Sliding Pressure Study - Beebee Unit 12

Craig Litt
Rochester Gas & Electric Corporation

Sliding Pressure Study

Beebee Unit 12

Craig Litt
Station Engineer Performance
Rochester Gas and Electric Corporation

ABSTRACT

A study was done at Rochester Gas and Electric Corporation utilizing PEPSE to evaluate the heat rate benefit of sliding pressure operation on a 35 year old, 85 megawatt gross, single reheat unit. The results of this study were included in a response to a Public Service Commission concern regarding the benefit of sliding pressure operation. The PEPSE model used was the Benchmark model modified to fix the flow passing capability of the throttle valve to four valves open. The benefit was calculated to be 300 BTU/kwh. Model development, results and difficulties encountered in this analysis are discussed.

INTRODUCTION

"R.G.&E. Unit 12 is a General Electric 75000 kw machine with a tandem compound, double flow reheat turbine and a hydrogen cooled generator. Steam for the turbine is supplied by a Combustion Engineering controlled circulation, reheat type steam generator. The unit is designed for a flow of 560000 lbs/hr at 1825 psig and 1055 deg F at the superheater outlet and a reheat flow of 441000 lbs/hr at 1005 deg F. There is one constant speed and one variable speed boiler feed pump."[1]

A PEPSE turbine model was used to evaluate the benefit of variable pressure operation. The model was developed by using the original vendor heat balances and PEPSE VER53 G.E. turbine components. The model was translated to General Turbine components that matched the PEPSE output from the G.E. components. This enabled the use of Special Option 6 (Automatic Test Data Reduction). Schedules on stage efficiency and shaper "constants" were added to allow the model to reflect loads from guarantee down to 25% load. The lowest heat balance was not able to be matched as it defies thermodynamic laws. Leakoffs from the valve stem and shaft packing combine and are piped to the lowest heater extraction line. The energy stated on the heat balance suggests the heater becomes an energy source. The hotwell makeup flow was made zero.

Cases were run first with the direct drive feedpump removed

---

[1] 1 Gilbert Associates "Engineering Data For Beebee Station Unit 12" Architect Engineers

from service at throttle flows less than 69.5% guarantee flow, then second with the hydraulic coupling pump removed from service over the same load range. Schedules based on pump curves supplied with the thermal kit were included in the model to simulate sliding pump pressure.This gave a comparison of the cost/benefit of running the direct drive vs. variable speed pump. The results plotted on Figure 1 are Heat Rate vs. Mw Output with each pump out to show the effect of pump drive on turbine heat rate. There is a 200 BTU/kW savings at minimum load using the hydraulic coupling pump vs the direct drive pump. These savings resulted only from the difference in predicted pump performance as given in the thermal kit.

The next set of cases run utilized PEPSE Special Option 1 (Performance Based on Reference Conditions) to determine the flow passing capability of the throttle valve. The variable TF1RST (first admission equivalent throttle flow ratio) value on the throttle valve card was lowered to 0.1. This negated any throttling losses PEPSE would calculate at low inlet flows. Inlet pressure was reduced in 100 psi decrements to develop a Mw Output vs. Inlet Pressure curve. The results displayed in Figure 2 show two operating regimes. The continuously increasing line is the result of full sliding pressure operation. The second line is a hybrid sliding pressure operation. Since G.E. suggests a 100 psi, 100 deg F per hour ramp rate to return to design inlet conditions, operation below 800 psia would not be recommended unless the unit was on spinning reserve. This is indicated on the Benchmark vs. Sliding Pressure graph where the 'Full Sld' mode curve intersects with the 4 Valves Hybrid mode curve (Figure 4). For loads below this point, admission valves should be used.

Another set of runs was made with the First Stage Efficiency fixed to the valves wide open value. As expected, the results showed a marked decrease in Heat Rate. The shape of the curve (as shown in Figure 3) is parallel to the results of a set of runs made allowing the governing stage efficiency to vary as in the benchmark case. The savings of operating in this hybrid mode were calculated to be nearly 300 BTU/kWh. This is within the range of savings reported by New York downstate utilities in discussions following a New York Power Pool subcommittee meeting.

The methodology used to analyze sliding pressure is predicated on the assumption that the PEPSE model will accurately predict heat rates below the lowest accurate heat balance. This may not be valid because of the use of inaccurate vendor heat balances to create the benchmark models. Turbines built pre-1960 do not match the GE Procedure 20007C. The heat balances, when plotted on a Mollier diagram, do not yield parallel expansion lines as predicted. This is why shapers were used to modify the expansion lines to fit best available documentation. The heat balances available to model this turbine do not have the first stage bowl state conditions indicated. This caused the assumption of varying stage efficiency to be used in the benchmark to match valve stem leakoff enthalpy. The stage efficiency should be constant and the throttle valves should show the throttling effects. The effects of these omissions are negligible at full load, and exaggerated at low loads.

The PEPSE input deck is in Appendix A along with a schematic heat balance.

CONCLUSIONS

A hybrid mode of operation for loads below a conservative value of 30 MwG would yield a savings . The throttle pressure should not go below 800 psia. This is the value shown on the Benchmark vs. Sliding Pressure graph where the Full Arc mode curve intersects with the 4 Valves Hybrid mode curve. For loads below this point, admission valves should be used. A test of actual results could be developed to quantify savings and unit response.

SUMMARY

A series of PEPSE cases were run to evaluate the benefits of sliding pressure operation on an 85 MwG G.E. turbine. Modeling techniques used included the use of Special Option 1 and schedules developed from the thermal kit supplied by the A.E.. Problems and assumptions made in this analysis include vendor heat balance inaccuracies, omissions of first stage design conditions and generic performance curves. Savings were calculated to be 300 BTU/kwh.

ACKNOWLEDGEMENTS

The author would like to acknowledge the following people for their time and patience:

Steve Bonner of Oklahoma Gas and Electric
Don Fleming and Gene Minner of NUS/EI
IHRAS members from ConEd, LILCO, and Central Hudson Utilities
Steve Klein of Stoller Company.

HEAT RATE vs. LOAD
VARIABLE vs. DIRECT DRIVE

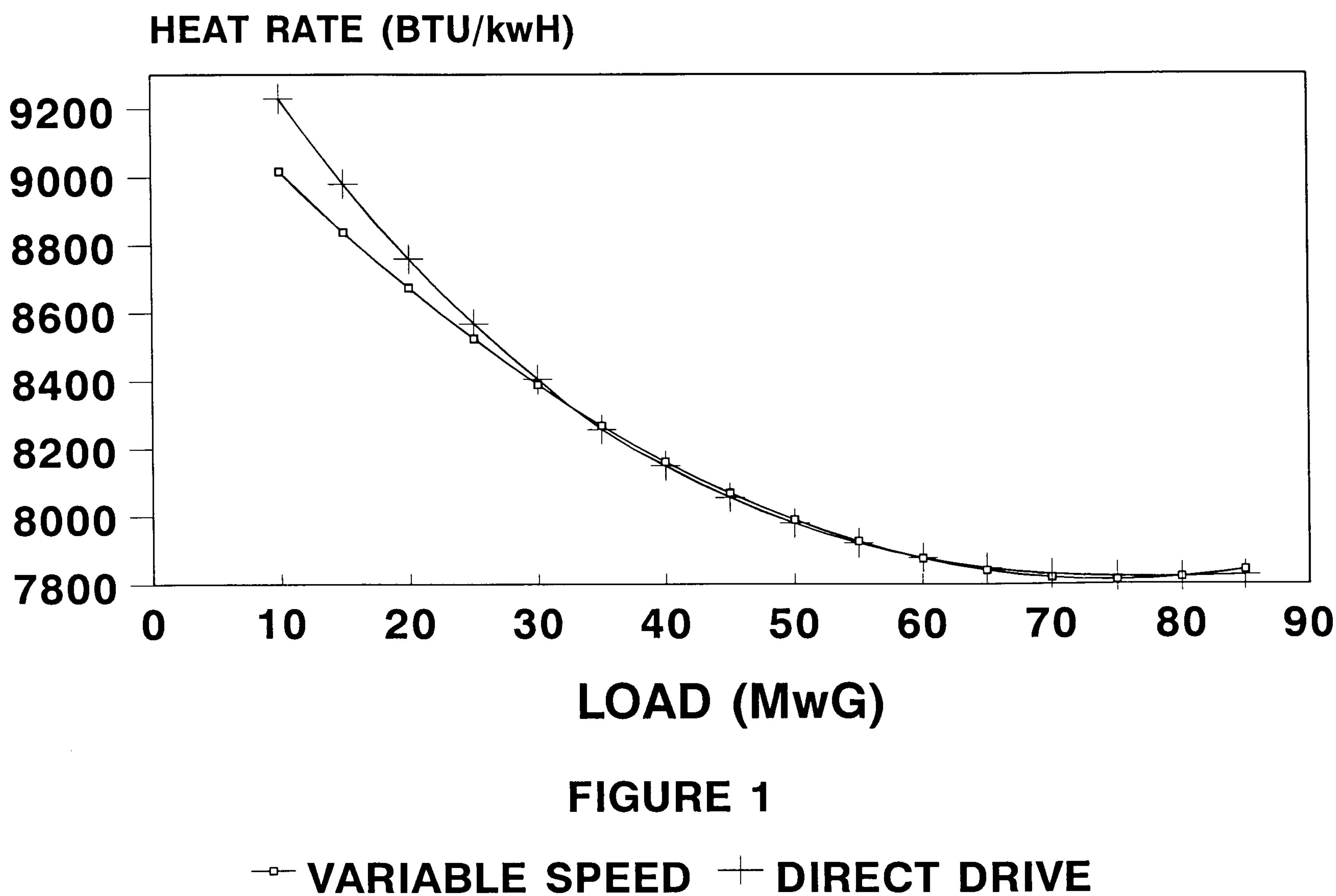


FIGURE 1

UNIT 12
THROTTLE PRESSURE vs. LOAD

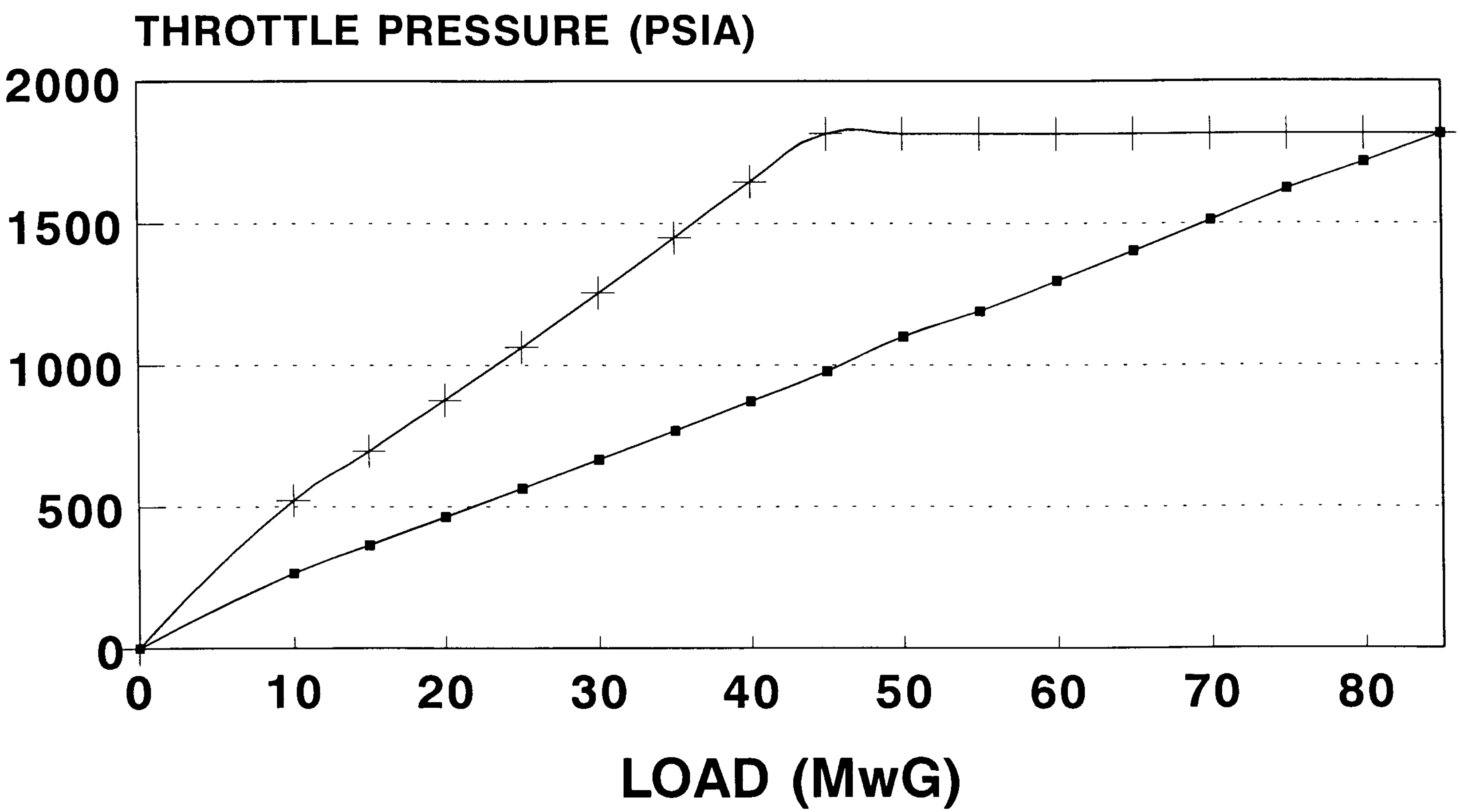


FIGURE 2

FULL ARC ADMISSION 4 VALVE HYBRID

UNIT 12 HEAT RATE
BENCHMARK vs. 4 VALVE HYBRID

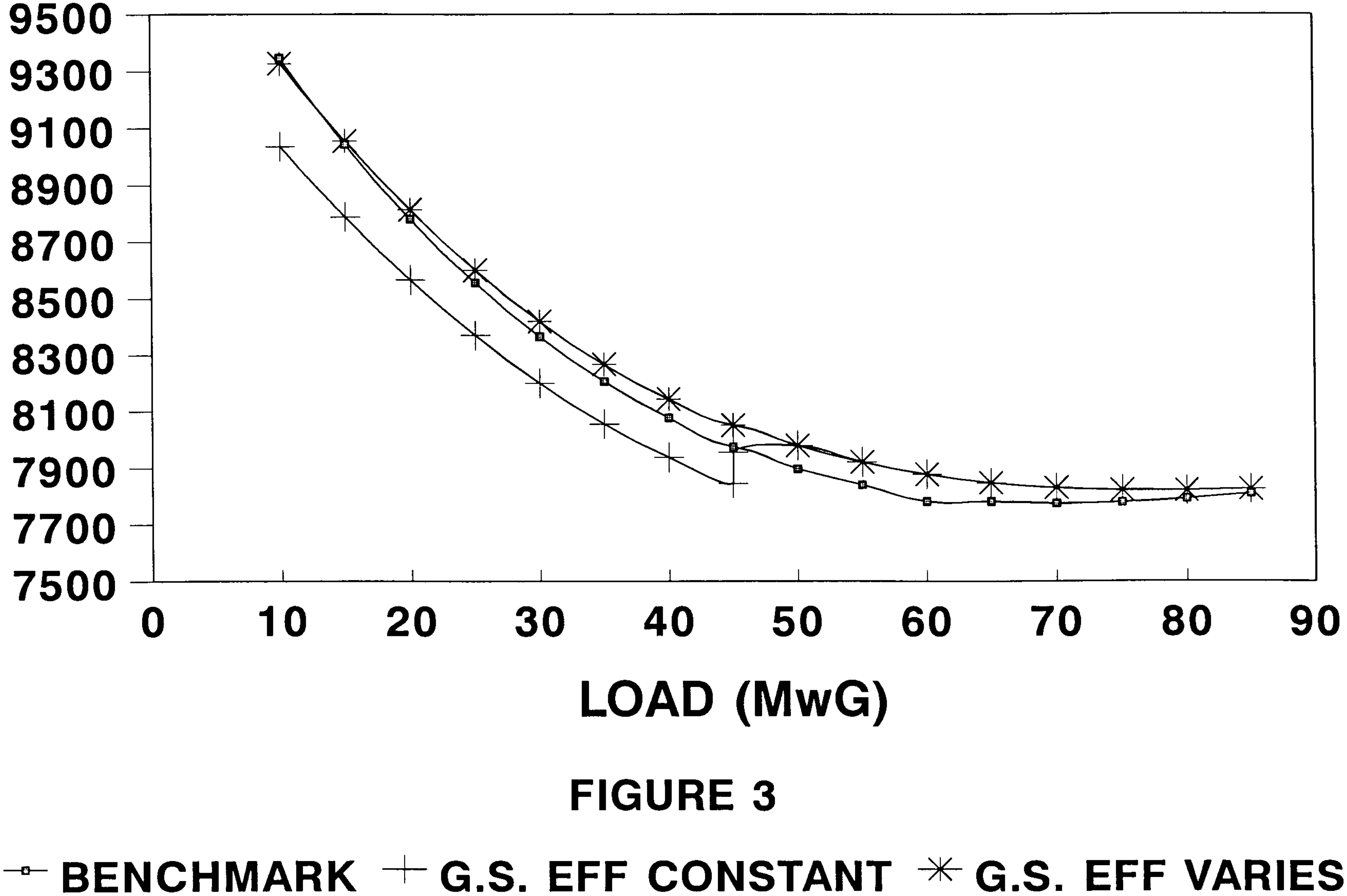


FIGURE 3

UNIT 12 HEAT RATE
FULL SLIDING vs. 4 VALVE HYBRID

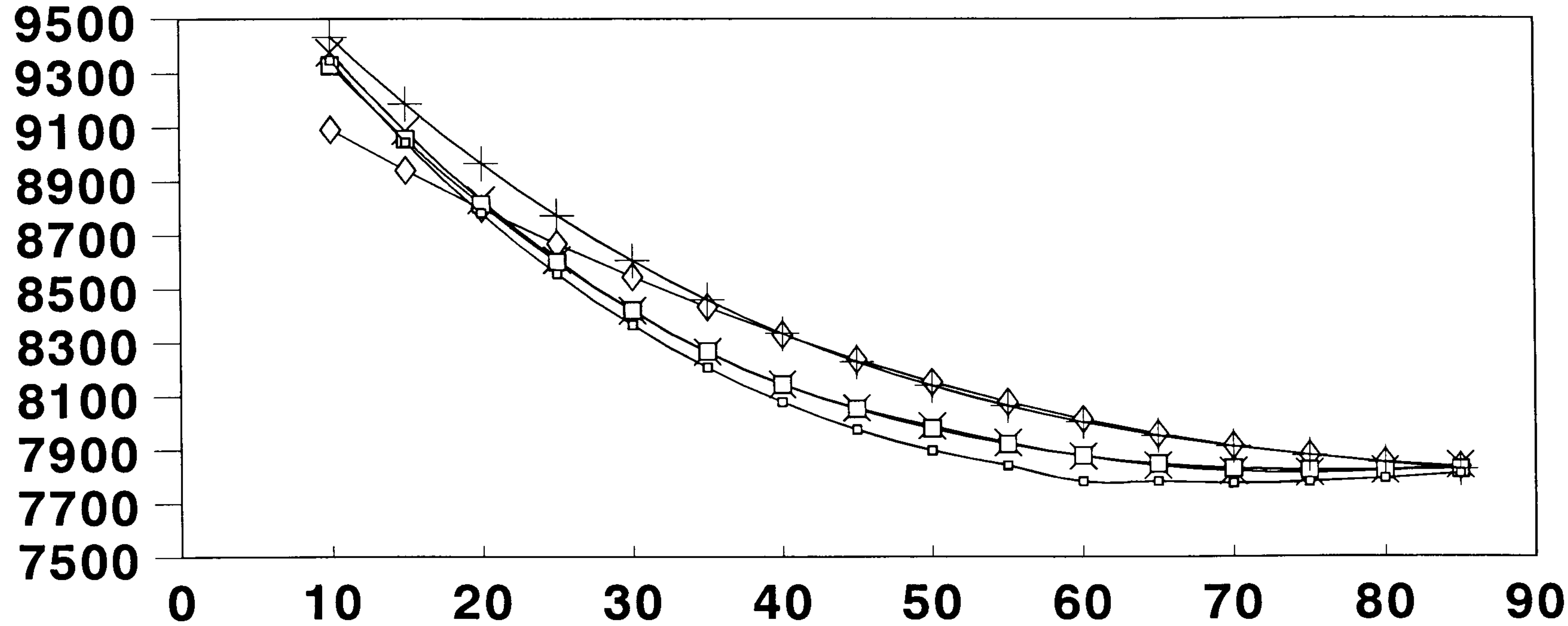
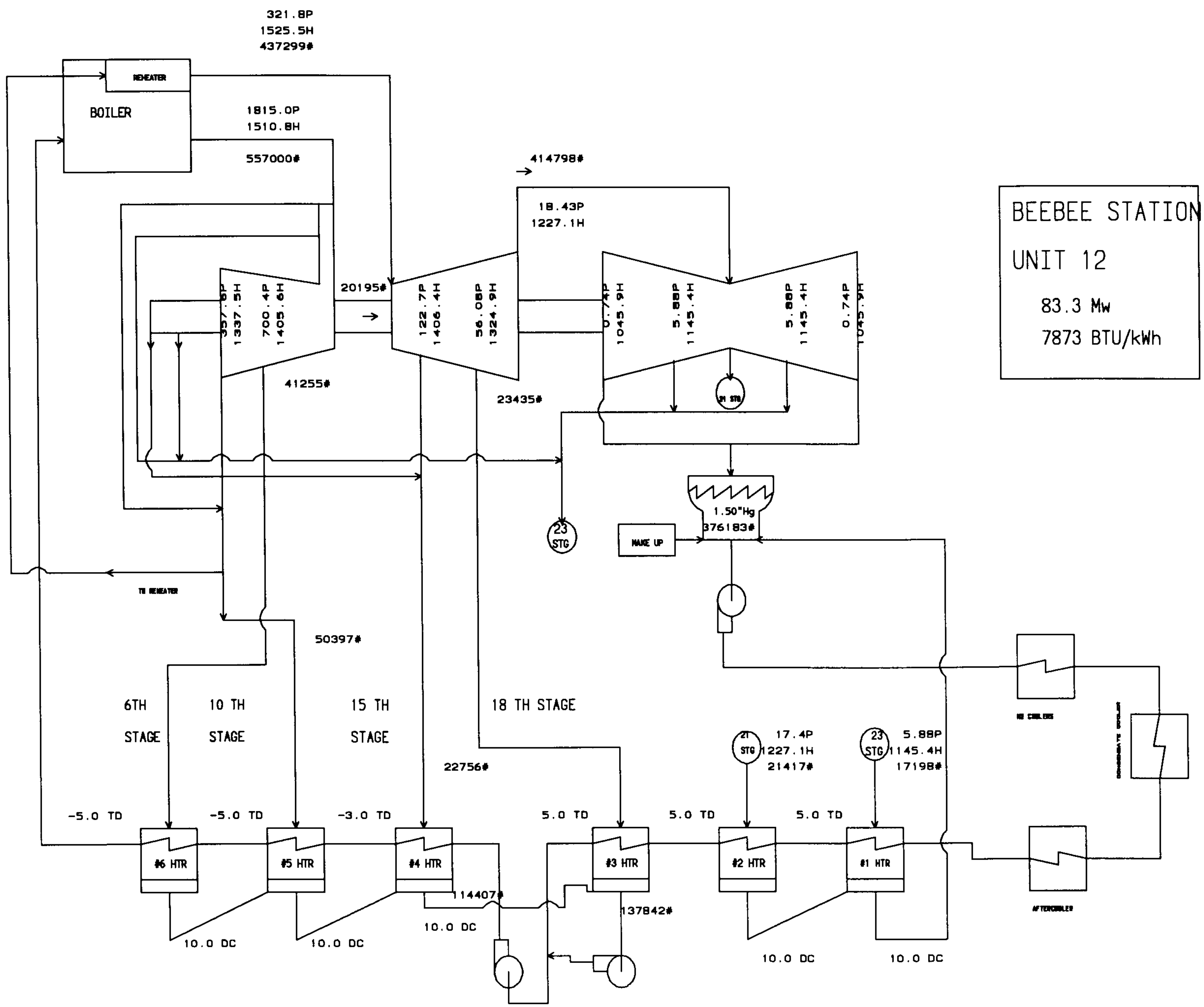


FIGURE 4

BENCHMARK (TEST) | FULL SLD "A" BFP | HYBRID 4 VLVS "A" | HYBRID 4 VLVS "B" | FULL SLD "B" BFP

BFP OUT AT 61 MwG

Appendix A



BEEBEE STATION
UNIT 12
83.3 Mw
7873 BTU/kWh
321.8P
1525.5H
437299#
REHEATER
BOILER
1815.0P
1510.8H
557000#
414798#
18.43P
1227.1H
20195#
357.6P
1337.5H
700.4P
1405.6H
41255#
122.7P
1406.4H
56.08P
1324.9H
23435#
0.74P
1045.9H
5.88P
1145.4H
5.88P
1145.4H
0.74P
1045.9H
1.50"Hg
376183#
MAKE UP
23
STG
TO REHEATER
50397#
6TH
STAGE
10 TH
STAGE
15 TH
STAGE
18 TH STAGE
22756#
21
STG
17.4P
1227.1H
21417#
23
STG
5.88P
1145.4H
17198#
-5.0 TD
-5.0 TD
-3.0 TD
5.0 TD
5.0 TD
5.0 TD
#6 HTR
#5 HTR
#4 HTR
#3 HTR
#2 HTR
#1 HTR
114407#
137842#
10.0 DC
10.0 DC
10.0 DC
10.0 DC
10.0 DC

= BEEBEE STATION - UNIT # 12 - 557000 #/HR - 83.270 MW GROSS

FILE NAME: 5BEN SLD
RUN DATE: 01/22/90
BENCHMARK B BFP OUT @ 400000#/HR

BEEBEE STATION - UNIT # 12

BENCHMARK CONFIGURATION MODEL
(CURRENT PLANT)

BUEHLMAN/LITT/O'CONNOR

01/02/90

THIS MODEL CONTAINS THE FOLLOWING SCHEDULES :

(1) HYDROGEN COOLER HEAT INPUT VS. THROTTLE FLOW
(2) TOTAL GENERATOR ELECTRICAL LOSS VS. GENERATOR GROSS OUTPUT
(3) GOV. STAGE (30) EFF. MULTIPLIER VS. EQ. THROTTLE FLOW RATIO
(4) FIRST STAGE I.P.(60) EFF. MULT. VS. HOT REHEAT PRESSURE
(5) GOV. STAGE EFFICIENCY VS. EQUIVALENT THROTTLE FLOW RATIO
(6) 6TH STAGE EFFICIENCY VS. EQUIVALENT THROTTLE FLOW RATIO
(7) 10TH STAGE EFFICIENCY VS. EQUIVALENT THROTTLE FLOW RATIO
(8) 15TH STAGE EFFICIENCY VS. EQUIVALENT THROTTLE FLOW RATIO
(9) 18TH STAGE EFFICIENCY VS. EQUIVALENT THROTTLE FLOW RATIO
(10) 21ST STAGE EFFICIENCY VS. EQUIVALENT THROTTLE FLOW RATIO
(11) 23RD STAGE EFFICIENCY VS. EQUIVALENT THROTTLE FLOW RATIO
(12) 25TH STAGE EFFICIENCY VS. EQUIVALENT THROTTLE FLOW RATIO
(13) # 6 EXTRACTION PRESSURE DROP CONSTANTS VS. THROTTLE FLOW
(14) # 5 EXTRACTION PRESSURE DROP CONSTANTS VS. THROTTLE FLOW
(15) # 3 EXTRACTION PRESSURE DROP CONSTANTS VS. THROTTLE FLOW
(16) # 2 EXTRACTION PRESSURE DROP CONSTANTS VS. THROTTLE FLOW
(17) # 1 EXTRACTION PRESSURE DROP CONSTANTS VS. THROTTLE FLOW
(18) 6TH STAGE SHAPER CONSTANT VS. THROTTLE FLOW
(19) 15TH STAGE SHAPER CONSTANT VS. THROTTLE FLOW
(20) 18TH STAGE SHAPER CONSTANT VS. THROTTLE FLOW
(21) 12-A FEEDWATER PUMP EFFICIENCY VS. FEEDWATER PUMP FLOW
(22) 12-A FEEDWATER PUMP HEAD VS. FEEDWATER PUMP FLOW
(23) 12-B FEEDWATER PUMP EFFICIENCY VS. FEEDWATER PUMP FLOW
(24) 12-B FEEDWATER PUMP HEAD VS. FEEDWATER PUMP FLOW

```
*
*
*
*
*
*
*************************************
****** TABLE SUPPRESSION CARDS ******
*************************************
*
*
*                      SYSTEMS TABLES
*
020001 NOPRNT  * FLAG SETTINGS AND DATA FOR SYSTEM
020002 NOPRNT   * GEOMETRY CONFIGURATION OF MODEL
020003 NOPRNT  * COMPONENT PROPERTIES
020004 NOPRNT   * STREAM PROPERTIES
020005 NOPRNT   * COMPARISON OF COMPONENT PORT TEST DATA WITH PEPSE
*                 EMPLOYED STREAM PROPERTIES
*020006 NOPRNT  * DETAILED TURBINE PERFORMANCE OUTPUT - TABLE A
*020007 NOPRNT  * DETAILED TURBINE PERFORMANCE OUTPUT - TABLE B
*020008 NOPRNT  * DETAILED TURBINE PERFORMANCE OUTPUT - TABLE C
*020009 NOPRNT  * DETAILED FEEDWATER HEATER PERFORMANCE OUTPUT - TABLE A
*020010 NOPRNT  * DETAILED FEEDWATER HEATER PERFORMANCE OUTPUT - TABLE B
*020012 NOPRNT   * DETAILED HEAT EXCHANGER PERFORMANCE OUTPUT, DETAILED
*                 HEAT EXCHANGER DESIGN OUTPUT, AND DETAILED ROTARY
*                 REGENERATOR DESIGN OUTPUT
*020013 NOPRNT   * DETAILED SOURCE, SINK, AND VALVE PERFORMANCE OUTPUT
*                 AND DETAILED THROTTLE VALVE PERFORMANCE OUTPUT
020014 NOPRNT  * DETAILED PUMP PERFORMANCE OUTPUT
020015 NOPRNT   * DETAILED MIXER PERFORMANCE OUTPUT
020016 NOPRNT   * DETAILED SPLITTER PERFORMANCE OUTPUT
020017 NOPRNT   * DETAILED FURNACE / COMBUSTER PERFORMANCE OUTPUT
*020019 NOPRNT   * PERFORMANCE SUMMARY OF GENERATORS
020020 NOPRNT  * FIRST LAW OF THERMODYNAMICS PERFORMANCE - SYSTEM
020021 NOPRNT   * SECOND LAW OF THERMODYNAMICS PERFORMANCE - COMPONENTS
020022 NOPRNT   * SECOND LAW OF THERMODYNAMICS PERFORMANCE - STREAMS
020023 NOPRNT   * SECOND LAW OF THERMODYNAMICS PERFORMANCE - SYSTEM
020024 NOPRNT   * MATERIAL DESCRIPTIONS USED IN THE MODEL
020025 NOPRNT   * FIRST LAW OF THERMODYNAMICS PERFORMANCE - ENVELOPE
*020026 NOPRNT  * TURBINE EXPANSION CHARACTERISTICS
020028 NOPRNT  * PROPERTIES OF ACTIVE STREAMS
*
*                      SPECIALIZED TABLES
*
020027 NOPRNT   * DETAILED TURBINE PERFORMANCE OUTPUT - TABLE D
020029 NOPRNT   * WARNINGS FROM WRITGC ABOUT SECOND LAW VIOLATIONS
020030 NOPRNT   * WARNING TABLE OF STREAM CLOSURES
020031 NOPRNT   * DETAILED NUCLEAR REHEATER DESIGN OUTPUT
020032 NOPRNT   * INPUT SCHEDULE NUMBER N TABLE OF VALUES
020033 NOPRNT   * VARIABLE SETS WHICH REFERENCE SCHEDULES
020034 NOPRNT   * CONTROLS INPUT
020035 NOPRNT   * SCHEDULED VARIABLE VALUES CALCULATED
020036 NOPRNT   * CONTROLLED VARIABLE VALUES CALCULATED
*020037 NOPRNT   * DEFINITIONS OF SPECIAL OPERATIONS SPECIFIED
**020038 NOPRNT  * SPECIAL INPUT VARIABLES, AS SPECIFIED
**020039 NOPRNT  * SPECIAL OUTPUT TABLE OF SPECIFIED VARIABLES
020040 NOPRNT   * DETAILED FEEDWATER HEATER DESIGN OUTPUT
020041 NOPRNT   * DETAILED CONDENSER DESIGN OUTPUT
020042 NOPRNT   * OPERATION SET VALUES CALCULATED
020043 NOPRNT   * IORDER ARRAY TABLE AND EORDER ARRAY TABLE
*020044 NOPRNT   * DEBUG PRINT OF COMPONENT AND STREAM RESULTS
*020045 NOPRNT   * DEBUG PRINT OF COMPONENT AND STREAM RESULTS PLUS
*                 WARNINGS ASSOCIATED WITH COMPONENT AND STREAM
*                 DEBUG OUTPUT
*020046 NOPRNT   * DEBUG OUTPUT, RUN PARAMETERS RELEVANT TO CONVERGENCE
020047 NOPRNT   * BOILER EFFICIENCY BY HEAT LOSS METHOD
020048 NOPRNT   * DESIGN MODE CONDENSER AND FEEDWATER HEATER DEBUG
*                 OUTPUT
020049 NOPRNT   * PERFORMANCE TEST ANALYSIS RESULTS (SPECIAL OPTION 6)
020050 NOPRNT   * CALCULATED CONTROL BLOCK GAINS
*020071 NOPRNT   * DEBUG OUTPUT COMPONENT TABLE
020072 NOPRNT   * DEBUG OUTPUT STREAM ARRAYS
020073 NOPRNT   * DEBUG OUTPUT COMPONENT ARRAYS
*020074 NOPRNT   * ABNORMAL TERMINATION RUN PARAMETERS RELEVANT TO
*                 CONVERGENCE
020075 NOPRNT   * CONTROL BLOCK STATUS REPORT
*
*
**************************************
```

```
****** GENERIC INPUT DATA CARDS ******
**************************************
*
*
011010 1 2 1 0 3600 96000. .85 44.70 44.70
011011 360. 1190. * VWO
*
*
**********************************
****** CONVERGENCE CRITERIA ******
**********************************
*
*
012000 50 50. 50. 0. 0. 0. 0 1.E5
010200 2 3 1 1 1
010201 3
*
*
**************************************
****** MAIN STREAM DESCRIPTIONS ******
**************************************
*
*
*STREAM    FROM   PORT ID      TO     PORT ID
500050     700,      U,        010,      I
500150     010,      U,        020,      I
500250     020,      U,        030,      I
500350     030,      U,        040,      I
500550     050,      U,        060,      I
500650     060,      U,        070,      I
500750     070,      U,        080,      IA
500850     080,      U,        090,      I
500950     090,      U,        100,      IA
501050     100,      U,        110,      T
501150     110,      T,        120,      I
501250     120,      U,        130,      IA
501650     160,      U,        170,      I
501750     170,      U,        180,      I
501850     180,      U,        190,      S
501950     190,      D,        200,      I
502050     200,      U,        220,      T
502250     220,      T,        230,      T
502350     230,      T,        250,      T
502550     250,      T,        260,      T
502650     260,      T,        270,      T
502750     270,      T,        280,      T
502850     280,      T,        290,      IA
502890     280,      D,        470,      I
504720     470,      U,        290,      IB
502950     290,      U,        300,      IA
503050     300,      U,        305,      I
503070     305,      B,        310,      I
503120     305,      U,        315,      I
503130     310,      U,        800,      IB
503170     315,      U,        800,      IA
503190     800,      U,        320,      I
503250     320,      U,        325,      I
503260     325,      U,        460,      I
503270     460,      U,        450,      I
503280     450,      U,        330,      T
503350     330,      T,        340,      T
503450     340,      T,        350,      T
503550     350,      T,        360,      I
*
*
********************************************
****** EXTRACTION STREAM DESCRIPTIONS ******
********************************************
*
*
500910     090,      B,        340,      S
504410     440,      U,        330,      S
501710     170,      E,        430,      IA
504310     430,      U,        260,      S
*
*
***************************************
****** DRAIN STREAM DESCRIPTIONS ******
***************************************
*
```

```
*
503590      350,     D,       340,     D
503490      340,     D,       330,     D
503390      330,     D,       280,     D
502790      270,     D,       260,     D
502690      260,     D,       490,     IA
504920      490,     U,       190,     D
*
*
***********************************************
****** MISCELLANEOUS STREAM DESCRIPTIONS ******
***********************************************
*
*
500220      020,     B,       400,     I
504030      400,     B,       420,     IB
504020      400,     U,       080,     IB
500420      040,     B,       130,     IB
500710      070,     B,       410,     I
504110      410,     U,       440,     IB
504120      410,     B,       420,     IA
504220      420,     U,       430,     IB
504630      450,     B,       100,     IB
509320      930,     U,       190,     T
501920      190,     T,       920,     I
509420      940,     U,       490,     IB
509620      960,     U,       300,     IB
503220      320,     B,       910,     I
504620      460,     B,       900,     I
*
*
************************************************
****** EXTRACTION PRESSURE DROP CONSTANTS ******
************************************************
*
*
600540 2 0.0516       * # 6 EXTRACTION
600910 2 0.0503       * # 5 EXTRACTION
604410 2 0.0522       * # 4 EXTRACTION
601540 2 0.0524       * # 3 EXTRACTION
601640 2 0.0549       * # 2 EXTRACTION
604310 2 0.0521       * # 1 EXTRACTION
*
*
******************************
****** TURBINE (TYPE 8) ******
******************************
*
*
* HIGH PRESSURE TURBINE STAGES
*
700300 8  1  0   0  1  0   1  3  0.0
700303 0.77898   10207.9
700309 1760.55   1510.79   553371.0
*
700500 8  1  1   1  2  0   1  3  0.03
700503 0.81974   18708.3
*
700600 8  1  3   0  2  0   1  1  0.0
700601 0.83112   357.346
*
* INTERMEDIATE PRESSURE TURBINE STAGES   * IPTYPE DESIGNATED AS LP
*
701400 8  1  0   1  4  0   1  3  0.03
701403 0.87128   95532.6
701409 315.214   1524.01   457225.0
*
701500 8  1  1   1  4  0   1  3  0.03
701503 0.85763   183621.0
*
701600 8  1  1   1  4  0   1  1  0.03
701601 0.87403   18.428
*
* LOW PRESSURE TURBINE STAGES
*
701700 8  1  1   1  4  0   2  3  0.03
701703 0.89719   1257000.0
701709 18.428   1227.16   392716.0
*
701800 8  1  3   0  4  0   2  1  0.0   0.0   26.175   * GE EXHAUST LOSS
```

```
701801 0.89413  0.737  * EFF. AT BASE PRESS.
*
*
***********************
****** CONDENSER ******
***********************
*
*
701900 10 1 2 0.0 -1.5
*
*
**************************************************
****** FEEDWATER HEATERS (PERFORMANCE MODE) ******
**************************************************
*
*
703500 18 0 050 2 0.0  -5.0  10.0         * # 6 HIGH PRESSURE HEATER
703400 18 1 090 2 0.0  -5.0  10.0         * # 5 HIGH PRESSURE HEATER
703300 18 1 140 2 0.0  -3.0  10.0         * # 4 HIGH PRESSURE HEATER
*
702800 17 1 150 2 0.0   5.0               * # 3 LOW PRESSURE HEATER
702700 16 0 160 2 0.0   5.0  10.0         * # 2 LOW PRESSURE HEATER
702600 16 1 170 2 0.0   5.0  10.0         * # 1 LOW PRESSURE HEATER
*
*
**********************
****** REHEATER ******
**********************
*
*
701100 25 2 1000.0 .0999
*
*
********************
****** VALVES ******
********************
*
*
* THROTTLE VALVE
*
700100 35 -2.0 -2.0 -2.0 .30 1815.0 1510.9 557000.0  * VWO - 83.270 MWG
*
* REHEAT VALVE
*
701200 34 0.02
*
* FEEDWATER VALVE
*
703250 34 0.10
*
*
*******************
****** PUMPS ******
*******************
*
*
* 12-A FEEDWATER PUMP (HYDRAULIC COUPLING)
*
703100 41 2208.0 0.87 1.0 0.70
*
* 12-B FEEDWATER PUMP (DIRECT DRIVE)
*
703150 41 2208.0 0.87 1.0 0.70
*
* CONDENSATE PUMP
*
702000 41 245.0
*
* HEATER DRAIN PUMP
*
704700 41 245.0
*
*
**********************************
****** MIXERS AND SPLITTERS ******
**********************************
*
*
* MIXERS
*
```

```
700800 50 1
704200 50
701000 50 1
701300 50 1
704400 50 1
704300 50 1
703000 50
702900 50
704900 50
708000 50
*
* SPLITTERS
*
700400 64 386.635          * PACLEK
700700 64 505.519          * PACLEK
700900 60 0.0 50554.0
704100 64 783.775          * PACLEK
700200 68 3629.0 57.7267 * PACLEK
704000 68 643.,52.1272    * PACLEK
704500 61 0.0 0.0
704600 61 0.0 0.0
703200 61 0.0 15000.0     * BWCP MAKE-UP
703050 63 0.0 0.5
*
*
*******************************
****** SOURCES AND SINKS ******
*******************************
*
*
707000 33 1050.0 1815.0 557000.0    * BOILER - VALVES WIDE OPEN
709300 31 54.0 26.0 19208448.0      * CIRCULATING WATER - INPUT
709200 30                           * CIRCULATING WATER - OUTPUT
709400 31 70. 14.7  0.0             * 2875.0          * MAKE-UP
709100 30                           * BWCP INJECTION
709000 30                           * SUPERHEAT SPRAY
709600 31 288.0 2245.0 12000.0      * BWCP RETURN
703600 32                           * FEEDWATER
*
*
*****************************
****** HEAT EXCHANGERS ******
*****************************
*
*
* CONDENSATE COOLER
*
702200 27 0.0
*
* HYDROGEN COOLER
*
702300 27 3754300.0
*
* AFTER COOLER
*
702500 27 0.0
*
*
***********************
****** SCHEDULES ******
***********************
*
*
* HYDROGEN COOLER HEAT INPUT VS. THROTTLE FLOW
*
810100 139000.  201000.  265000.  328500.  389000.  442000.
810101 500500.  557000.
810110 0.0  388.0  445.0  518.0  596.0  687.0  788.0
810111 959.0  1100.0
820100 3412.13
830100 01, BBHXGR, 230, WW, 005
*
* TOTAL GENERATOR ELECTRICAL LOSS VS. GENERATOR GROSS OUTPUT
*
810200 21.530  31.823  42.146  51.979  60.963  68.427  76.202  83.270
810210 0.0  478.  535.  608.  686.  777.  878.  1049.  1190.
830200 02, BKELEI, 1, BKGRO, 1
*
* GOV. STAGE EFFICIENCY VS. EQUIVALENT THROTTLE FLOW RATIO
*
```

```
810500      0.36083 0.47572 0.58972 0.69833 0.79347 0.89849 1.00000
810510 0.0 0.40195 0.45493 0.51648 0.58379 0.64753 0.72025 0.77898
830500 05, EFFTRE, 030, EQTFR, 10
*
* 6TH STAGE EFFICIENCY VS. EQUIVALENT THROTTLE FLOW RATIO
*
810600      0.36083 0.47572 0.58972 0.69833 0.79347 0.89849 1.00000
810610 0.0 0.86918 0.86591 0.85199 0.83701 0.82466 0.81791 0.81974
830600 06, EFFTRE, 050, EQTFR, 10
*
* 10TH STAGE EFFICIENCY VS. EQUIVALENT THROTTLE FLOW RATIO
*
810700      0.36083 0.47572 0.58972 0.69833 0.79347 0.89849 1.00000
810710 0.0 0.80048 0.81444 0.82242 0.82906 0.83258 0.83367 0.83112
830700 07, EFFTRE, 060, EQTFR, 10
*
* 15TH STAGE EFFICIENCY VS. EQUIVALENT THROTTLE FLOW RATIO
*
810800      0.36083 0.47572 0.58972 0.69833 0.79347 0.89849 1.00000
810810 0.0 0.88727 0.88146 0.87896 0.87598 0.87363 0.87151 0.87129
830800 08, EFFTRE, 140, EQTFR, 10
*
* 18TH STAGE EFFICIENCY VS. EQUIVALENT THROTTLE FLOW RATIO
*
810900      0.36083 0.47572 0.58972 0.69833 0.79347 0.89849 1.00000
810910 0.0 0.86929 0.86719 0.86445 0.86541 0.86506 0.86214 0.85763
830900 09, EFFTRE, 150, EQTFR, 10
*
* 21ST STAGE EFFICIENCY VS. EQUIVALENT THROTTLE FLOW RATIO
*
811000      0.36083 0.47572 0.58972 0.69833 0.79347 0.89849 1.00000
811010 0.0 0.87604 0.87073 0.87033 0.86748 0.86727 0.86938 0.87403
831000 10, EFFTRE, 160, EQTFR, 10
*
* 23RD STAGE EFFICIENCY VS. EQUIVALENT THROTTLE FLOW RATIO
*
811100      0.36083 0.47572 0.58972 0.69833 0.79347 0.89849 1.00000
811110 0.0 0.89778 0.89628 0.89634 0.89597 0.89598 0.89616 0.89719
831100 11, EFFTRE, 170, EQTFR, 10
*
* 25TH STAGE EFFICIENCY VS. EQUIVALENT THROTTLE FLOW RATIO
*
811200      0.36083 0.47572 0.58972 0.69833 0.79347 0.89849 1.00000
811210 0.0 0.89686 0.89500 0.89455 0.89390 0.89365 0.89357 0.89414
831200 12, EFFTRE, 180, EQTFR, 10
*
* # 6 EXTRACTION PRESSURE DROP CONSTANTS VS. THROTTLE FLOW - STREAM 54
*
811300 201000.  265000.  328500.  389000.  442000.  500500.  557000.
811310 0.0 0.0558 0.0551 0.0539 0.0528 0.0520 0.0514 0.0516
831300 13, PFAC1, 054, WW, 005
*
* # 5 EXTRACTION PRESSURE DROP CONSTANTS VS. THROTTLE FLOW - STREAM 91
*
811400 201000.  265000.  328500.  389000.  442000.  500500.  557000.
811410 0.0 0.0502 0.0503 0.0502 0.0496 0.0497 0.0500 0.0503
831400 14, PFAC1, 091, WW, 005
*
* # 4 EXTRACTION PRESSURE DROP CONSTANTS ARE NOT SCHEDULED - STREAM 441
*
* # 3 EXTRACTION PRESSURE DROP CONSTANTS VS. THROTTLE FLOW - STREAM 154
*
811500 201000.  265000.  328500.  389000.  442000.  500500.  557000.
811510 0.0 0.0503 0.0513 0.0526 0.0512 0.0514 0.0514 0.0524
831500 15, PFAC1, 154, WW, 005
*
* # 2 EXTRACTION PRESSURE DROP CONSTANTS VS. THROTTLE FLOW - STREAM 164
*
811600 201000.  265000.  328500.  389000.  442000.  500500.  557000.
811610 0.0 0.0528 0.0562 0.0537 0.0497 0.0502 0.0523 0.0549
831600 16, PFAC1, 164, WW, 005
*
* # 1 EXTRACTION PRESSURE DROP CONSTANTS VS. THROTTLE FLOW - STREAM 431
*
811700 201000.  265000.  328500.  389000.  442000.  500500.  557000.
811710 0.0 0.0531 0.0512 0.0562 0.0514 0.0525 0.0532 0.0521
831700 17, PFAC1, 431, WW, 005
*
* 6TH STAGE SHAPER CONSTANT VS. THROTTLE FLOW
*
```

```
811800 201000.  265000.  328500.  389000.  442000.  500500.  557000.
811810 0.0 443.57 487.10 551.29 650.00 804.58 1029.32 860.27
831800 18, SHAPER, 50, WW, 005
*
* 15TH STAGE SHAPER CONSTANT VS. THROTTLE FLOW
*
811900 201000.  265000.  328500.  389000.  442000.  500500.  557000.
811910 0.0 550.74 549.18 548.39 549.35 552.32 555.91 558.09
831900 19, SHAPER, 140, WW, 005
*
* 18TH STAGE SHAPER CONSTANT VS. THROTTLE FLOW
*
812000 201000.  265000.  328500.  389000.  442000.  500500.  557000.
812010 0.0 592.18 584.94 586.95 581.32 582.43 591.09 606.16
832000 20, SHAPER, 150, WW, 005
*
* 12-A FEEDWATER PUMP EFFICIENCY VS. FEEDWATER PUMP FLOW
*
812100       89767.0 112208.0 134650.0 157092.0 179533.0 201975.0 224417.0
812110 0.0   0.365    0.436    0.488    0.532    0.572    0.610    0.645
812101     246858.0 269300.0 291745.0 314187.0 336629.0 359071.0 381513.0
812111        0.675    0.695    0.713    0.723    0.730    0.736    0.730
812102     403955.0 426397.0 448839.0
812112        0.726    0.722    0.720
832100 21, EFFPMP, 310, WW, 313
*
* 12-A FEEDWATER PUMP HEAD VS. FEEDWATER PUMP FLOW
*
812200       89767.0 112208.0 134650.0 157092.0 179533.0 201975.0 224417.0
812210 0.0  2394.0   2380.0   2373.0   2363.0   2352.0   2332.0   2303.0
812201     246858.0 269300.0 291745.0 314187.0 336629.0 359071.0 381513.0
812211       2270.0   2237.0   2208.0   2156.0   2105.0   2053.0   1991.0
812202     403955.0 426397.0 448839.0
812212       1940.0   1868.0   1795.0
832200 22, PMPDIS, 310, WW, 313
*
* 12-B FEEDWATER PUMP EFFICIENCY VS. FEEDWATER PUMP FLOW
*
812300          0.0  22442.0  44884.0  67326.0  89767.0 112208.0 134650.0
812310 0.0      0.0    0.110    0.205    0.290    0.370    0.435    0.495
812301     157092.0 179533.0 201975.0 224417.0 246858.0 269300.0 291745.0
812311        0.550    0.595    0.630    0.660    0.680    0.700    0.715
812302     314187.0 336629.0 359071.0 381513.0 403955.0 426397.0
812312        0.725    0.730    0.738    0.740    0.742    0.740
832300 23, EFFPMP, 315, WW, 317
*
* 12-B FEEDWATER PUMP HEAD VS. FEEDWATER PUMP FLOW
*
812400       44883.0  67325.0  89767.0 112208.0 134650.0 157092.0 179533.0
812410 0.0  2404.0   2394.0   2390.0   2383.0   2380.0   2361.0   2252.0
812401     201975.0 224417.0 246858.0 269300.0 291745.0 314187.0 336629.0
812411       2332.0   2303.0   2270.0   2229.0   2208.0   2163.0   2117.0
812402     359071.0 381513.0 403955.0 426397.0
812412       2043.0   1981.0   1909.0   1816.0
832400 24, PMPDIS, 315, WW, 317
*
*
**************************************
****** SPECIAL OUTPUT VARIABLES ******
**************************************
*
*
890010 'GROSS TURBINE CYCLE POWER OUTPUT   (MW)'
890011 BKGROS, 0
*
* OPERATION TO CALCULATE THE GROSS TURBINE CYCLE HEAT RATE
*
870080 1000.      * MW TO KW CONVERSION
880010 HH, 005, SUB, HH, 355, OPVB, 10
880020 OPVB, 10, MUL, WW, 005, OPVB, 11
880030 HH, 115, SUB, HH, 105, OPVB, 12
880040 OPVB, 12, MUL, WW, 115, OPVB, 13
880050 OPVB, 11, ADD, OPVB, 13, OPVB, 14
880060 OPVB, 14, DIV, BKGROS, 1, OPVB, 15
880070 OPVB, 15, DIV, OPVB, 8, OPVB, 16
*
890020 'GROSS TURBINE CYCLE HEAT RATE (BTU/KWH)'
890021 OPVB, 16
*
* OPERATION TO CALCULATE THE GROSS TURBINE CYCLE
```

```
* THERMAL EFFICIENCY BASED ON OPVB 16 ABOVE
*
870330 3412.1416       * KW THERMAL CONVERSION FACTOR
880080 OPVB, 33, DIV, OPVB, 16, OPVB, 34
*
* OPERATION TO CONVERT CYCLE THERMAL EFFICIENCY TO PERCENT
*
870980 100.       * CONVERSION TO PERCENT
880090 OPVB, 34, MUL, OPVB, 98, OPVB, 35
*
* OPERATION TO CALCULATE INTERMEDIATE PRESSURE SECTION EFFICIENCY
*
880100 HH, 115, SUB, HH, 165, OPVB, 39
880110 PP, -165, PSH, SS, 115, OPVB, 40
880120 HH, 115, SUB, OPVB, 40, OPVB, 41
880130 OPVB, 39, DIV, OPVB, 41, OPVB, 42
*
* OPERATION TO CALCULATE LOW PRESSURE SECTION EFFICIENCY
*
880140 HH, 165, SUB, HH, 185, OPVB, 43
880150 PP, -185, PSH, SS, 165, OPVB, 44
880160 HH, 165, SUB, OPVB, 44, OPVB, 45
880170 OPVB, 43, DIV, OPVB, 45, OPVB, 46
*
* OPERATION TO CONVERT HIGH PRESSURE SECTION EFFICIENCY TO PERCENT
*
880180 EFFSEC, 060, MUL, OPVB, 98, OPVB, 36
*
* OPERATION TO CONVERT INT. PRESSURE SECTION EFFICIENCY TO PERCENT
*
880190 OPVB, 42, MUL, OPVB, 98, OPVB, 37
*
* OPERATION TO CONVERT LOW PRESSURE SECTION EFFICIENCY TO PERCENT
*
880200 OPVB, 46, MUL, OPVB, 98, OPVB, 38
*
890030 'GROSS TURBINE CYCLE THERMAL EFFIC.  (%)'
890031 OPVB, 35
*
890040 'H.P. TURBINE SECTION EFFIC.         (%)'
890041 OPVB, 36
*
890050 'I.P. TURBINE SECTION EFFIC.         (%)'
890051 OPVB, 37
*
890060 'L.P. TURBINE SECTION EFFIC.         (%)'
890061 OPVB, 38
*
890070 'MAIN STEAM FLOW                   (#/HR)'
890071 WW, 005
*
890080 'MAIN STEAM PRESSURE               (PSIA)'
890081 PP, 005
*
890090 'MAIN STEAM TEMPERATURE           (DEG-F)'
890091 TT, 005
*
890100 '1ST STAGE PRESSURE                (PSIA)'
890101 PP, 035
*
890110 '10TH STAGE PRESSURE               (PSIA)'
890111 PP, 065
*
890120 'COLD REHEAT PRESSURE              (PSIA)'
890121 PP, 095
*
890130 'COLD REHEAT TEMPERATURE          (DEG-F)'
890131 TT, 095
*
890140 'HOT REHEAT PRESSURE               (PSIA)'
890141 PP, 115
*
890150 'HOT REHEAT TEMPERATURE           (DEG-F)'
890151 TT, 115
*
890160 'I.P. INLET PRESSURE               (PSIA)'
890161 PP, 136
*
890170 'I.P. EXHAUST PRESSURE             (PSIA)'
890171 PP, 165
```

```
*
890180 'CONDENSER BACK PRESSURE          (IN-HG)'
890181 PP, 195
*
890190 'CIRC. WATER INLET TEMPERATURE   (DEG-F)'
890191 TT, 932
*
*
*************************************
****** SPECIAL INPUT VARIABLES ******
*************************************
*
*
890200 '12-A FEEDWATER PUMP MOTOR POWER    (KW)'
*890201 BKPMOT, 310,  929.0,    I
*
890210 '12-B FEEDWATER PUMP MOTOR POWER    (KW)'
*890211 BKPMOT, 315,  895.0,    I
*
890220 '# 6 HEATER F.W. PRESSURE DROP    (PSIA)'
890221 PDFW,    350,   12.0,    I
*
890230 '# 5 HEATER F.W. PRESSURE DROP    (PSIA)'
890231 PDFW,    340,    7.9,    I
*
890240 '# 4 HEATER F.W. PRESSURE DROP    (PSIA)'
890241 PDFW,    330,   13.8,    I
*
890250 '# 3 HEATER F.W. PRESSURE DROP    (PSIA)'
890251 PDFW,    280,   11.6,    I
*
890260 '# 2 HEATER F.W. PRESSURE DROP    (PSIA)'
890261 PDFW,    270,   14.4,    I
*
890270 '# 1 HEATER F.W. PRESSURE DROP    (PSIA)'
890271 PDFW,    260,    6.0,    I
*
*
890000 1  1             * OUTPUT FORMAT CONTROL FOR FLOATING POINT
*
020000 PRINT  NOPRNT  * SUPPRESSION OF 80 COLUMN PC OUTPUT
*
010002 1              * 132 COLUMN PC FORMAT
*
*
**********************************
****** TIP LEAKAGE GEOMETRY ******
**********************************
*
*
* 6TH STAGE
*
500450    040,    U,    001,    I
500460    001,    U,    050,    I
500470    001,    B,    011,    IB
500510    050,    E,    011,    IA
500540    011,    U,    350,    S
*
* 15TH STAGE
*
501350    130,    U,    002,    I
501360    002,    U,    140,    I
501370    002,    B,    021,    IB
501410    140,    E,    021,    IA
501440    021,    U,    440,    IA
*
* 18TH STAGE
*
501450    140,    U,    003,    I
501460    003,    U,    150,    I
501470    003,    B,    031,    IB
501510    150,    E,    031,    IA
501540    031,    U,    280,    S
*
* 21ST STAGE
*
501550    150,    U,    004,    I
501560    004,    U,    160,    I
501570    004,    B,    041,    IB
501610    160,    E,    041,    IA
```

```
501640    041,    U,    270,    S
*
*
**********************************************
****** TIP LEAKAGE MIXERS AND SPLITTERS ******
**********************************************
*
*
* MIXERS
*
700110  50  1
700210  50  1
700310  50  1
700410  50  1
*
* SPLITTERS
*
700010  61  0.0  0.0
700020  61  0.0  0.0
700030  61  0.0  0.0
700040  61  0.0  0.0
*
*
******************************************************************
********  REPLACEMENT CARDS FOR VARIABLE LOAD CONDITIONS *********
******************************************************************
*
/
= BEEBEE STATION - UNIT # 12 - 500500 #/HR FLOW - 76.202 MW - GROSS
*
707000 33 1050. 1815. 500500.
*709400 31 70. 14.7 2502.
011010 1 2 1 0 3600 96000. 0.85 44.7 32.2
*
/
= BEEBEE STATION - UNIT # 12 - 442000 #/HR FLOW - 68.427 MW - GROSS
*
707000 33 1050. 1815. 442000.
*709400 31 70. 14.7 2210.
011010 1 2 1 0 3600 96000. 0.85 44.7 20.4
*
/
= BEEBEE STATION - UNIT # 12 - 389000 #/HR FLOW - 60.963 MW - GROSS
*
707000 33 1050. 1815. 389000.
703050 63 0.0 0.0
*709400 31 70. 14.7 1945.
011010 1 2 1 0 3600 96000. 0.85 44.7 15.2
*
/
= BEEBEE STATION - UNIT # 12 - 328500 #/HR FLOW - 51.979 MW - GROSS
*
707000 33 1050. 1815. 328500.
*709400 31 70. 14.7 1642.
011010 1 2 1 0 3600 96000. 0.85 44.7 15.2
*
/
= BEEBEE STATION - UNIT # 12 - 265000 #/HR FLOW - 42.146 MW - GROSS
*
707000 33 1050. 1815. 265000.
*709400 31 70. 14.7 1325.
011010 1 2 1 0 3600 96000. 0.85 44.7 15.2
*
/
= BEEBEE STATION - UNIT # 12 - 201000 #/HR FLOW - 31.823 MW - GROSS
*
707000 33 1050. 1815. 201000.
*709400 31 70. 14.7 1005.
011010 1 2 1 0 3600 96000. 0.85 44.7 15.2
*
*/
*= BEEBEE STATION - UNIT # 12 - 139000 #/HR FLOW - 21.530 MW - GROSS
*       NOTE:  IN THE THERMAL KIT HEAT BALANCE THE EXTRACTION
*              FLOW TO # 1 FEEDWATER HEATER DOES NOT OBEY THE FIRST
*              LAW OF THERMODYNAMICS AND WILL NOT CONVERGE.
*
*707000 33 1050. 1815. 139000.
*709400 31 70. 14.7 695.
*
*
```

```
/
*
= SPECIAL OPTION 1 TO SET FLOW CAPACITY 4 VLVS OPEN
850000  1
700101 1815.  1510.7855  328500.
700109 1815.  1510.7855  178.22
891981 PPVSC 700 1500.  I
700100 35 -2.0 .03 -2.0 .361 1815.0 1510.9 557000.0  * SET ADMISSION
*    EQUIVALENT THROTTLE FLOW RATIO TO 4 VALVES OPEN. ASSUMED TO BE
*    HALF LOAD. NO DOCUMENTATION AVAILABLE.
/
= PRESSURE LOWERED TO 1425 PSIA. DIRECT DRIVE PUMP OUT
020001 PRINT  * FLAG SETTINGS AND DATA FOR SYSTEM
020003 PRINT  * COMPONENT PROPERTIES
020006 PRINT  * DETAILED TURBINE PERFORMANCE OUTPUT - TABLE A
020007 PRINT  * DETAILED TURBINE PERFORMANCE OUTPUT - TABLE B
020008 PRINT  * DETAILED TURBINE PERFORMANCE OUTPUT - TABLE C
020009 PRINT  * DETAILED FEEDWATER HEATER PERFORMANCE OUTPUT - TABLE A
020010 PRINT  * DETAILED FEEDWATER HEATER PERFORMANCE OUTPUT - TABLE B
020014 PRINT  * DETAILED PUMP PERFORMANCE OUTPUT
020020 PRINT  * FIRST LAW OF THERMODYNAMICS PERFORMANCE - SYSTEM
020026 PRINT  * TURBINE EXPANSION CHARACTERISTICS
020028 PRINT  * PROPERTIES OF ACTIVE STREAMS
020038 PRINT  * SPECIAL INPUT VARIABLES, AS SPECIFIED
020039 PRINT  * SPECIAL OUTPUT TABLE OF SPECIFIED VARIABLES
*                 WARNINGS ASSOCIATED WITH COMPONENT AND STREAM
*                 DEBUG OUTPUT
*= SPECIAL OPTION 3 TO EVALUATE CHANGE IN FLOW
*
*850000  3
*011010 1 2 1 0 3600 96000. .85 44.70 44.70 42500.
891981 PPVSC 700 1425.  I
891971 WWVSC 700 201000.  I
703050 63 0.0 0.0
*
/
= PRESSURE REDUCED TO 1200 PSIA
891981 PPVSC 700 1200.  I
*
.
```