Long Term Experience With PEPSE®
Special Option 6 For Nuclear BOP Performance Monitoring

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ABSTRACT

PEPSE Special Option 6 has been used at the Louisiana Power & Light Co. Waterford 3 nuclear plant extensively for the past two years.

Plant experience has shown effective model utilization encompasses three areas. These areas include model benchmarking and characterization using actual test data, application of turbine diagnostics techniques for test data analyses, and routine plant walkdowns.

The plant has successfully implemented PEPSE Special Option 6 for its weekly balance of plant performance monitoring program.

Introduction

The nuclear utility industry is a heavily regulated and monitored business environment. While non-nuclear units are most concerned with their public service commissions, nuclear plants must also contend with agencies such as the NRC, INPO, NUMARC, and others. Often, performance indicators are used for plant comparisons. Plant staff salaries are often tied these ratings. The NRC Maintenance Rule, 10CFR Part 65, will affect the scope of nuclear plant performance monitoring programs. So, it can be seen, an effective BOP (balance of plant) performance monitoring program is an important nuclear plant engineering function.

Definitions

The nuclear industry uses many acronyms and jargon. Major items pertaining to performance are listed below.

1. **BOP** - Balance of plant. The turbine, condensate feedwater, extraction steam, main steam, and auxiliaries, etc. The steam plant.

   NSSS - The nuclear steam supply system. The steam generator.

2. **Secondary** - The steam plant and auxiliaries.

3. **Primary** - The reactor plant and auxiliaries.

4. **Mwe** - Megawatts electric. Generator power.

5. **Mwth** - Megawatts thermal. The reactor plant rating. Plants are licensed for a certain thermal megawatt rating.

6. **Calorimetric** - Calculates percentage of rated reactor power. 100% would be 100% of licensed reactor power. There are typically five or six calorimetrics used at a nuclear plant. The most important calorimetric is the secondary calorimetric. This calculation is a BOP side heat balance around the NSSS. Feedwater flow is the most important input.

7. **NRC** - Nuclear Regulatory Commission. The federal body that governs the U.S. nuclear utility industry.

Program History

The Waterford 3 nuclear plant is owned by Louisiana Power and Light Company and operated by Energy Operations, Inc.. The plant is rated at 3390 Mwth, and began commercial operation in 1985. Waterford 3 is situated on the banks of the Mississippi River approximately 30 miles upstream of New Orleans, La..

The original BOP plant performance monitoring program, developed by a consultant, primarily used a "Quick-Check Performance Curve (see Figure 1). Weekly, the performance engineer would collect data from the plant process computer, normalize, or correct, the data to 100% reactor power, and plot the data on the curve. This provided a preliminary indication of performance problems.

Also, procedures were in place for data collection, individual equipment performance tests (feedwater heaters, MSR, condenser, etc), reporting requirements, etc. Special Tests, such as tracer - injection feedwater flow element testing, would be conducted as determined by the performance engineer.

The initial program was successful, however, after being in place for a short period of time several weaknesses were observed. These are:

1. Management desired more information. Specifically a breakdown of losses per secondary plant component.

2. There was a lack of documentation with the consultant supplied program.

3. Cycle diagnostics procedures could be improved.

Various program options were explored, including the use of on-line and off-line performance monitoring systems.

Due to process computer limitations, an on-line system was not feasible.

Of the off-line programs evaluated, most had limited successful implemention, or were quite expensive. Since the company had a systemwide license for PEPSE, and good experience had been gathered at our fossil units in using the code for component performance deviation studies, the decision was made to pursue implemation of a PEPSE based system.

Model Development

The goal for any performance program is to have a standard for comparison of unit performance. This standard, or benchmark, could be the vendor's heat balance diagrams and thermal kit, acceptance test data, or recent performance test data.

The first step in the evolution of the Benchmark PEPSE model for Waterford involved the development of the Vendor Verification model. Vendor heat balance diagrams and thermal kit data were the primary sources of data for the base PEPSE deck. This model was then "tuned" to match the vendor heat balances. These tuning factors (Efmults and Shapers) modify the base PEPSE turbine expansion line calculations (GE procedures), and allow modeling of a non-GE unit. The tuning factors were calculated using controls and by matching each vendor heat balance sheet. Schedules of these values were then applied to the base model. Other schedules (such as FW heater TTDs, generator losses, etc.), and PEPSE Special Features (Controls, Operations, Special Input/Output) were developed to customize the base PEPSE model. The end result, the Vendor Verification Model, closely matches the vendor heat balances while featuring automatic load switching. In other words, the user can input various operating parameters such as feedwater flow, throttle pressure, and turbine exhaust pressure and the model will calculate the proper generation and performance information. The model geometry is given in Figure 2.

The second step in the model development cycle was to develop a preliminary Special Option 6 model using the Vendor Verification model as the Benchmark case. Approximately 10 sets of actual plant test data from early cycle operation were then run through this model. Performance factors for each case were compared and one data set was selected as being most typical of the 10 case model analysis.

The vendor verification model was then tuned to match this selected performance test data set.

This newly tuned model became the new Benchmark model for Waterford 3.

Finally, a Special Option 6 model was constructed using this model for the Benchmark Step.

A conceptual diagram of the model structure (named WF3DEV, for Waterford 3 Deviation Analysis model) is given in Figure 3.

Other Program Enhancements

It was understood early on during the modeling process that effective use of PEPSE for test data analysis would require good turbine cycle diagnostics coupled with routine plant walkdowns. Diagnostics methods learned from K.C. Cotton's Heat Rate Improvement class were incorporated into the weekly data analysis. Specifically, corrected turbine stage pressure (test data) values are compared (and trended) to the Benchmark values.

This enables diagnostics of changes in the turbine flow path, which might not be visible with normal plant walkdowns.

Selected Special Option 6 calculated variables, such as corrected Mws, condenser cleanliness factor, circulating water flow rate, and others are also trended.

The weekly BOP performance report (Figure 4), given to management, was also upgraded to incoporate the PEPSE Special Option 6 output.

How Well Does It Work?

The model has been used successfully to diagnose and determine losses with $\leq$.5%. This includes items such as ruptured extraction line bellows, MSR tube leakage, rubbed turbine seals, and dirty condensers. A summary of overall unit losses, since using the Special Option 6 model, is given in Figure 5.

The key areas for successful Special Option 6 implementation are:

1. The proper application of data analysis and diagnostics techniques.

2. A good working knowledge of the plant condition through knowledge of the plant walkdowns (check control system operation, alternate drains, steam traps and drain pots, leaking valves, etc.)

A Special Option 6 tip sheet is included in Figure 6.

Summary and Conclusions

Special Option 6 has been used routinely at Waterford 3 for the past two years. Effective model utilization requires a characterized model, the proper application of turbine diagnostics, and routine plant walkdowns.

The Plant has successfully implemented PEPSE Special Option 6 for its weekly balance of plant performance monitoring program.

FIGURE 1

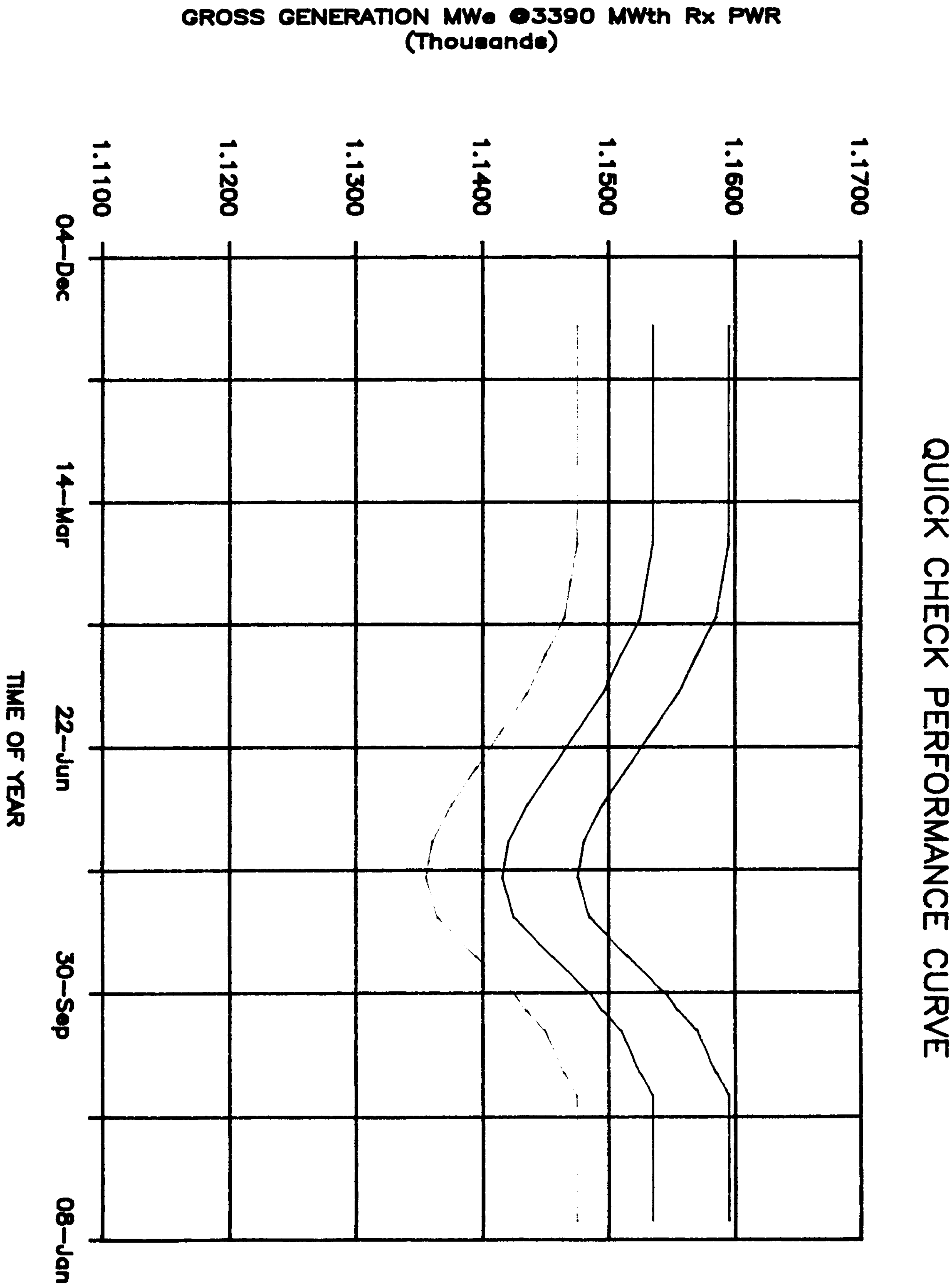

GROSS GENERATION MWe @3390 MWth Rx PWR
(Thousands)
1.1100
1.1200
1.1300
1.1400
1.1500
1.1600
1.1700
04-Dec
14-Mar
22-Jun
30-Sep
08-Jan
TIME OF YEAR
QUICK CHECK PERFORMANCE CURVE

FIGURE 2

MODEL — L

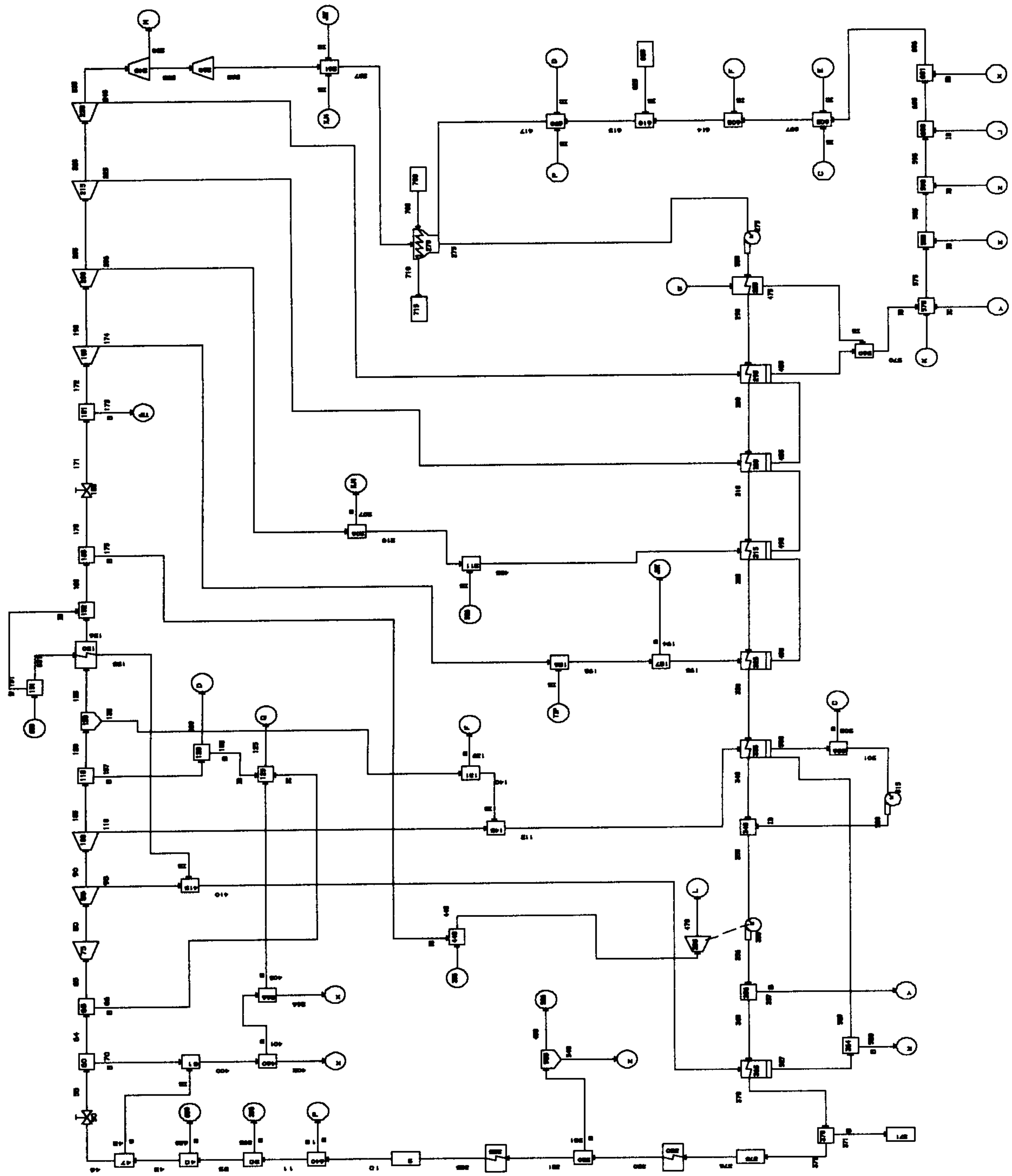


FIGURE 3

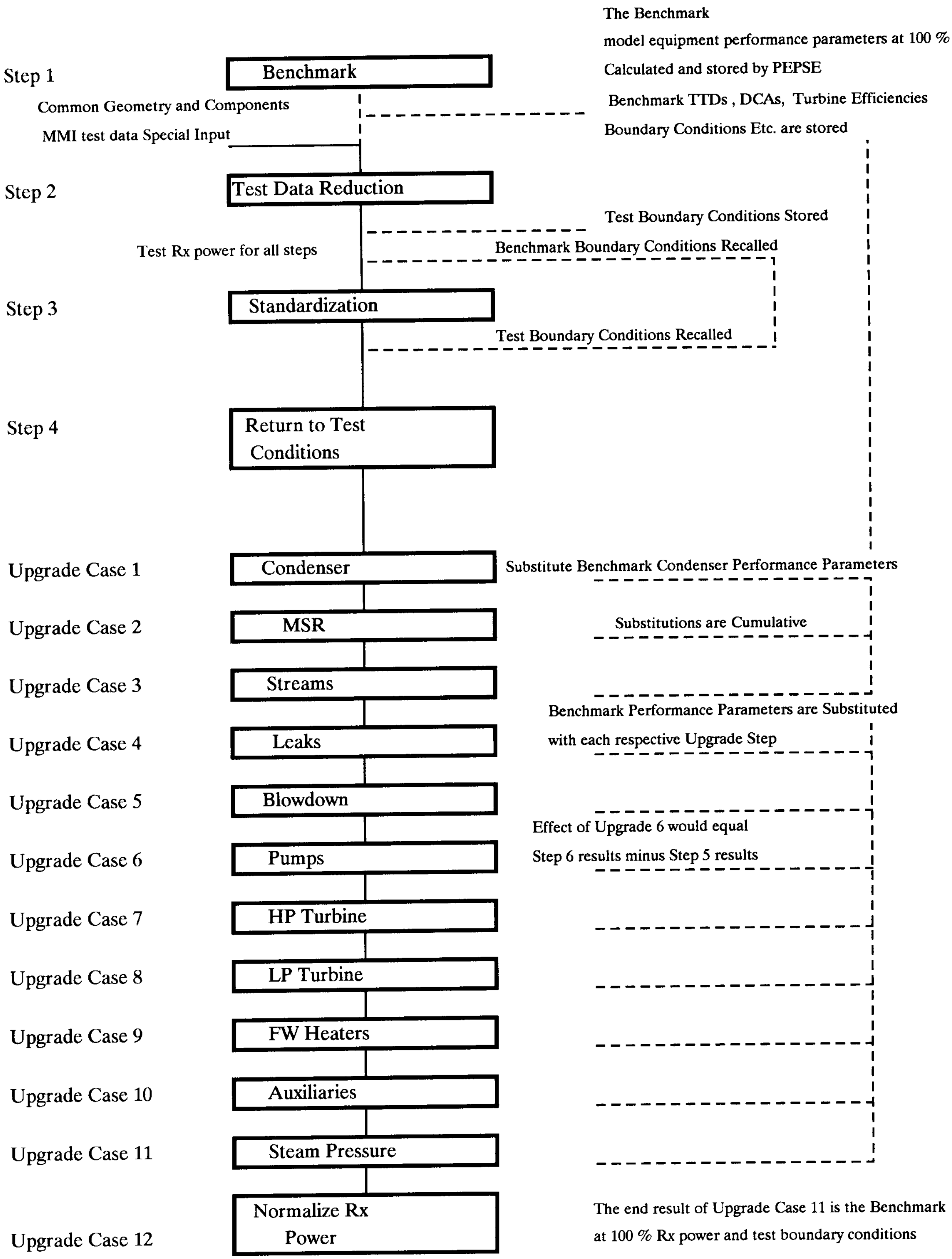
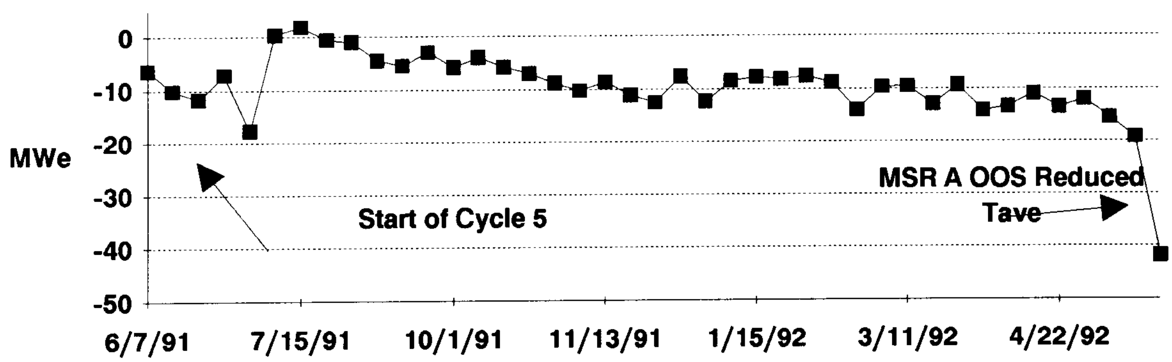

The Benchmark
model equipment performance parameters at 100 %
Calculated and stored by PEPSE
Step 1
Benchmark
Common Geometry and Components
MMI test data Special Input
Benchmark TTDs , DCAs, Turbine Efficiencies
Boundary Conditions Etc. are stored
Step 2
Test Data Reduction
Test Boundary Conditions Stored
Test Rx power for all steps
Benchmark Boundary Conditions Recalled
Step 3
Standardization
Test Boundary Conditions Recalled
Step 4
Return to Test Conditions
Upgrade Case 1
Condenser
Substitute Benchmark Condenser Performance Parameters
Upgrade Case 2
MSR
Substitutions are Cumulative
Upgrade Case 3
Streams
Benchmark Performance Parameters are Substituted
with each respective Upgrade Step
Upgrade Case 4
Leaks
Upgrade Case 5
Blowdown
Effect of Upgrade 6 would equal
Step 6 results minus Step 5 results
Upgrade Case 6
Pumps
Upgrade Case 7
HP Turbine
Upgrade Case 8
LP Turbine
Upgrade Case 9
FW Heaters
Upgrade Case 10
Auxiliaries
Upgrade Case 11
Steam Pressure
Upgrade Case 12
Normalize Rx Power
The end result of Upgrade Case 11 is the Benchmark
at 100 % Rx power and test boundary conditions

FIGURE 4

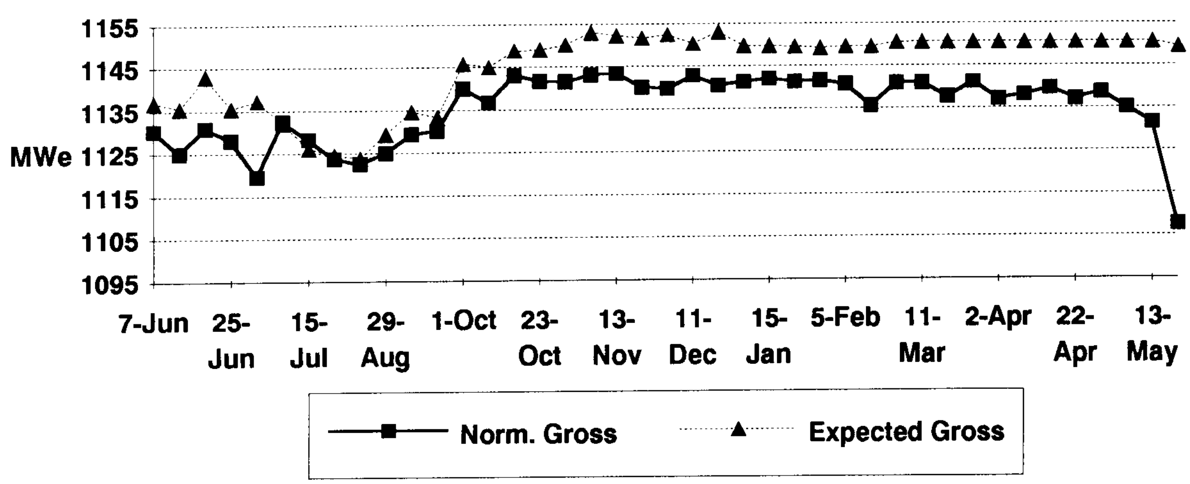
Waterford 3 Weekly BOP Performance Report

Operating Conditions :	MSR A OOS	PEPSE Run Date :	5/27/92
Rx Power	99.92 % BSCAL	Normalized Gross	1107.4 Mw
Unit Heat Ra	10454.9 Btu/kwh	Accounted for Gross Gains	0.7 Mw
Gross Load	1105.5 Mw	Accounted for Gross Losses	-39.8 Mw
Aux Load	52.4 Mw	Unaccounted for	-2.9 Mw
Net Load	1053.1 Mw	Expected Gross	1149.4 Mw

Total Gross Losses Cycle 5



Actual versus Expected Losses Cycle 5

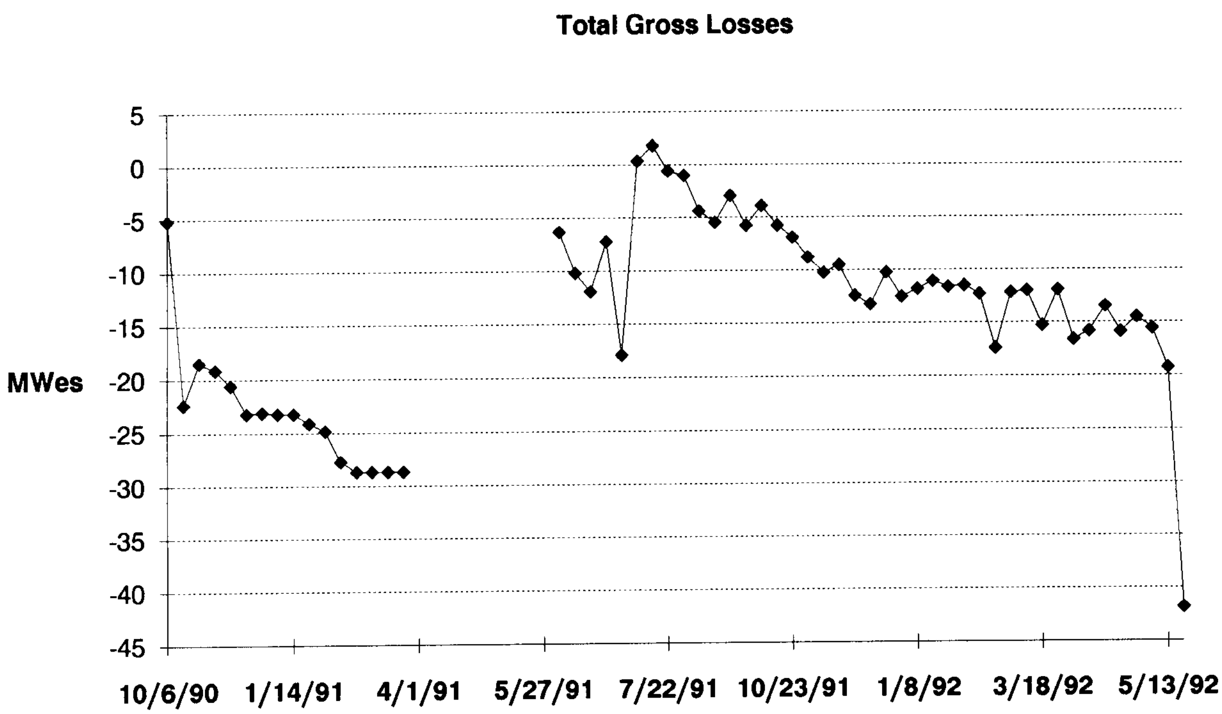


Approved by : ______________________

RE&P Department

Questions or comments ?
Call M. G. Hunt (x6670)

FIGURE 5



Total Gross Losses
MWes
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
10/6/90
1/14/91
4/1/91
5/27/91
7/22/91
10/23/91
1/8/92
3/18/92
5/13/92

FIGURE 6

Special Option 6 Model Tips

* Training

- ASME PTC Series
- K.C. Cotton Seminar

* Model Characterization

- Use actual plant data
- Use G.E. Procedures
- Use EFMULTS - Match Test Flow coefficients
- Use correction to ELEP for ExhP(CRBAEP)
- KISS - keep it simple - single
  train geometry and <50 data points
- Challenge the model - use varying sets of test data

* Diagnostics

- Monitor corrected turbine stage pressures and corrected Mws

* Plant Walkdowns

- Cycle Isolation
- Steam traps, drain pots, alt. drain valves recirc. lines
- Get to know your plant, OPS and Maint.