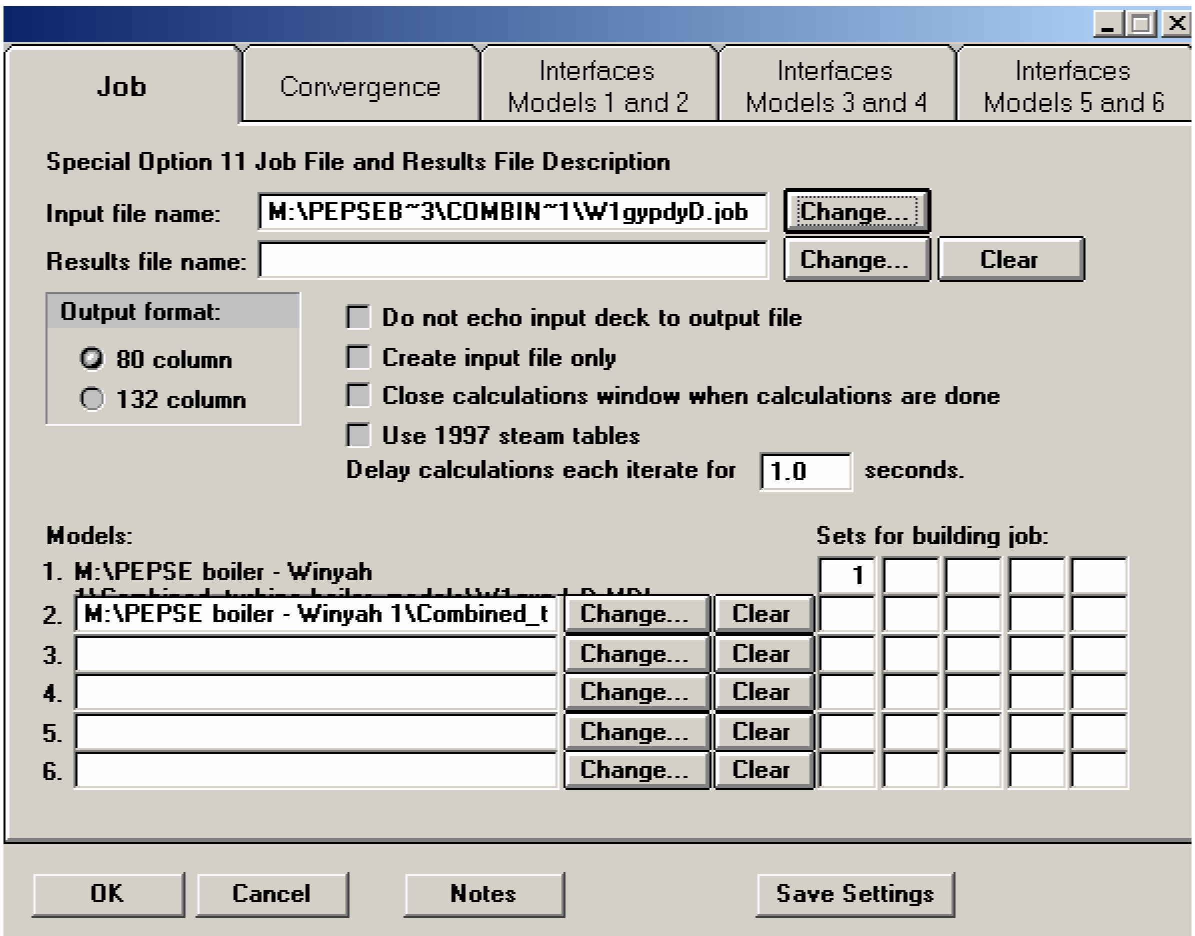


Figure 6

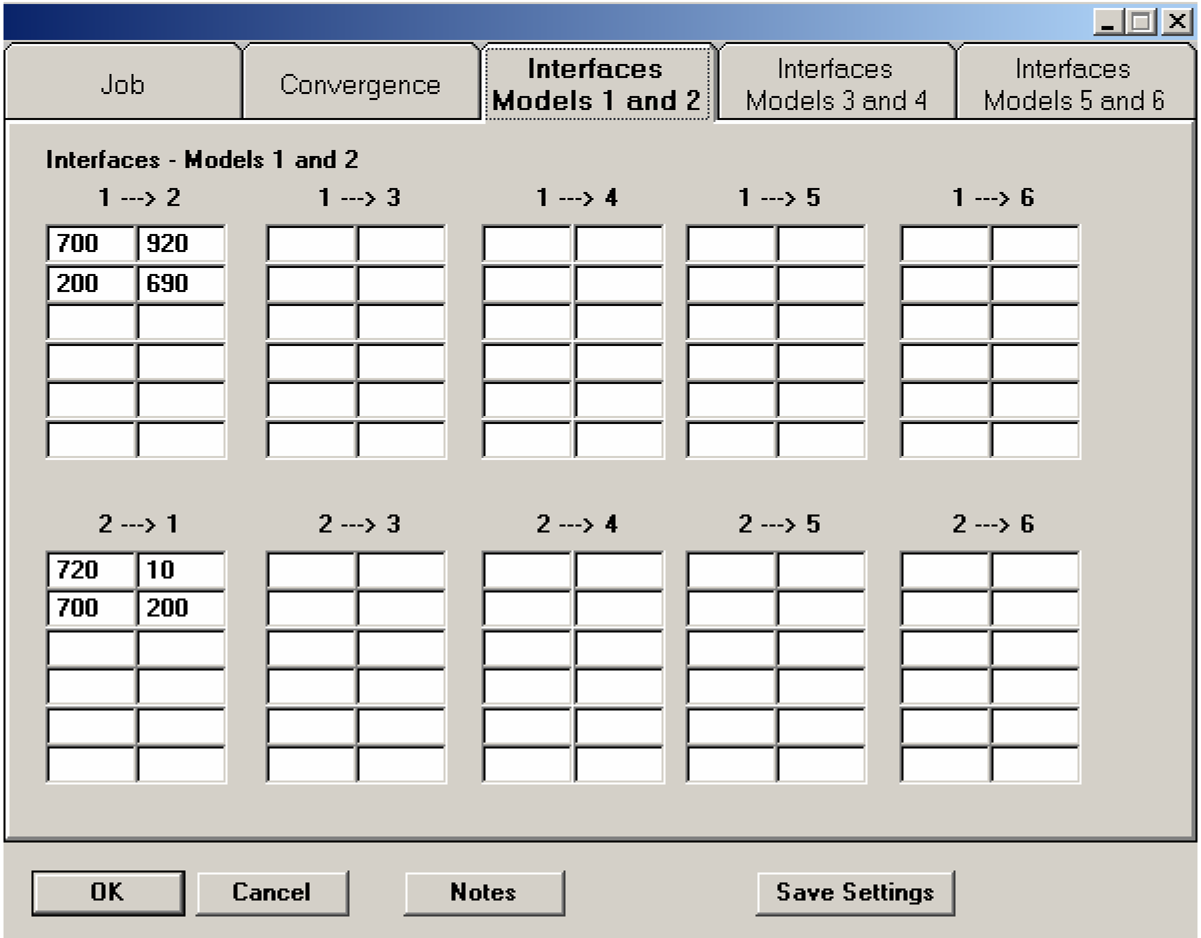


Figure 7

The Appendix has the PEPSE® schematics for the boiler and the turbine models along with some schematics with results on them for full load without and with the process steam.

Results

The results of this study are that the hot reheat temperature will improve along with smaller improvements in superheat temperature. This will happen throughout the loading range and since the process steam requirement is for a fixed amount of heat, the improvements are greater at the lower loads. This is very helpful since both superheat and reheat temperatures “fall off” in these lower load ranges. The gain in reheat temperature is between 17 ºF and 32 ºF; the superheat temperature gain is between 4 ºF and 6 ºF. The modeling results are in the tables below.

Overall Results – Table 1

Case		1A	1B	2A	2B	3A	3B	4A	4B
Fuel Flow	Lbs/hr	206,142	206,142	194,194	194,194	164,917	164,917	129,228	129,228
Process Flow	Lbs/hr	0	113,567	0	114,015	0	117,488	0	117,296
Output	MWg	319.0	308.1	299.8	288.9	249.9	239.3	190.0	179.6
Superheat Temp.	ºF	1,006.9	1,012.6	1,003.7	1,008.8	944.8	949.3	931.9	936.2
Reheat Temp.	ºF	978.2	996.3	955.4	973.2	931.4	958.1	852.1	883.6

Conclusions

Projects arise that use knowledge obtained from previous experience and older PEPSE models. As in this case, the modeling uses newly developed boiler models running them with modified turbine models that have the steam side information. In this case we are able to show that we can improve the operating temperatures of the unit by sending this steam to the process. We can also see the impacts over the expected operating range of the unit.

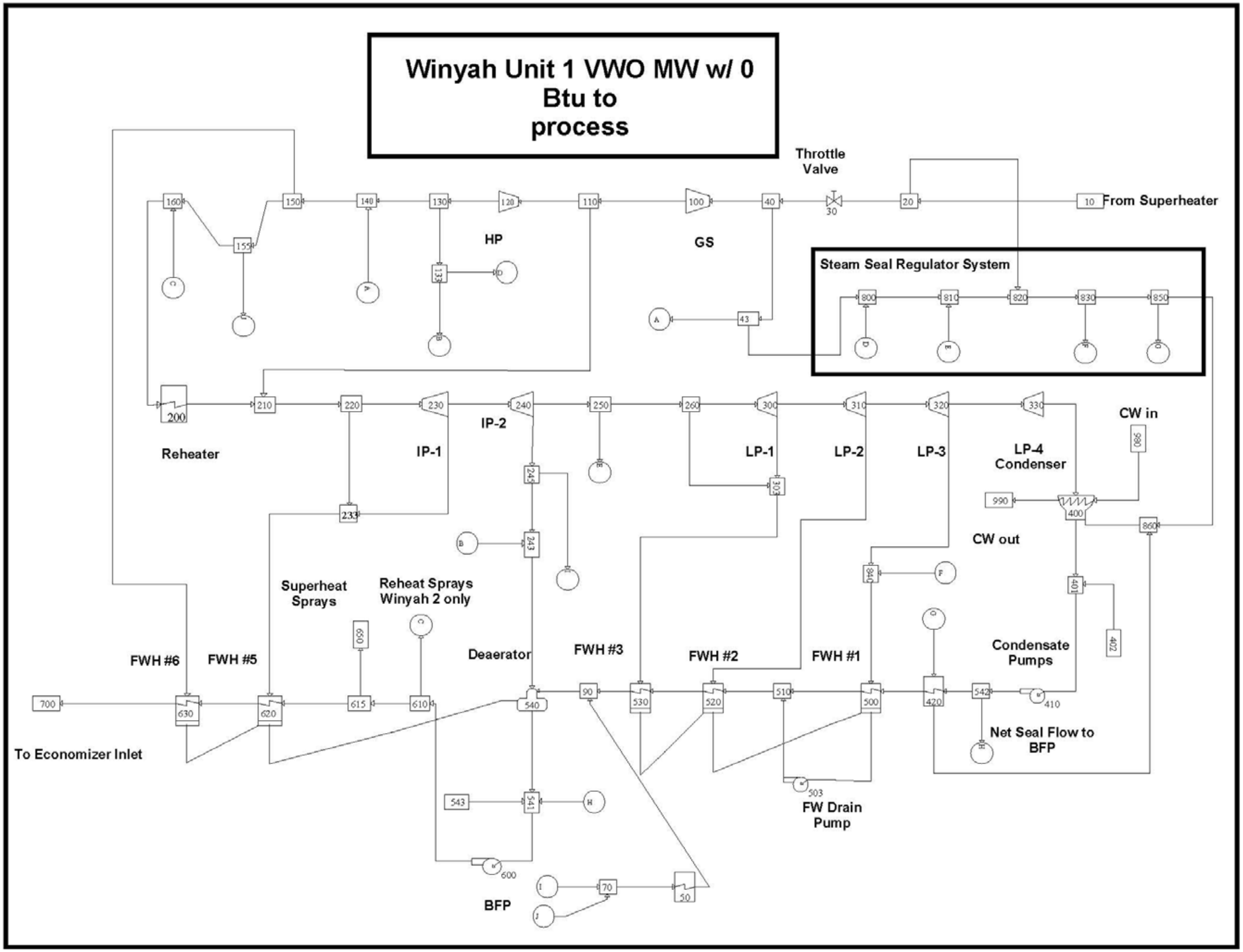
References

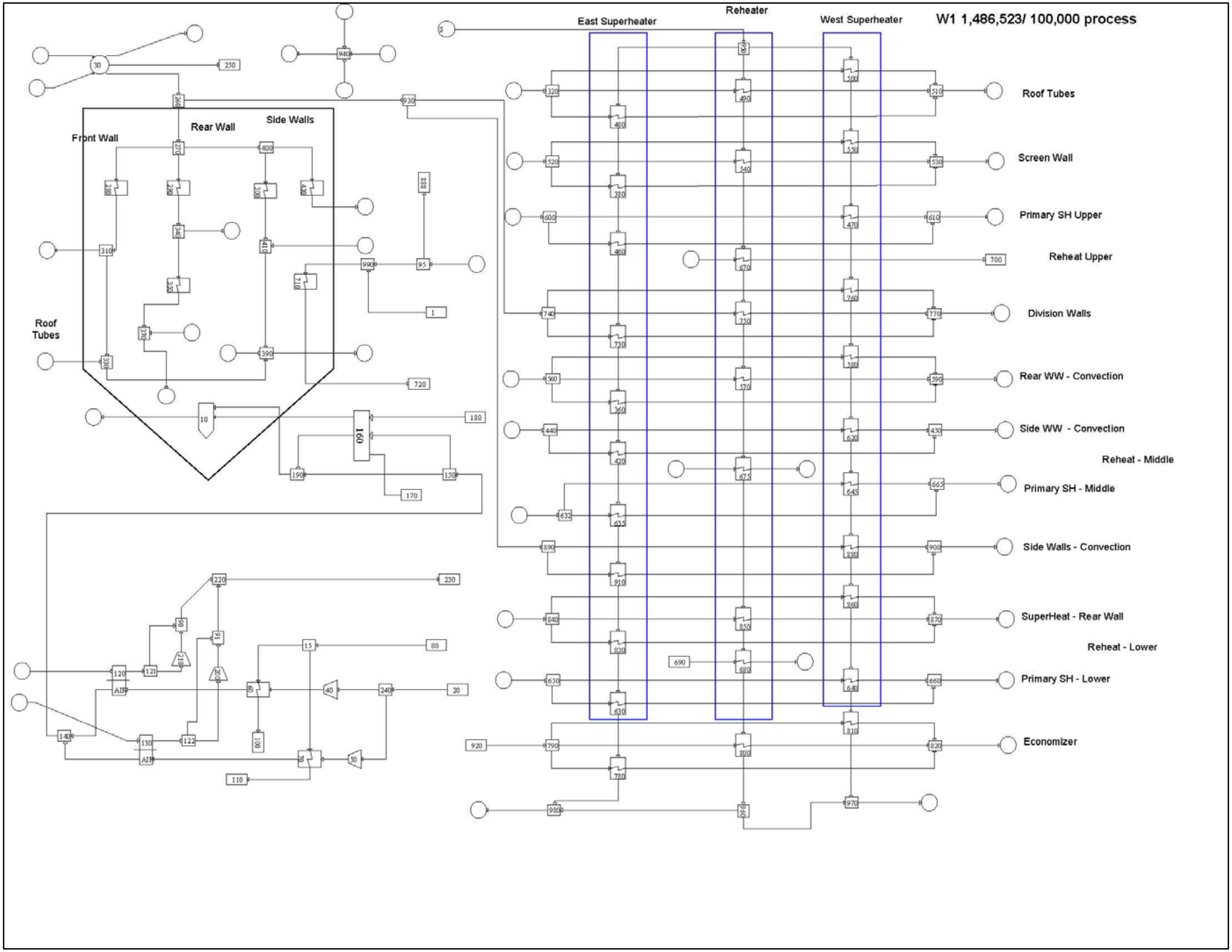
The following references were used during the course of the analysis and in preparation of this paper.

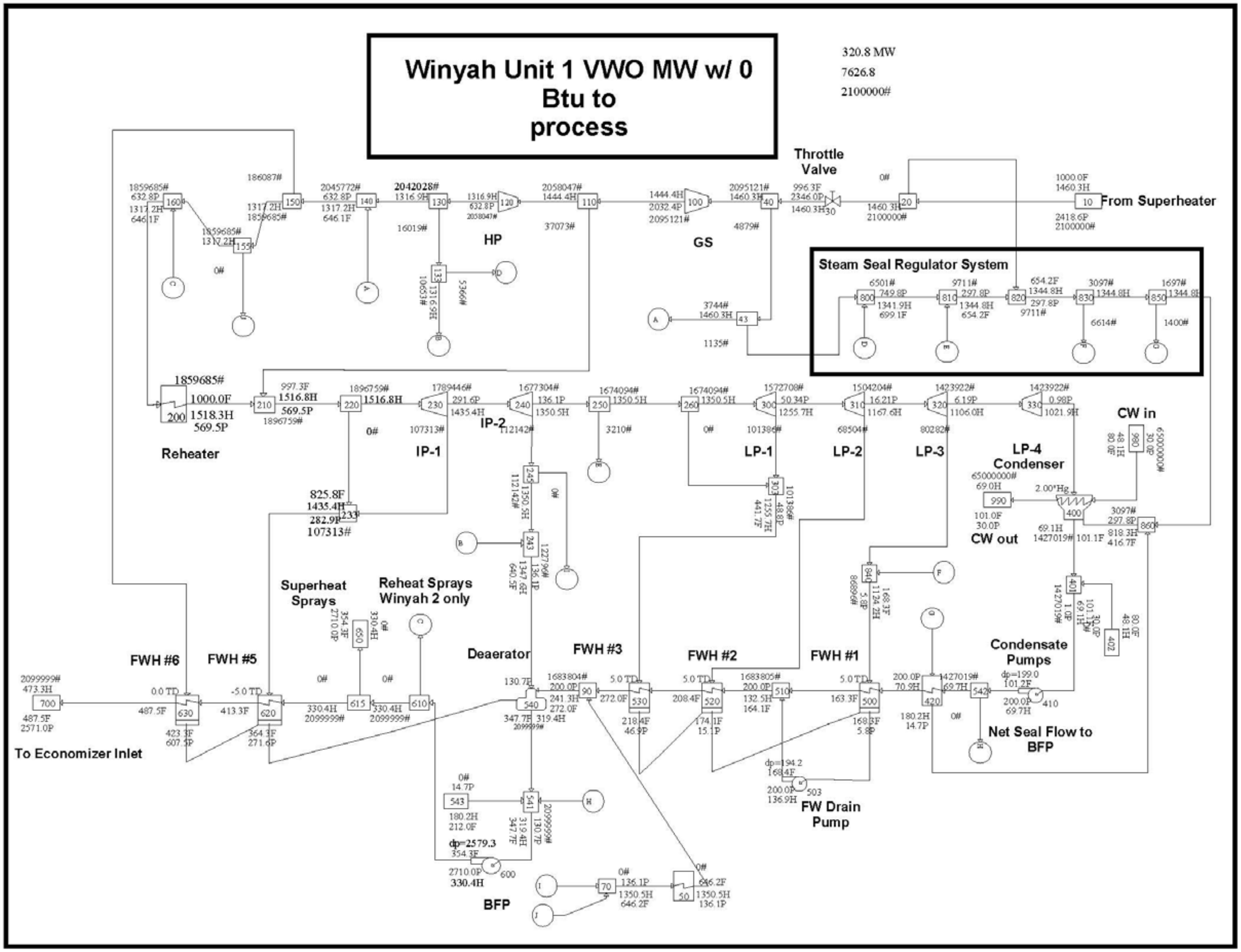
1 - PEPSE computer code, Scientech Inc, PO box 50736, Idaho Falls, Idaho, Version 62H

2 - PEPSE manual: volumes I, II, III, IV, Scientech Inc, PO box 50736, Idaho Falls, Idaho, Version 62H

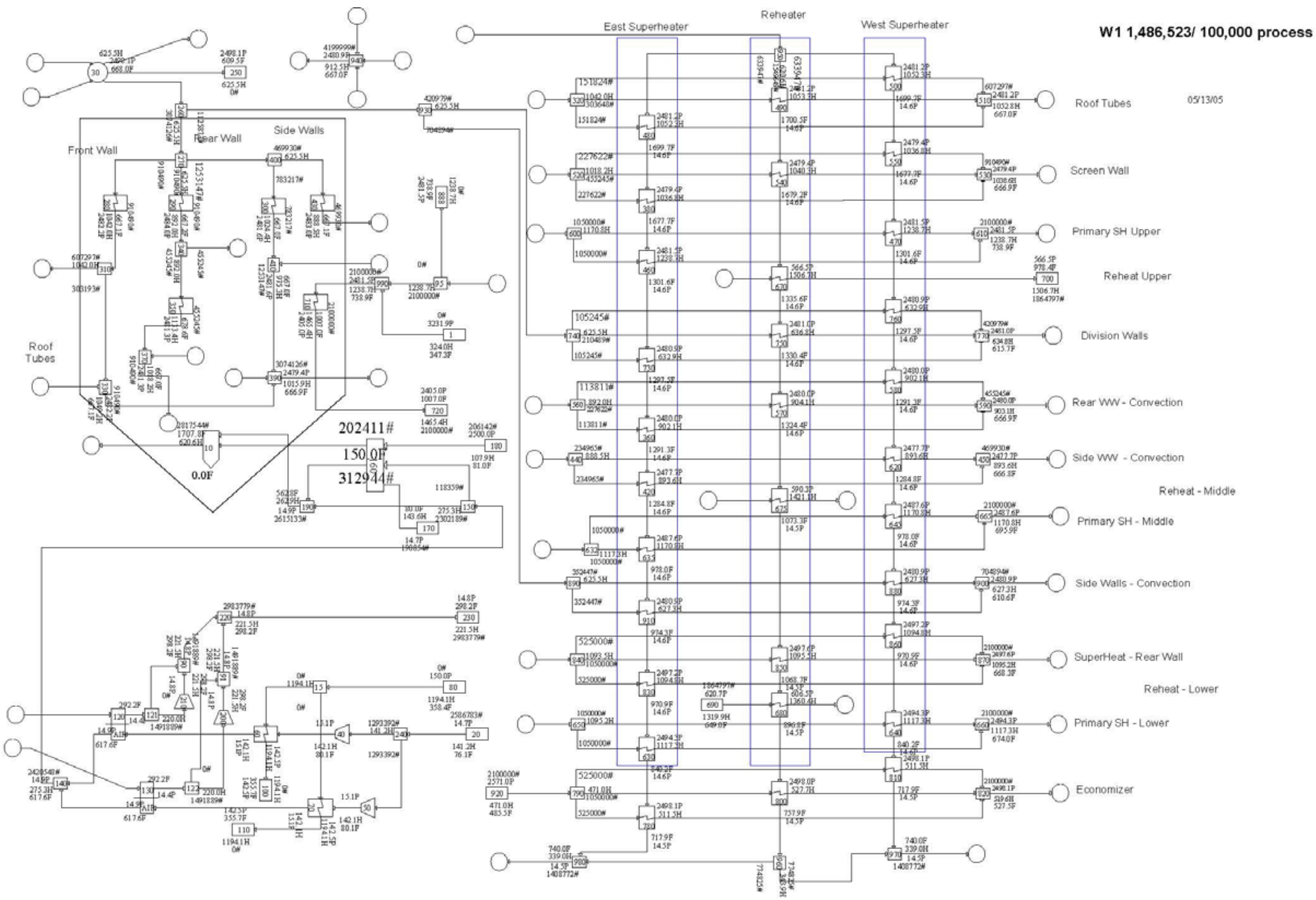
Appendix


Winyah Unit 1 VWO MW w/ 0 Btu to process
Throttle Valve
From Superheater
HP
GS
Steam Seal Regulator System
Reheater
IP-1
IP-2
LP-1
LP-2
LP-3
LP-4 Condenser
CW in
CW out
Superheat Sprays
Reheat Sprays Winyah 2 only
Deaerator
FWH #6
FWH #5
FWH #3
FWH #2
FWH #1
Condensate Pumps
Net Seal Flow to BFP
To Economizer Inlet
FW Drain Pump
BFP

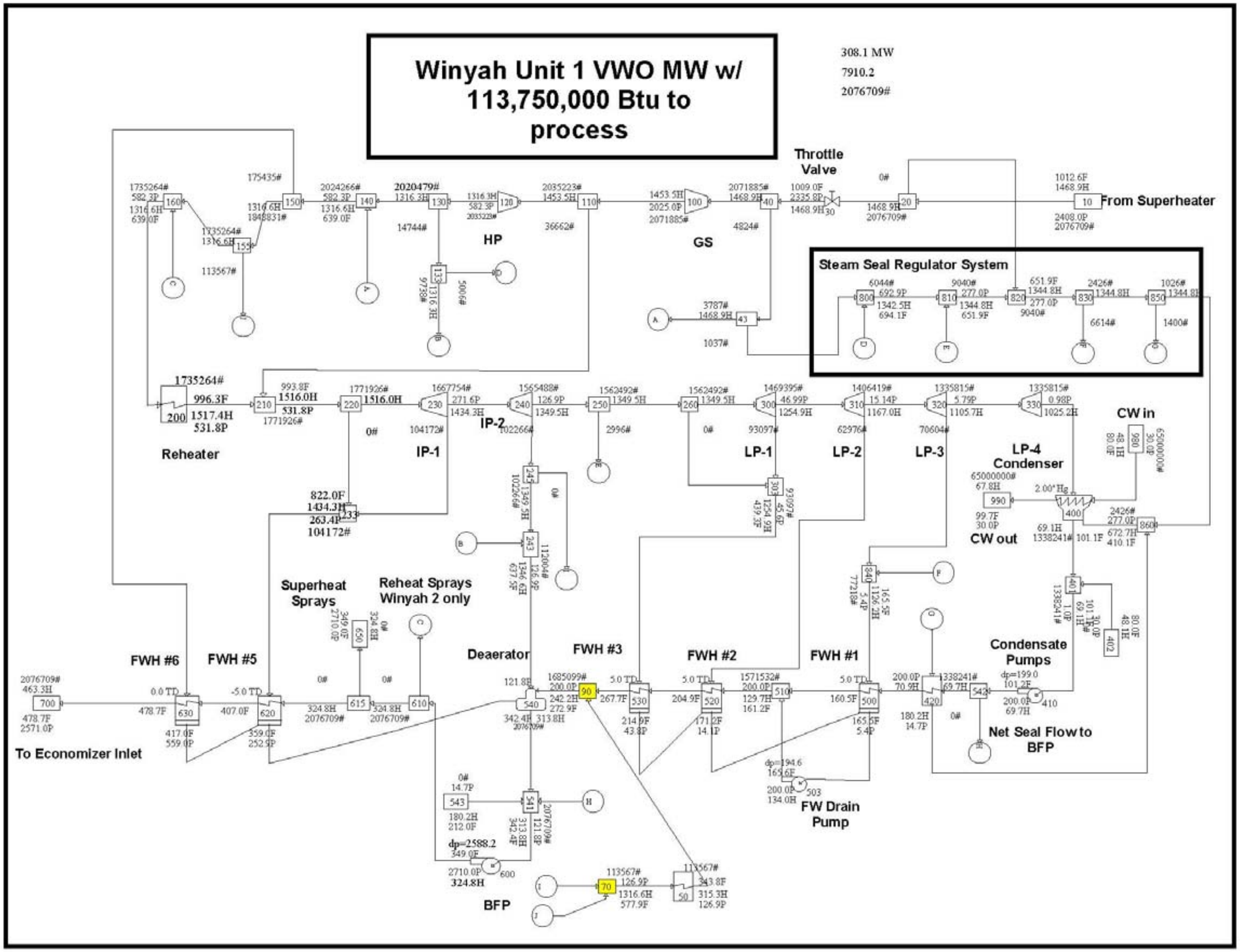

W1 1,486,523/ 100,000 process
East Superheater
Reheater
West Superheater
Roof Tubes
Screen Wall
Primary SH Upper
Reheat Upper
Division Walls
Rear WW - Convection
Side WW - Convection
Reheat - Middle
Primary SH - Middle
Side Walls - Convection
SuperHeat - Rear Wall
Reheat - Lower
Primary SH - Lower
Economizer
Front Wall
Rear Wall
Side Walls
Roof
Tubes



Winyah Unit 1 VWO MW w/ 0 Btu to process
320.8 MW
7626.8
2100000#
Throttle Valve
From Superheater
HP
GS
Steam Seal Regulator System
Reheater
IP-1
IP-2
LP-1
LP-2
LP-3
LP-4 Condenser
CW in
CW out
Superheat Sprays
Reheat Sprays Winyah 2 only
Deaerator
FWH #6
FWH #5
FWH #3
FWH #2
FWH #1
Condensate Pumps
Net Seal Flow to BFP
FW Drain Pump
BFP
To Economizer Inlet

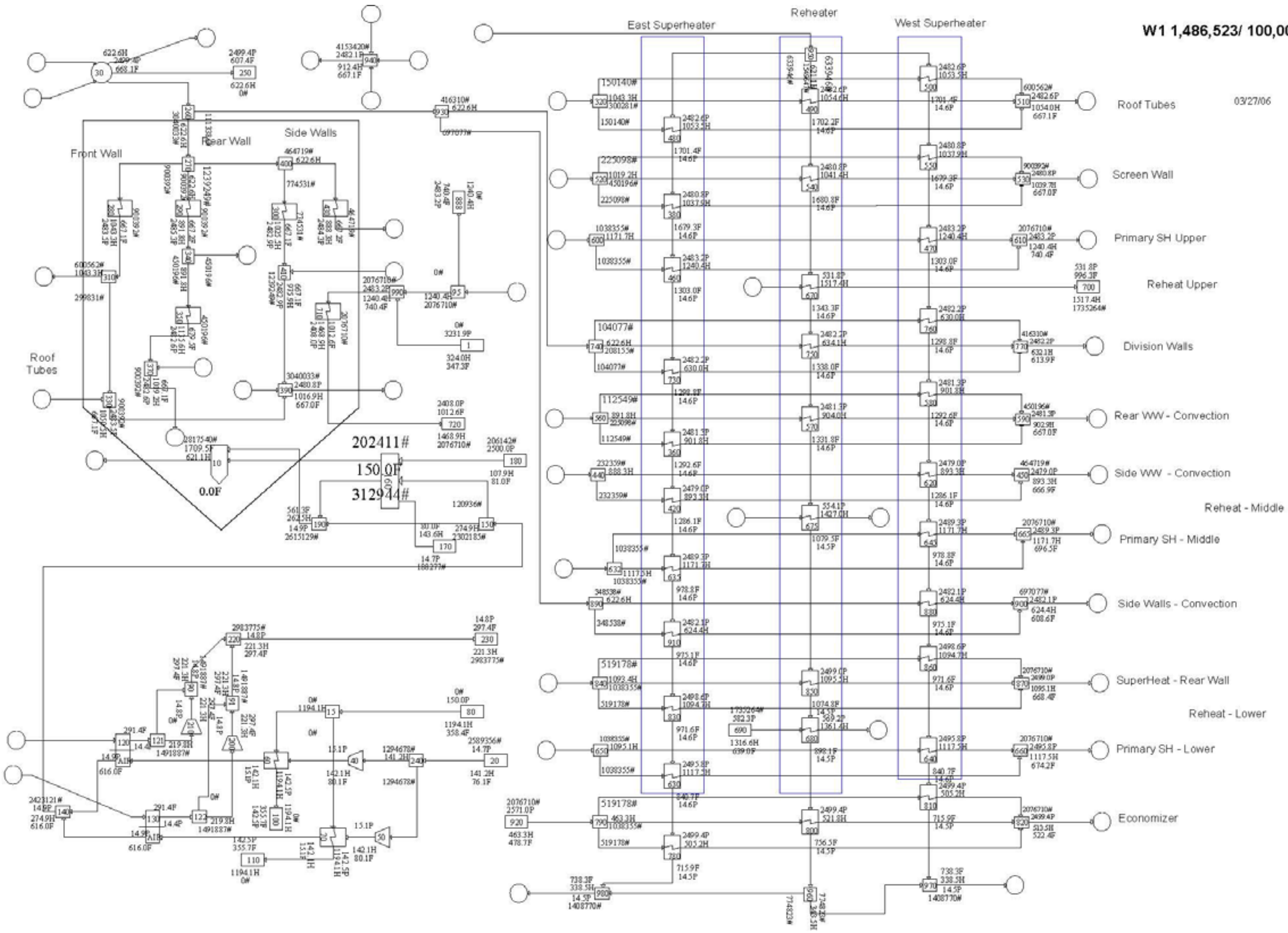


W1 1,486,523/ 100,000 process
05/13/05
East Superheater
Reheater
West Superheater
Front Wall
Rear Wall
Side Walls
Roof Tubes
Roof Tubes
Screen Wall
Primary SH Upper
Reheat Upper
Division Walls
Rear WW - Convection
Side WW - Convection
Reheat - Middle
Primary SH - Middle
Side Walls - Convection
SuperHeat - Rear Wall
Reheat - Lower
Primary SH - Lower
Economizer
202411#
150.0F
312944#
0.0F

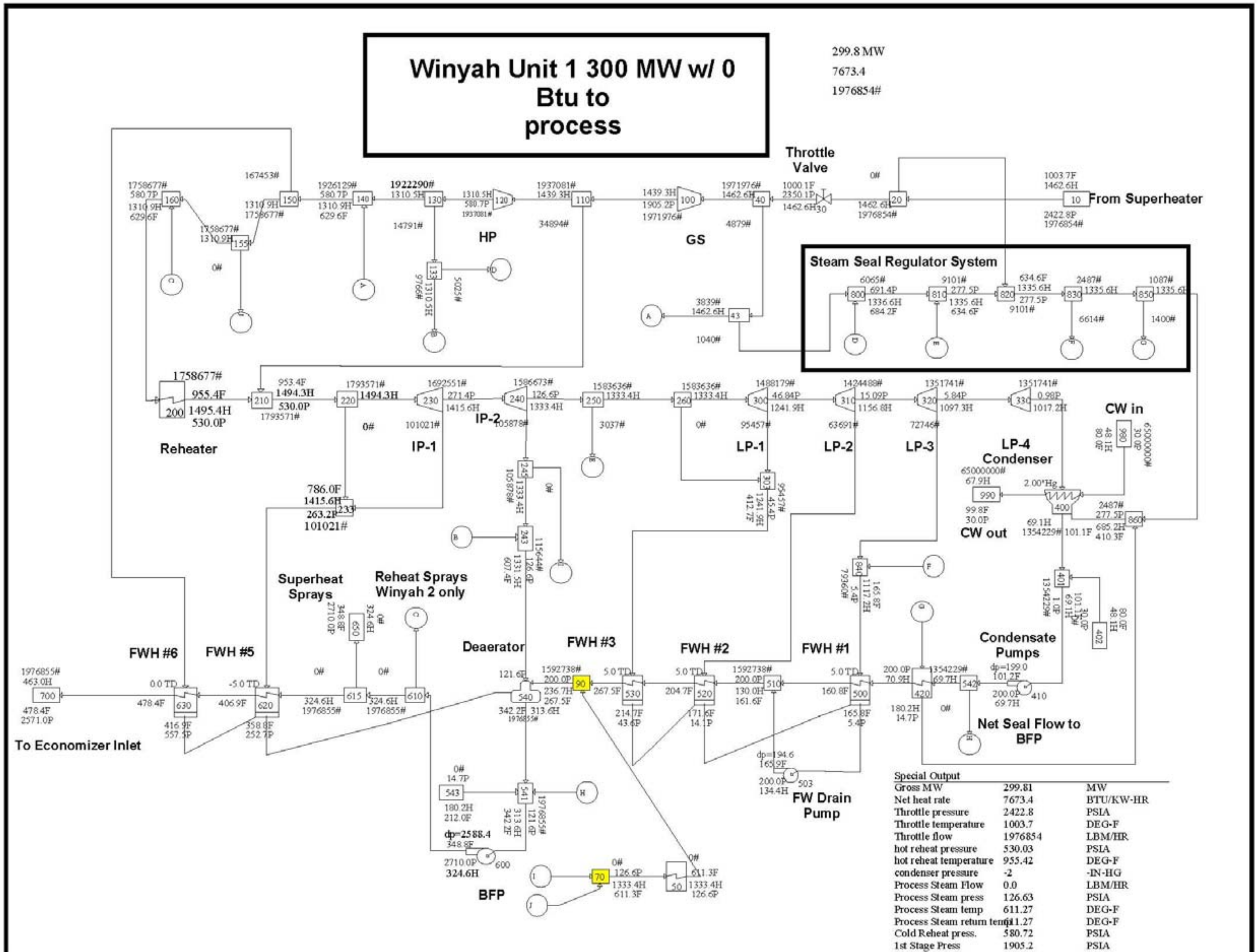

Winyah Unit 1 VWO MW w/ 113,750,000 Btu to process
308.1 MW
7910.2
2076709#
Throttle Valve
From Superheater
HP
GS
Steam Seal Regulator System
Reheater
IP-1
IP-2
LP-1
LP-2
LP-3
LP-4 Condenser
CW in
CW out
Superheat Sprays
Reheat Sprays Winyah 2 only
Deaerator
FWH #6
FWH #5
FWH #3
FWH #2
FWH #1
Condensate Pumps
Net Seal Flow to BFP
FW Drain Pump
BFP
To Economizer Inlet

W1 1,486,523/ 100,000 process

03/27/06



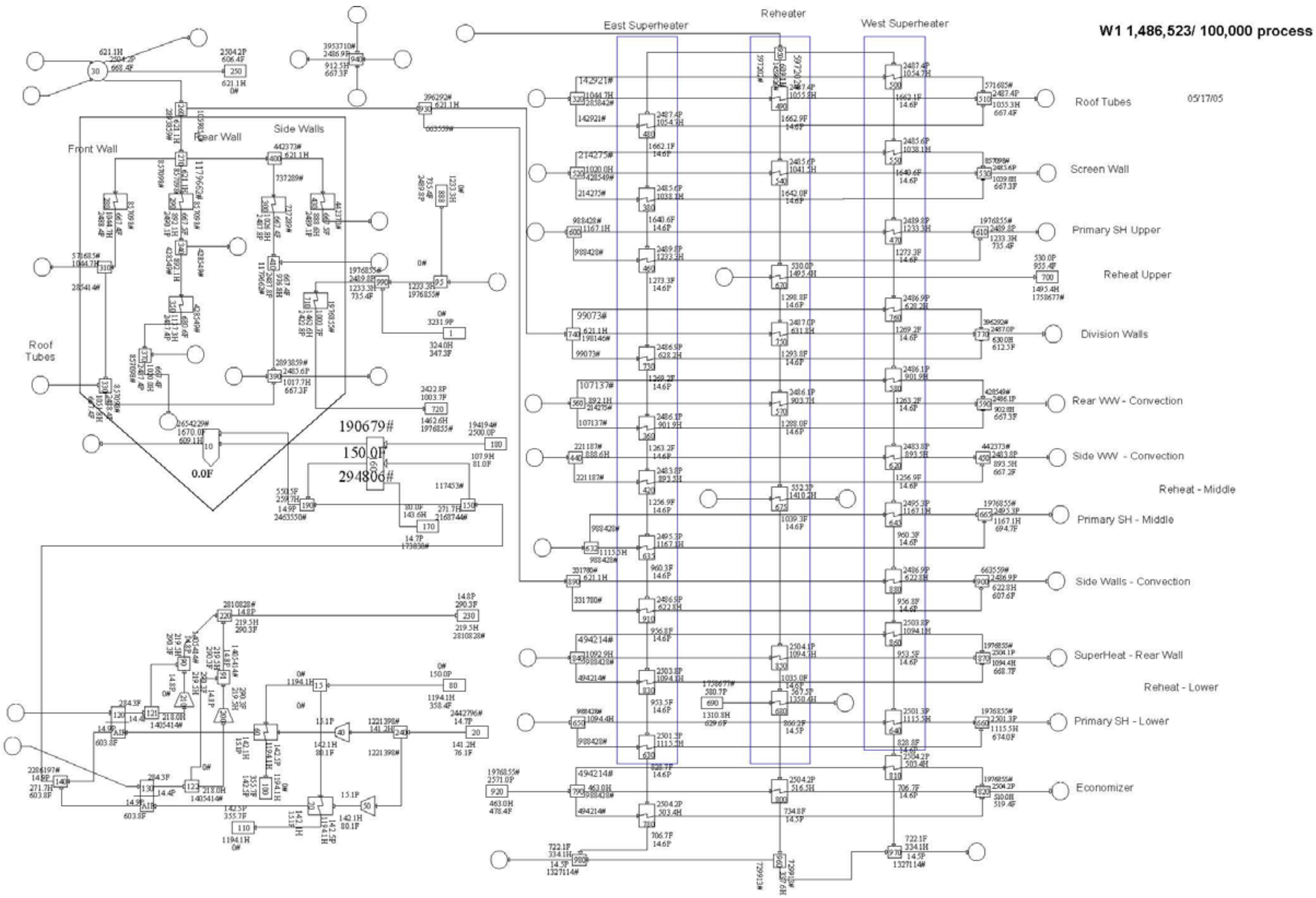
Winyah Unit 1 300 MW w/ 0 Btu to process

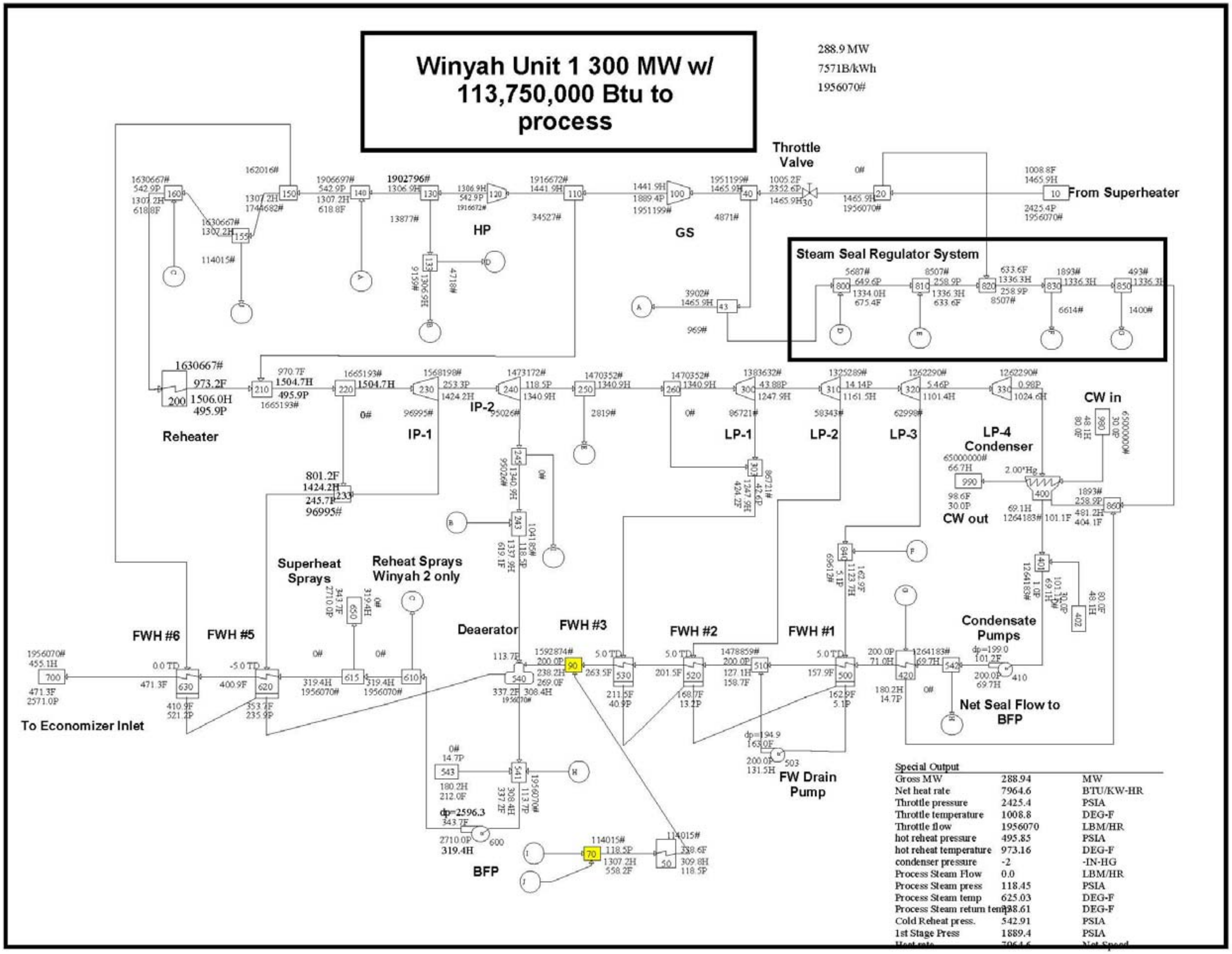


Special Output

Gross MW	299.81	MW
Net heat rate	7673.4	BTU/KW-HR
Throttle pressure	2422.8	PSIA
Throttle temperature	1003.7	DEG-F
Throttle flow	1976854	LBM/HR
hot reheat pressure	530.03	PSIA
hot reheat temperature	955.42	DEG-F
condenser pressure	-2	-IN-HG
Process Steam Flow	0.0	LBM/HR
Process Steam press	126.63	PSIA
Process Steam temp	611.27	DEG-F
Process Steam return temp	611.27	DEG-F
Cold Reheat press.	580.72	PSIA
1st Stage Press	1905.2	PSIA

W1 1,486,523/ 100,000 process

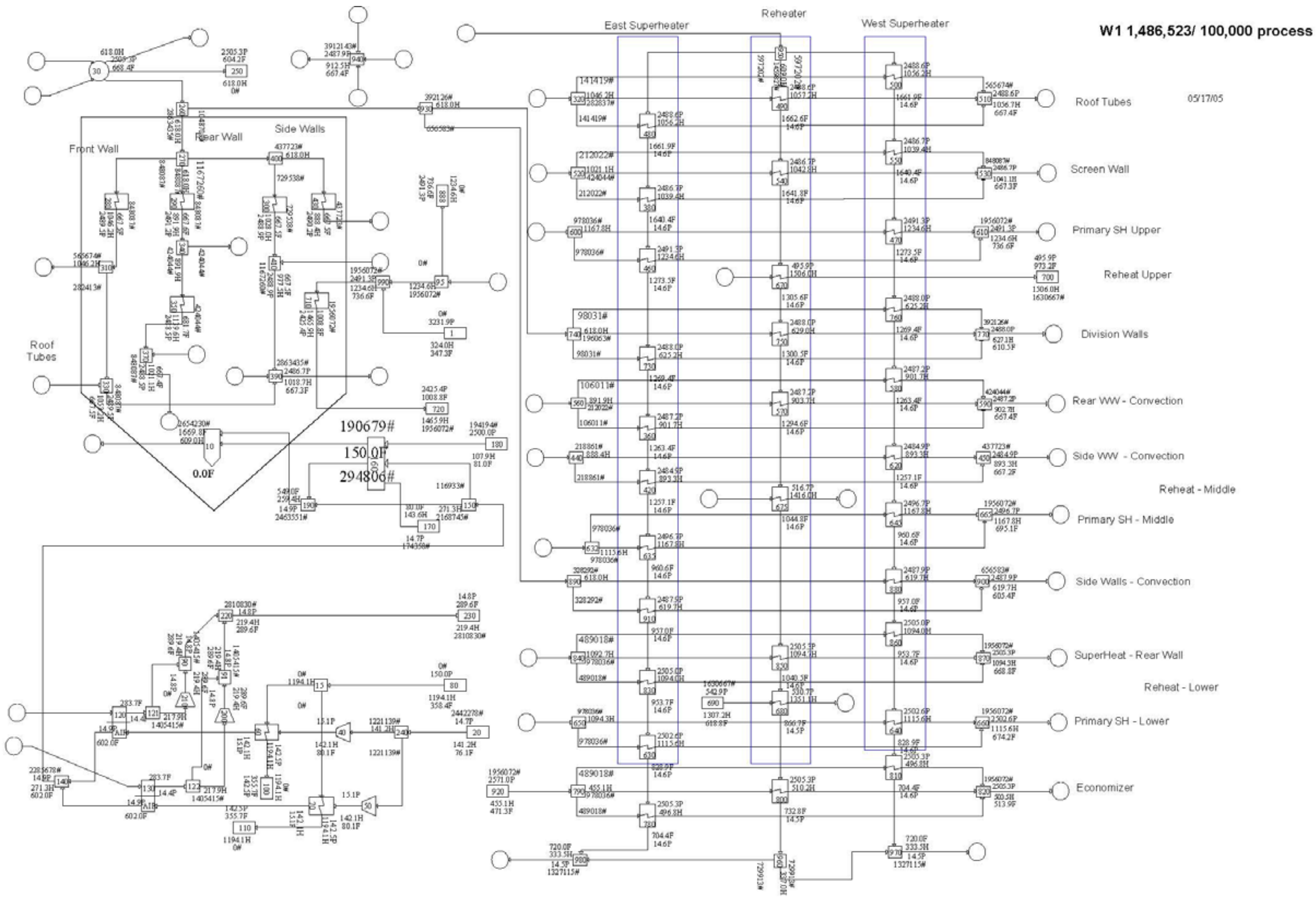


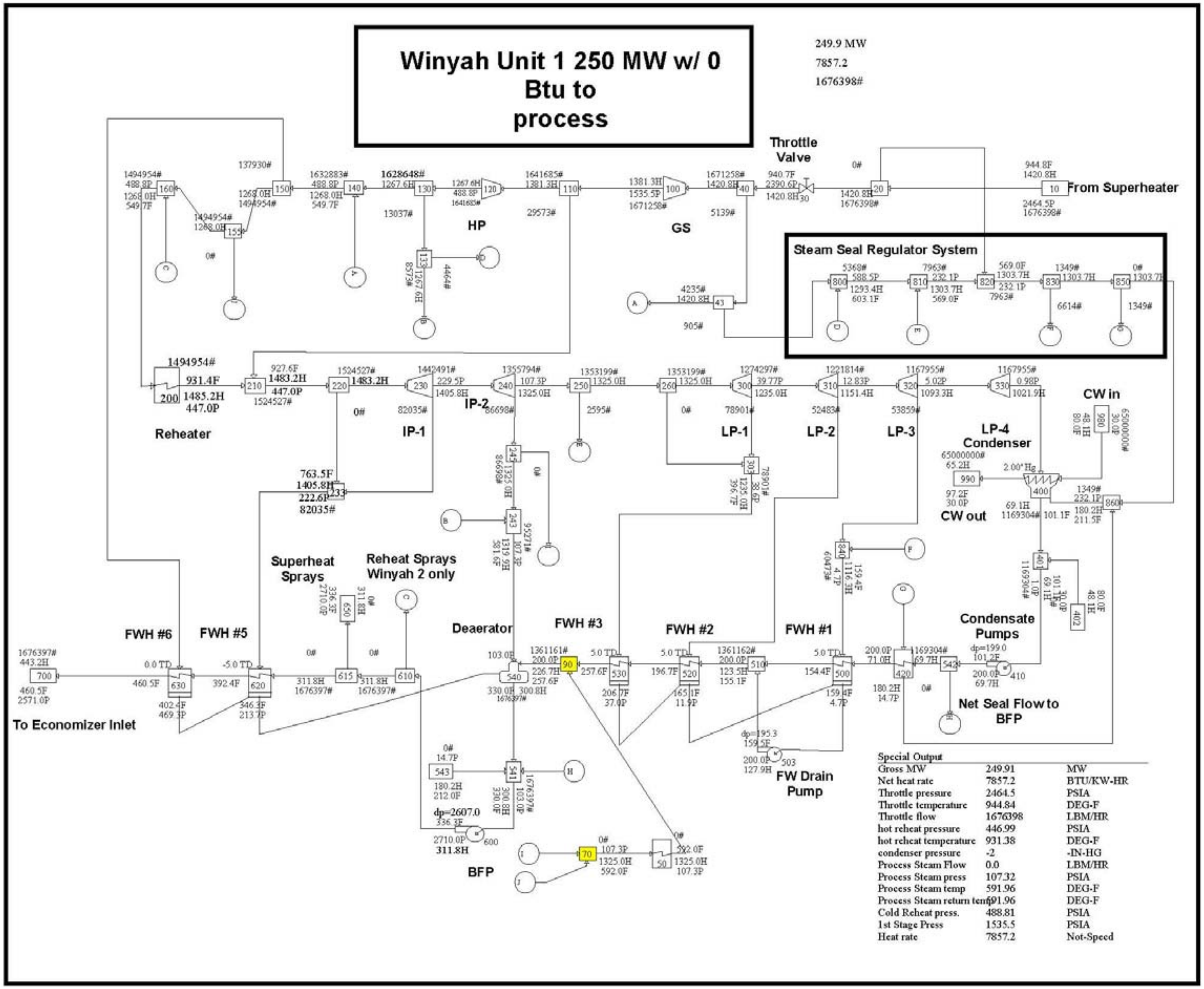


Special Output

Gross MW	288.94	MW
Net heat rate	7964.6	BTU/KW-HR
Throttle pressure	2425.4	PSIA
Throttle temperature	1008.8	DEG-F
Throttle flow	1956070	LBM/HR
hot reheat pressure	495.85	PSIA
hot reheat temperature	973.16	DEG-F
condenser pressure	-2	-IN-HG
Process Steam Flow	0.0	LBM/HR
Process Steam press	118.45	PSIA
Process Steam temp	625.03	DEG-F
Process Steam return temp	[illegible]38.61	DEG-F
Cold Reheat press.	542.91	PSIA
1st Stage Press	1889.4	PSIA

W1 1,486,523/ 100,000 process

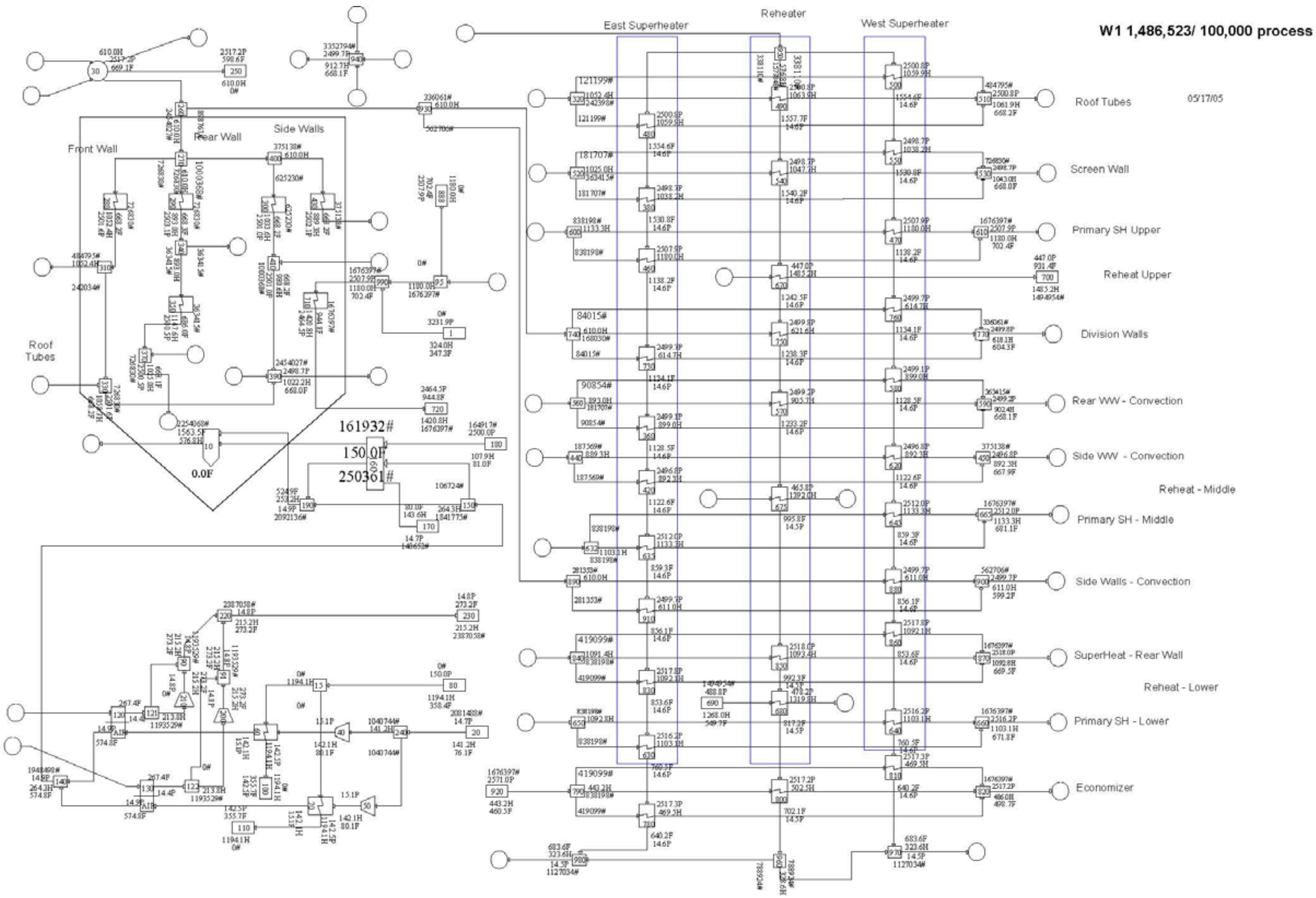


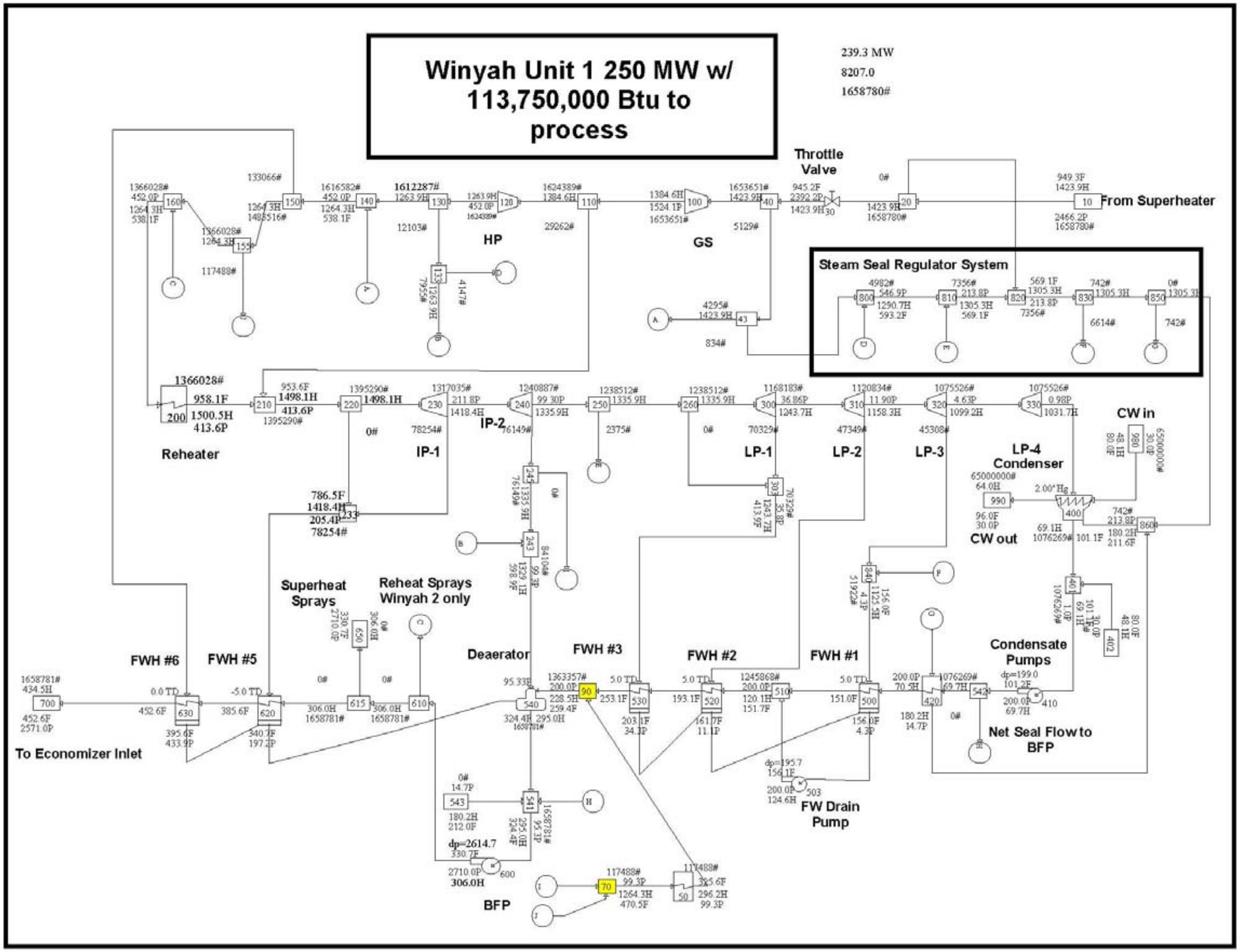


Special Output

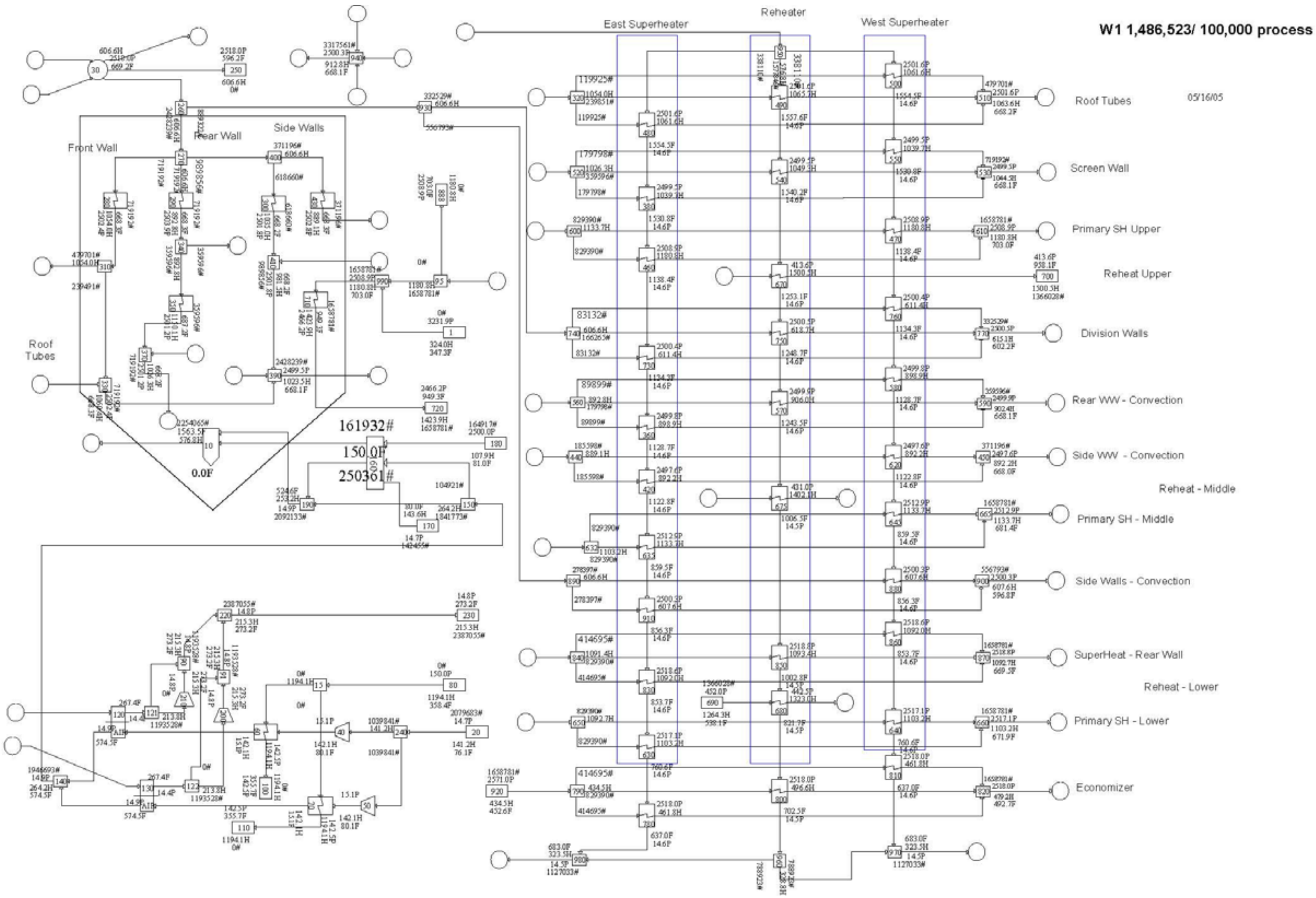
Gross MW	249.91	MW
Net heat rate	7857.2	BTU/KW-HR
Throttle pressure	2464.5	PSIA
Throttle temperature	944.84	DEG-F
Throttle flow	1676398	LBM/HR
hot reheat pressure	446.99	PSIA
hot reheat temperature	931.38	DEG-F
condenser pressure	-2	-IN-HG
Process Steam Flow	0.0	LBM/HR
Process Steam press	107.32	PSIA
Process Steam temp	591.96	DEG-F
Process Steam return temp	591.96	DEG-F
Cold Reheat press.	488.81	PSIA
1st Stage Press	1535.5	PSIA
Heat rate	7857.2	Not-Speed

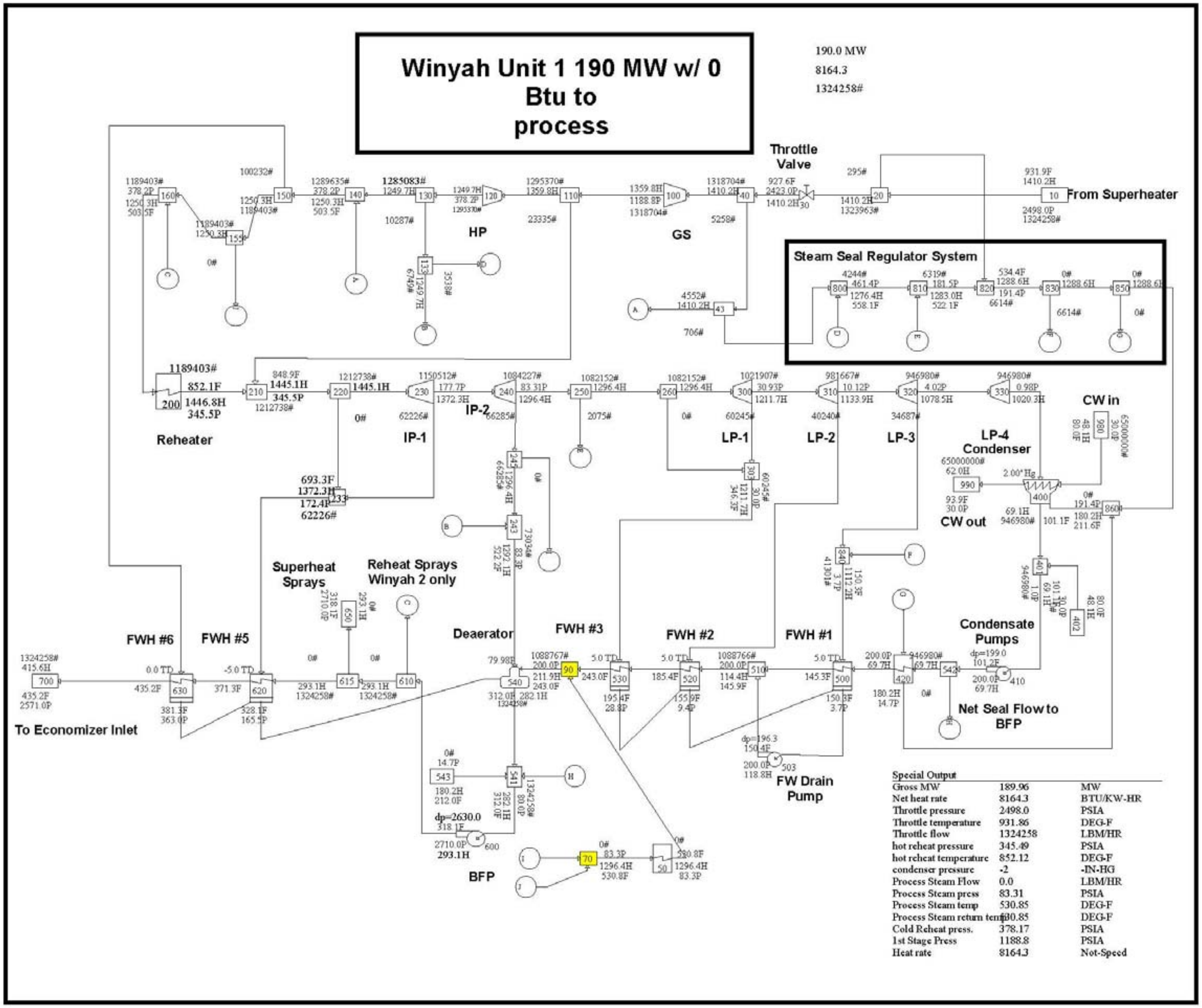
W1 1,486,523/ 100,000 process



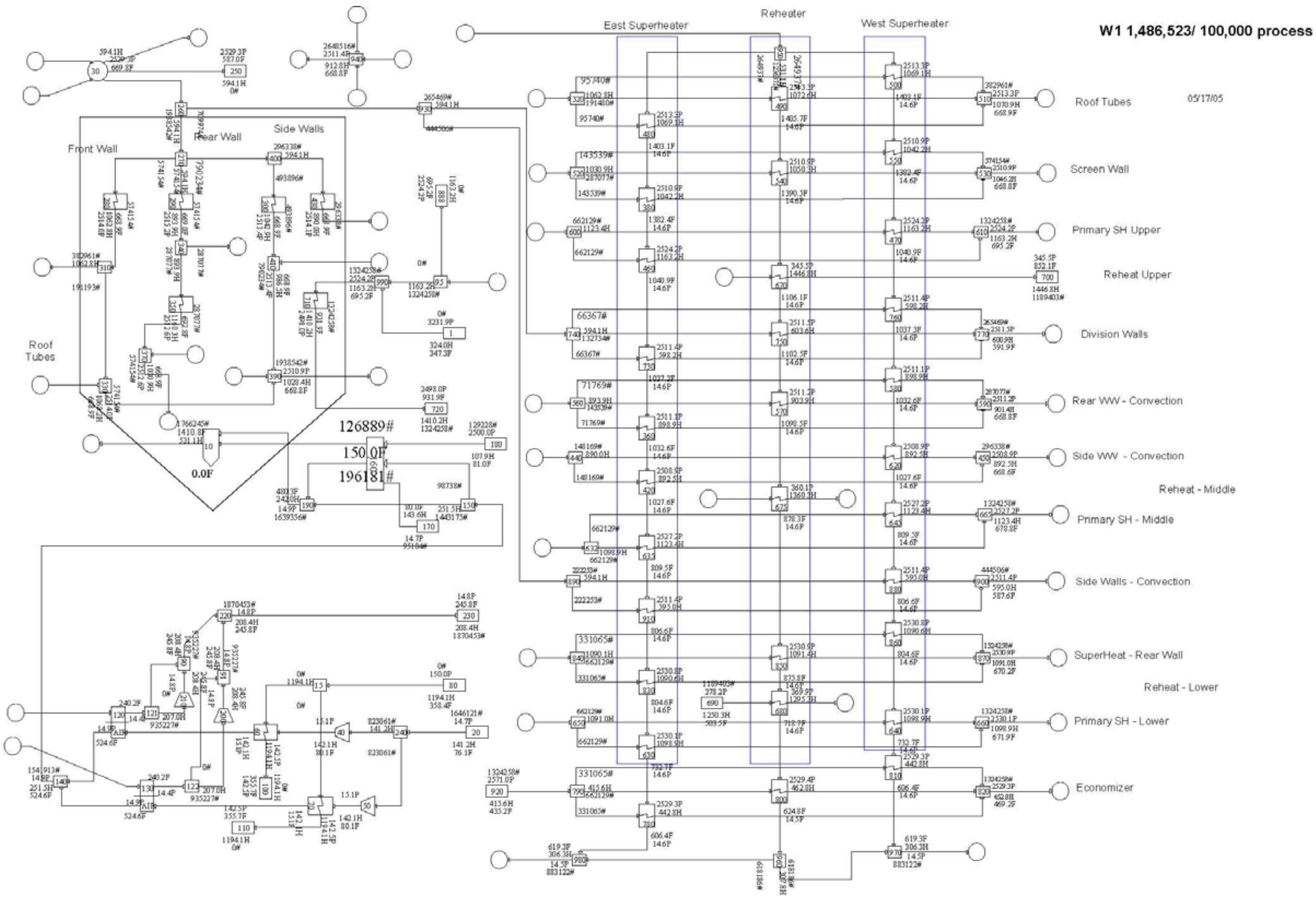

Winyah Unit 1 250 MW w/ 113,750,000 Btu to process
239.3 MW
8207.0
1658780#
Throttle Valve
From Superheater
HP
GS
Steam Seal Regulator System
Reheater
IP-1
IP-2
LP-1
LP-2
LP-3
LP-4 Condenser
CW in
CW out
Superheat Sprays
Reheat Sprays Winyah 2 only
Deaerator
FWH #6
FWH #5
FWH #3
FWH #2
FWH #1
Condensate Pumps
Net Seal Flow to BFP
FW Drain Pump
BFP
To Economizer Inlet

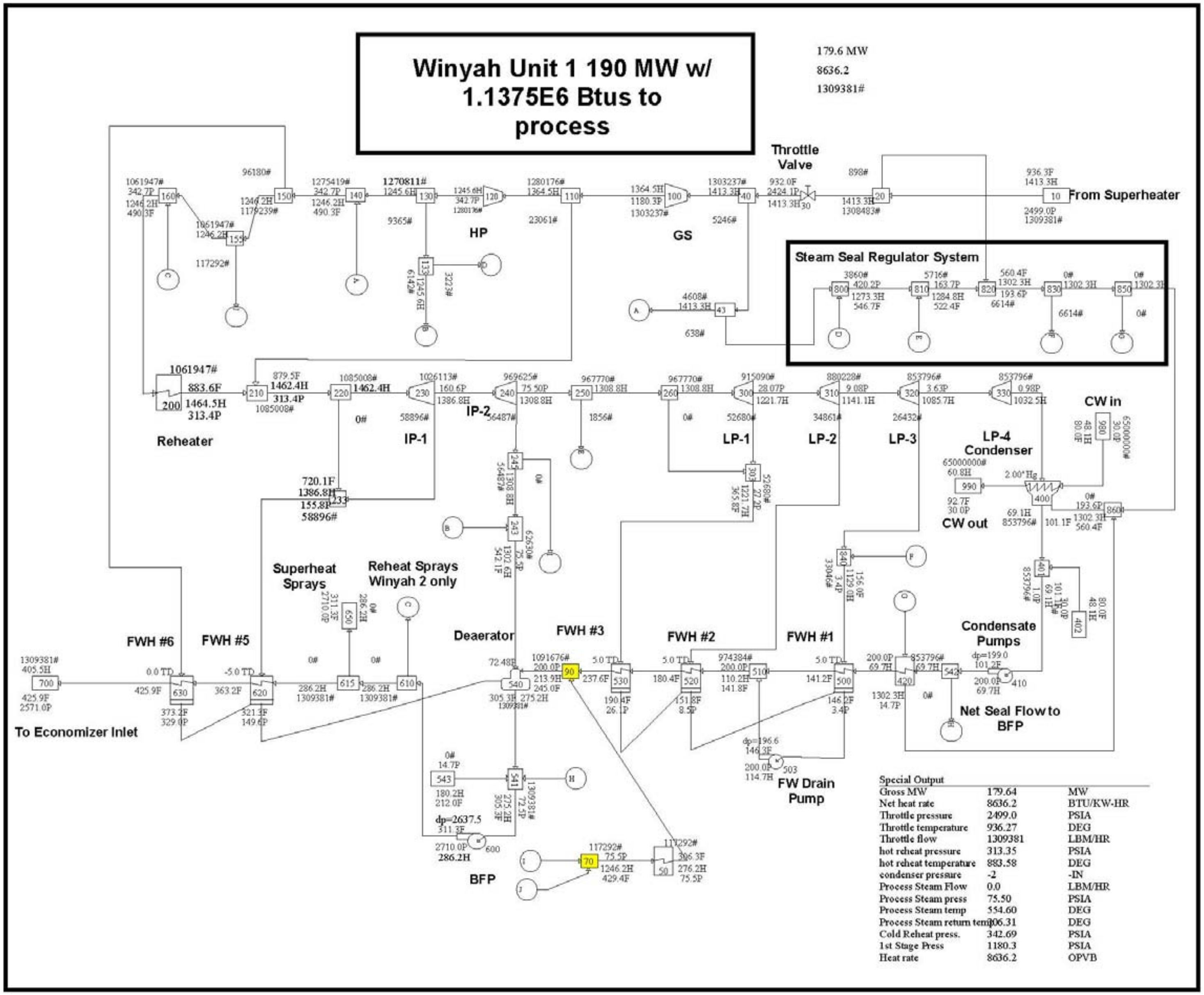
W1 1,486,523/ 100,000 process





Special Output		
Gross MW	189.96	MW
Net heat rate	8164.3	BTU/KW-HR
Throttle pressure	2498.0	PSIA
Throttle temperature	931.86	DEG-F
Throttle flow	1324258	LBM/HR
hot reheat pressure	345.49	PSIA
hot reheat temperature	852.12	DEG-F
condenser pressure	-2	-IN-HG
Process Steam Flow	0.0	LBM/HR
Process Steam press	83.31	PSIA
Process Steam temp	530.85	DEG-F
Process Steam return temp	[illegible]30.85	DEG-F
Cold Reheat press.	378.17	PSIA
1st Stage Press	1188.8	PSIA
Heat rate	8164.3	Not-Speed


W1 1,486,523/ 100,000 process
05/17/05
East Superheater
Reheater
West Superheater
Front Wall
Rear Wall
Side Walls
Roof Tubes
Roof Tubes
Screen Wall
Primary SH Upper
Reheat Upper
Division Walls
Rear WW - Convection
Side WW - Convection
Reheat - Middle
Primary SH - Middle
Side Walls - Convection
SuperHeat - Rear Wall
Reheat - Lower
Primary SH - Lower
Economizer
126889#
150.0F
196181#
0.0F



Winyah Unit 1 190 MW w/ 1.1375E6 Btus to process
179.6 MW
8636.2
1309381#
Throttle Valve
From Superheater
HP
GS
Steam Seal Regulator System
Reheater
IP-1
IP-2
LP-1
LP-2
LP-3
LP-4 Condenser
CW in
CW out
Superheat Sprays
Reheat Sprays Winyah 2 only
Deaerator
FWH #6
FWH #5
FWH #3
FWH #2
FWH #1
Condensate Pumps
Net Seal Flow to BFP
FW Drain Pump
BFP
To Economizer Inlet
Special Output
Gross MW 179.64 MW
Net heat rate 8636.2 BTU/KW-HR
Throttle pressure 2499.0 PSIA
Throttle temperature 936.27 DEG
Throttle flow 1309381 LBM/HR
hot reheat pressure 313.35 PSIA
hot reheat temperature 883.58 DEG
condenser pressure -2 -IN
Process Steam Flow 0.0 LBM/HR
Process Steam press 75.50 PSIA
Process Steam temp 554.60 DEG
Process Steam return temp 306.31 DEG
Cold Reheat press. 342.69 PSIA
1st Stage Press 1180.3 PSIA
Heat rate 8636.2 OPVB

W1 1,486,523/ 100,000 process