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Thermal Performance Program Assessment Guideline

2015 TECHNICAL REPORT

Thermal Performance Program Assessment Guideline

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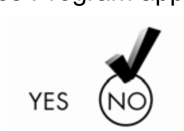

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PRODUCT DESCRIPTION

This report provides the framework for an assessment that can be used by nuclear power plants to measure the effectiveness of their thermal performance programs. Thermal performance engineers can use the results of the assessment to make improvements to plant efficiency.

Background

Thermal performance is a term that can be used in a narrow sense to describe how well a power plant converts thermal energy to electrical energy. However, the ultimate goal of a nuclear power plant is to safely produce the optimal amount of electricity. Therefore, a thermal performance program entails not only the evaluation of plant efficiency but also the optimization of electricity production through means such as limiting power reductions or scheduling maintenance at the most beneficial times. An effective thermal performance program is the key to maintaining efficiency in the plant. By performing an assessment of a plant's thermal performance program, weaknesses in the thermal performance program can be identified and corrective actions can be taken to improve the program's effectiveness in identifying avoidable losses and maximize plant efficiency.

Objective

To provide the framework for the assessment of thermal performance programs at nuclear power plants.

Approach

This report provides nuclear power plants guidance in performing assessments of the plant thermal performance program. A checklist with sample interview questions is included with guidance in this report to perform an effective self-assessment of a thermal performance program.

Results

This report provides the station with a method for measuring the effectiveness of its thermal performance program. The guidance and the checklist provided in this report can be used to perform an assessment of the thermal performance program of a nuclear power plant. The guidance provided in the report can be used for internal self-assessments, as well as external peer assessments.

Keywords

Monitoring and trending
Performance goals
Plant baseline and modeling
Search and recovery
Self-assessment
Thermal losses
Thermal performance

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1 INTRODUCTION

An effective thermal performance (TP) program ensures that equipment that could affect plant power output is functioning efficiently and will continue to perform reliably. Malfunctioning equipment can cause reduced output, plant trips, derates and forced outages. These incidences can be minimized by implementing a comprehensive program that includes plant performance testing, analysis, and results feedback. The thermal performance program will enhance and complement the equipment surveillances performed under other plant programs.

Based on the aforementioned challenges, EPRI has developed the Thermal Performance Engineering Handbook series. The handbook can be used for the development or basis of a plant thermal performance program. The handbooks are divided into three volumes:

- **Volume 1** (3002000560) describes the essential elements of a thermal performance program at a nuclear power station. The report provides guidance for plants establishing new programs or seeking to make improvements to and existing program [1].
- **Volume 2** (3002000489) provides the supporting technical details of the elements of a thermal performance program that are described in Volume 1 [2].
- **Volume 3** (3002005346) provides detailed information regarding evaluation of thermal performance issues [3].

Also, in the 1990s the EPRI Plant Performance Enhancement Program (P2EP) performed a number of nuclear plant thermal performance program assessments. These self-assessments are contained in the EPRI's P2EP Technical Library, which is an online database on the EPRI website.

1.1 Scope

The scope of this report includes reviewing the summary information, good practices, and recommendations provided in previously conducted self-assessments and those provided by current P2EP utility members. Utilizing the information provided in these sources, guidance and a checklist has been developed for performing an assessment of the thermal performance program at a nuclear power plant."

1.2 Abbreviations and Acronyms

ALARA	As Low As Reasonably Achievable
ASME	American Society of Mechanical Engineers
BAHR	Best Achievable Heat Rate
BAP	Best Achievable Performance
BOP	Balance of Plant
BOPPMG	EPRI's Balance of Plant Performance Monitoring Group
BWR	Boiling Water Reactor
DCA	Drain Cooler Approach
dT	Differential Temperature
EC	Erosion Corrosion
EPRI	Electric Power Research Institute
FAC	Flow Accelerated Corrosion
FLR	Forced Loss Rate
HP	High Pressure
I&C	Instrumentation and Control
LEFM	Leading Edge Flow meter
LMTD	Log Mean Temperature Difference
LP	Low Pressure
MOV	Motor Operated Valve
MSR	Moisture Separator/Reheater
MVAR	Mega Volt Ampere Reactive
MWO	Maintenance Work Order
NPDES	National Pollutant Discharge Elimination System
O&M	Operations and Maintenance
OE	Operating Experience
P2EP	EPRI Plant Support Engineering/Plant Performance Enhancement Program
PdM	Predictive Maintenance
PDS	Plant Data System
PHC	Plant Health Committee
PM	Preventive Maintenance

PTC	Power Test code (ASME)
PWR	Pressurized Water Reactor
SJAE	Steam Jet Air Ejector
SSC	Structure, System, Component
TP	Thermal Performance
TPE	Thermal Performance Engineer
TPMP	Thermal Performance Monitoring Program
TTD	Terminal Temperature Difference
UCLF	Unit Capacity Loss Factor
UFM	Ultrasonic Flow Measurement
WR	Work request

1.3 Definitions

Thermal performance engineer (TPE). A plant engineer assigned to overall responsibility for the site thermal performance program.

Thermal kit. A collection of correction curves normally provided by the Turbine manufacturer and used to correct turbine cycle field data for off-design conditions.

Efficiency. Measure of how effective the power plant is converting thermal power into electrical (power) output.

Reliability. A measure of the ability of a plant, system, or component to operate. For example, repeated trips of the main turbine have a severe impact on plant reliability but the steam cycle efficiency is not affected.

Heat Rate. The amount of fuel (thermal power) required to generate one unit of electrical power output.

2
ESSENTIAL ELEMENTS OF A THERMAL PERFORMANCE PROGRAM

The following summary is obtained from the Thermal Performance Engineer's Handbook Volume 1 [1]. Please refer to the Thermal Performance Engineer's Handbook Volume 1 for detailed information requiring the elements described herein.

Improving thermal efficiency of a nuclear plant is important to reduce the generation cost and to increase power output. To maintain and/or improve thermal efficiency, it is important to accurately monitor the performance of the individual components and systems. Therefore, a programmatic approach is needed to monitor the plant thermal efficiency and make adjustments and/or take corrective actions as necessary. The goals for power plant efficiency and production include:

- The efficiency of plant power generation should be consistent with the baseline generation that is corrected to the plant environmental conditions.
- The power production should be commensurate with projected plant capacity factor.

The goals of a TP monitoring program are that it effectively:

- Identifies and reports TP issues and enables corrective actions
- Optimizes outage and maintenance planning
- Optimizes plant efficiency to maximize power production

The elements that create an effective TP program foundation are described in the following sections and include:

- Baseline and modeling
- Training and qualification
- Performance goals
- Monitoring and trending
- Cycle Isolation
- Data collection and validation
- Work control and communication
- Search and recovery
- Management reporting
- Program implementation
- Industry participation

2.1 Baseline and Modeling

2.1.1 Baseline

Plant Thermal Performance Baseline data refers to the generating capability of the plant and its associated component performance under ideal conditions when the plant was new and equipment hasn't degraded. Baseline reference data is used to develop a TP model. The baseline data is needed to compare with actual generation output to identify TP issues and to search for lost generation, such as determining component degradation. Without good baseline data, megawatt losses may remain undetected and the achievable power output cannot be accurately predicted.

Testing of major components, such as the main turbine, moisture separator reheater (MSR) and condenser is performed using applicable codes and standards. Performance of feedwater heaters, condensers and other heat exchangers may be calculated and monitored per Heat Exchange Institute standards. Baseline data should be established during Turbine Testing following initial startup or through an inspection/MWe recovery program. Baseline test data is collected when the plant is operating at full power under optimum conditions (that is, known losses have been isolated and test equipment has been installed). Turbine testing verifies that the turbines meet the vendor's guaranteed performance, but also provides the utility with excellent baseline data to trend performance and to make future upgrade evaluations.

In the absence of available test data, design information (for example, turbine vendor thermal kit) can be used as an alternative to baseline testing after corrections are made to operating conditions that may differ from design assumptions, such as cooling water (river/lake) temperature or core thermal power. As a minimum, the following baseline data should be established:

- Best Achievable Heat Rate (BAHR)
- Gross Electrical Output
- Turbine Back pressure
- Turbine Throttle Pressure
- Feedwater Temperature
- Feedwater Heater Performance
- MSR (or Moisture Separator) Performance

The baseline performance data should be reviewed and updated periodically to reflect significant changes in the cycle configuration (for example, Equipment Upgrades or Thermal Power Uprates) or long-term degraded equipment performance issues.

2.1.2 Model

A well-developed model consisting of plant systems and components whose degradation or failure could potentially impact plant cycle efficiency, capacity factor, and availability can predict expected performance based on plant parameters, and indicate cycle sensitivity and response to individual parameter changes. It can also be used to perform "what if" type evaluations to prioritize maintenance or evaluate potential modifications. A detailed model would help the TPE to determine complex interactions resulting from changes to system operating parameters and/or component operations.

The plant turbine cycle systems may be modeled using commercial software and validated using the baseline data. The output of the software may also be used in analyzing performance or baseline tests. The baseline models need to be verified against plant operating data to confirm the accuracy of the model in reflecting actual plant capability. If the accuracy is not confirmed, the output of the model may mask undetected degradation.

2.1.3 Key Parameters and Indicators

The parameters and indicators, which provide information how systems and components that are important for TP are performing, should be identified. The instruments that provide this information should be identified and should be in good working order. The periodic tests or data collection, required to monitor the performance of the systems and components, should be performed in coordination with other plant activities.

2.2 Training

As the TPE strives to improve the efficiency of the unit and its components through performance trending and troubleshooting, the TPE should have a basic understanding of TP, heat balances and performance analysis. The TPE should also become comfortable with effectively using the computerized TP model. Formal training on the development and use of the modeling tool is essential, as the computer model is a complicated tool, and many TPEs often inherit heat balance models developed by their predecessors, rather than developing their own initial baseline models. It is important that the TPEs have a thorough understanding of the modeling technique, their inputs and bases, in order to make effective and accurate use of the tool.

Experience and expertise in the following areas are recognized as valuable to this function:

- Knowledge of turbine cycle systems
- Cycle heat balance experience
- System and component testing
- Instrumentation and controls
- Data acquisition, trending, and analysis
- ASME Performance Test Codes and steam turbine testing
- Reactor calorimetric

- Thermal and acoustic monitoring
- Problem-solving and root cause analysis
- Thermal performance model user training

Training may be obtained from trade organizations, various industry experts, and suppliers.

Continuing training is accomplished through participation in industry forums and annual meetings. Participation in peer reviews and evaluations of programs, methods, experience, problems, and improvements at other stations and utilities would broaden the knowledge base, and keep the TPE abreast of technological developments.

The TPE's training of other station personnel on TP and the types of activities the TPE performs, promotes better awareness of plant TP monitoring and further establishes the TPE as the point-of-contact for reporting issues.

2.3 Performance Goals

Plant Performance Goals can be established for thermal performance programs. These goals should be based on the best achievable performance (BAP) of the plant using baseline data for the current plant configuration for select performance indicators such as cycle efficiency and power output. The goal should be set at an attainable value (measurable and achievable). Goals need to be published regularly, and the plant operation with respect to the goals should be published in a timely manner. As a minimum, operation of the plant within a specified percentage or MWe variance from baseline output should be documented within the TP program.

Lower tier goals should be established such as the following to assess the TP program:

- Unplanned capability loss factor
- Weather corrected generator output
- Trigger level for unidentified MWe losses to initiate a search and recovery effort (for example, unidentified losses to more than 2 MWe).

2.4 Monitoring and Trending

TP monitoring and trending is the tool by which the TPE detects changes in plant operating conditions that may be the cause of MWe losses. Plant monitoring normally consists of routine trending of plant data and periodic monitoring of equipment parameters. Data trending involves the download, manipulation and evaluation of specific data points from the plant computer as well as manually collected data. Equipment monitoring is conducted to minimize cycle isolation leakage and optimize equipment performance.

An effective TP program will include a combination of data trending and equipment monitoring to minimize cycle isolation leakage [4] and optimize equipment performance. The trends also provide early warning of any declining performance so that timely corrective actions can be initiated. A full list of critical parameters should be identified and those parameters that currently don't have instrumentation or other monitoring methods should be instrumented. In addition to the equipment in the thermal systems, auxiliary supporting equipment should also be monitored as necessary to prevent degradation of primary equipment. While monitoring the plant systems and equipment, seasonal effects should be considered in predicting the generator output.

All data that is being monitored should be listed in a document such as a Thermal Performance Trending and Monitoring Plan along with target values and trigger values, potential causes for deviations and frequency of monitoring. TP program target values should be defined specifically. The target values should be established to allow objective evaluation of the plant health consistent with those of the system health ratings for the main systems and components contributing to plant TP. Trigger Values are used to determine the initiation of corrective actions.

Trend reports prepared by system and component engineers may also be used in preparing the TP trend reports. When adverse trends are identified, the frequency of data collection and evaluation should be increased. Historic trends of the critical parameters can be used to identify corrective actions that will improve plant efficiency and reliability. TP data and trends should be periodically reviewed against established goals and to verify the effectiveness of corrective actions. The TPE should become familiar with the components so as to assist in the determination of potential failure mechanisms that may be detected by routine monitoring.

An effective trending program should include the following elements for the overall unit as well as individual component performance:

- Key process parameters are identified and instrumented.
- Instrumentation is properly applied and installed.
- Instrumentation is maintained in calibration.
- Data acquisition and trending tools and capabilities are sufficient.

Software applications may be used to automate trending, and provide graphic displays and alarms when performance is declining. The TPE should develop TP reports and display to accurately communicate unit performance relative to baseline standards.

A typical monitoring and trending activity is as follows.

2.4.1 Daily Review

The TPE should review cycle efficiency and gross electrical output daily to quickly detect changes in performance and to initiate corrective action, as required. The operations staff is likely the first to identify changes in plant performance and, therefore, the TPE should develop a close interface with the operations staff and respond to Operations' needs for TP indicators and/or training.

2.4.2 Weekly Monitoring and Trending

Each week, the TPE should compare unit performance to the goal and evaluate any observed negative trend for potential corrective action. The weekly trend should be monitored for unanticipated changes, negative trends and excessive losses. The system engineer or component engineer may be able to help in identifying the causes and determining the appropriate corrective actions. A weekly report containing the relevant indicators, power losses and their causes should be communicated to management for further action.

2.4.3 Monthly or Quarterly Monitoring and Trending

The performance indicator for the month or quarter should be compared to the plant goal. The monthly or quarterly report, including the performance indicators and the performance of the key systems and components relative to unit TP, should be reported to station and corporate management.

2.4.4 Yearly Monitoring and Trending

The entire program should be evaluated annually for its effectiveness and to determine the need for any programmatic changes.

2.4.5 Trending Software and Tools

Computer tools can be used to make the TPE more efficient and effective. For example, trending tools for automating trending and monitoring help reduce the time required by the TPE for this job function. This will improve the plant monitoring program. Commercially available software may be used for trending. The software monitors best attainable conditions for individual components and integrates with TP modeling software program.

Computer spreadsheet programs macros or other computer software applications are highly useful for data collection and plant thermal evaluation. They minimize the TPE's time in trending. As more data is trended, enhanced computer software and hardware will be required. Detailed trending is accomplished through downloads of plant monitoring system data and data acquired by the TPE. The data is trended and graphed for all significant balance of plant components. The capability of electronically acquiring data from the Plant Data System (PDS) to the station Local Area Network (LAN) facilitates evaluation and reporting of TP data in a timely manner. The TPE needs a direct link between his PC and the Plant Process Computer to help automate report generation.

2.5 Cycle Isolation

Cycle isolation refers to eliminating energy losses through normally closed valves (for example, start-up drains to the condenser), which reduces the overall turbine cycle efficiency. Cycle isolation is an integral part of TP monitoring. This program is important for controlling minor efficiency losses in systems and components as well as for ensuring that cycle isolation losses do not contribute to equipment degradation and increased maintenance.

Often, this is an area where plant personnel can find “low hanging fruit” with great return on investment, especially with high energy valve leakage. Leakages can occur from tank-level control problems, air-operated valve setting issues, motor-operated valve thermal expansion, relief valve drifting, steam cutting of valves, improper valve alignment, foreign material in a valve and steam traps.

High energy leaks lead to decreased cycle efficiency, potential valve damage, flow accelerated corrosion and lost generation. High energy valves typically include feedwater heater dump valves, main steam line drain valves, gland seal unloader valves, turbine bypass valves, feedwater heater vent valves, reheater drain tank dump valves, condenser sparger valves, gland steam isolation valves, extraction steam line drain valves, moisture separator dump valves, heater bypass valves, feed pump recirc valves, before and after seat drain valves, steam traps and steam drain line orifice bypass valves. There are several methods to assist in detecting leaking valves and to monitor cycle isolation. Valve location, type and characteristics play a part in what method to use.

One plant estimated that about 70% of the steam traps were leaking or blowing by and causing increased water hammer and erosion downstream of the traps, as well as decreased TP. A program for routinely reviewing the status of the steam traps may offer some TP improvements. One steam trap monitoring software program compares ultrasonic and temperature readings with laboratory data, and determines if the trap operation is normal or failed, and the estimated amount of steam leakage. Other software programs may be available to calculate the leakage. If leakage is indicated, the estimated dollar cost of leakage can be calculated and trap repairs can be scheduled. Detailed information on Cycle Isolation can be found in EPRI report 1025264 – *Heat Cycle Isolation Valve Leakage Identification and Quantification* [4].

2.6 Data Collection

Data may be collected from plant computers, installed indicators or hand held monitors. Cycle isolation points may be trended using permanently installed thermocouples downstream of isolation points (and upstream for more accuracy). For those isolation valves not instrumented, temperatures may be measured with hand held pyrometer/ infrared thermometer with logging capabilities at least once every two weeks. The temperature is automatically trended at predetermined cycle isolation points. From the temperature data, leaks can be quantified.

2.7 Work Control and Communication

Good communications between the TPE and various work groups are essential in maintaining a plant's cycle efficiency as high as possible. It is important that the TPE form very strong relationships and brainstorm with Systems Engineering, Maintenance, Operations and Chemistry Management to improve TP and to ensure full plant awareness of the TP issues and resolution of MWe loss issues.

When deviations in performance are identified, condition reports and troubleshooting plans (as appropriate) should be initiated in a timely manner, the program should properly investigate and quantify the deviation(s) and actions to remedy the deviation(s) should be initiated and tracked. Appropriate actions should be initiated for <u>repeat</u> TP problems to identify why the problem recurred and what actions were taken to avoid future recurrence. The issues should be escalated to Engineering leadership via the reporting process.

The TPE's interface with the work control process ensures TPE awareness of, or concurrence with the deletion or deferral of any work activities initiated to correct TP declines. This interface allows TP goals to be adjusted in a timely manner.

The interfaces of the TP program with other plant programs and activities such as preventive maintenance (PM) inspections should be coordinated so that an overall performance testing and reliability analysis program is defined and maintained without duplication of effort.

2.7.1 Operations Interface

The operators often are first to observe performance declines or questionable changes in parameters, and they should be encouraged to consult the TPE immediately in those instances.

2.7.2 Maintenance and Outage Interface

Maintenance tasks that affect TP should be given the appropriate priority to ensure timely completion. Maintenance and outage management staff should be made aware of the impact of not performing the tasks related to TP. The tasks may be prioritized according to economic/reliability value.

2.7.3 Engineering Interface

The TPE is typically assigned from the system engineering organization, which facilitates a strong communication link with the system and component engineers for problem identification and resolution at the system/component level. In addition, a good interface must be developed between the TPE and the design engineering staff to ensure that design modifications are properly evaluated for TP impact. The TPE also interacts with other engineering programs such as the flow-accelerated corrosion, air-operated valve and steam generator programs to address known leakage paths and performance problems.

2.7.4 Chemistry Interface

The station chemistry department maintains condensate/feedwater chemistry, including dissolved oxygen levels, within appropriate limits for control of corrosion in the fluid system components. Excessive air in-leakage to the condenser may cause elevated back pressure and reduced electrical output, and is often evident in excess dissolved oxygen levels in the condensate/feedwater. Other condenser system or air-removal equipment deficiencies may cause elevated dissolved oxygen. For these reasons, the TPE and TP program must work closely with the chemistry department.

2.7.5 Business Analysis/Generation Planning Interface

It is important that the TP program interface directly with the business analysis/generation planning organization to establish measurable and achievable annual performance goals. This interface will also ensure that critical parameters are consistently selected and used to report unit TP. For program monitoring and overall program effectiveness, the TPE and the business analysis/generation planning representatives should meet with the station management at least once a year to review TP indicator trends versus goals and program effectiveness.

2.8 Search and Recovery

If plant operation cannot be maintained at the baseline, or if goals cannot be achieved, then a search should be initiated to identify how the losses are occurring. The Search and Recovery team should include the TPE, system engineers, Chemistry, Operations, Maintenance and I&C as required. A structured approach may be used to identify MWe losses. The TP program should identify critical performance parameters and a list of all cycle isolation valves that isolate high-energy steam, feedwater, condensate or drain flows from the condenser during normal, full-power operation. These flow paths should be evaluated using the heat balance model or other methods, such as special testing, to quantify their potential contribution to power losses. Thermal performance Troubleshooting information is provided in EPRI Report 3002005346 – *Thermal Performance Engineering Handbook, Volume 3* [3].

2.9 Management Communication and Reporting

There should be frequent communications between the TPE and all levels of plant management involving goal setting, trends and lost MWe recovery actions. Continued management interest in TP should be encouraged. The effectiveness of the thermal performance monitoring program should be periodically evaluated, and the results should be used to make program improvements. Industry and plant operating experience, test results, and so on, should be factored into the program. Major results of the evaluation should be summarized and disseminated to management.

The TPE should evaluate potential operating and design configuration changes that may impact TP, and communicate any significant impact to the appropriate group and to the plant management before the changes are implemented.

Emergent TP issues should be effectively communicated to management and to relevant plant personnel via periodic reports. All MWe losses should be included and categorized by system or cause-area in the periodic reports to management. The report should also assign dollar amounts to each MWe loss. This may help management prioritize work.

The daily report and a curve of best achievable MWe vs. circulating water inlet temperature should be issued to Operations, so that Operators are sensitized to TP issues, are able to understand where the plant is operating with respect to the expected output based on turbine back pressure and thermal power, and be able to proactively manage system configurations to maximize TP.

A summary weekly report should typically consist of electrical output, standard plant parameters (turbine back pressures, circulating water temperatures, and so on) and electrical losses, showing deviation from the baseline. The report should also identify individual components or systems responsible for lost MWe that have been accounted for but could be recovered with proper maintenance or attention.

Monthly and quarterly trend reports should provide concise high-level performance information (efficiency loss, derates, capacity factors) for advising management on issues relative to TP trends to goals. The Monthly Report should also present the impact of equipment deficiencies and the problem type.

The TPE should review generation losses recorded in the monthly TP reports from the previous 12 months with Management. The review should include the actual net generation versus the expected generation and the causes. A cost-benefit analysis may be performed for the losses versus fixing the causes of the losses. Where fixing the causes of the losses is justified, the TPE can initiate corrective actions and follow through by tracking the status in the Monthly TP Report completion.

2.9.1 Health Reports

The TP program health report is a very effective tool to document and communicate the status and effectiveness of the TP program. The TP program health report provides the basis for revision to the program structure and objectives. The TP program health report should focus more on the ability of the TP program to provide monitoring and reporting of the plant TP, not necessarily how well the plant is operating.

Although the health report may be adopted in place of TP monthly or quarterly reports, it should also concentrate on the programmatic health. The program health report should address overall program health criteria and indicators such as the following:

- Program health status (color)
- Station cumulative TP compared to goals
- Open/significant program problem reports
- Open program issues backlog
- Recent operating experience/disposition status
- Recent assessment findings and status
- Adverse program trends/action plans/responsibility
- Outage activities preparedness

The TP program health may be monitored using the following criteria:

- Unaccounted power output deviation exceeds TP trigger values.
- No backlog of open issues or corrective actions exists that affect TP.
- All required program documentation is in place and up to date with unit configuration.
- TP program personnel are appropriately trained and qualified.
- Risks to the health of the program are recognized and addressed, for example, pending TP retirements/transfers, budget concerns, and so on.
- TP program periodic self-assessments are conducted.
- Actions required to recover from any degraded or unacceptable programmatic health status are being implemented.

The TP program health rating is determined from the weighted score of each of the attributes. Each attribute should be weighted based on its importance to the TP program and then scored based on its deviation relative to its target value.

2.10 Program Implementation

A TP program document should be prepared, and the TP program should be implemented in accordance with the program document. A TP program document is crucial to improving the attention to TP at the station. TP program should have a formalized governing procedure(s) covering all important aspects of a TP program and should be well written and easy to understand. The program documents should contain job position description for the TPE and additional lower tier goals for the TPE delineating the position's roles, responsibilities, authorities, interfaces, and so on, The TPE should be responsible to implement the TP program. The TPE should also be responsible for day-to-day monitoring and supervising the program as well as updating the program based on lessons learned and industry input. The TPE will also maintain the program documentation. With program document(s) in place, a new TPE should be able to step in and keep the program performing in a manner expected by management.

Procedures should contain problem identification and fault tree analyses with expected plant response for changing plant conditions. A desktop instruction is recommended to be prepared to detail the daily activities of the TP program.

2.11 Industry Participation

As the industry continues to increase its focus on cost containment and efficiency improvement, it becomes increasingly important to share experience and to standardize methods. Participation in industry meetings such as EPRI's annual P2EP can increase the TPE’s awareness of industry issues and solutions. Networking contacts made with others in the performance engineering community add to the TPE’s understanding of plant performance evaluations and provides improvement strategies for future use.

The TPE’s participation in self-assessments and benchmarking reviews of TP programs at other plants and utilities is very beneficial and should be encouraged as an integral part of the TP program.

Being aware of and using operating experience is an important tool in defining TP program weaknesses. This information may be obtained from a station organization responsible for operating experience or directly from relevant websites.

3 EFFECTIVE SELF-ASSESSMENT

The TP program should be assessed for effectiveness on a periodic basis. Because TP deals with economics rather than regulatory compliance, the frequency of the TP assessments is flexible. The assessment frequency may be adjusted based on the results of prior assessments, with increased frequency warranted to monitor improvement of weak TP programs.

The self-assessment should be performed in accordance with the station self-assessment process, if it exists. The self-assessment should be performed by reviewing the TP program documentation and databases, as well as interviews with plant TPE and other plant personnel. The self-assessment can help with suggestions and recommendations for TP program improvements.

The following guidelines are generic and can be followed or modified in performing a self-assessment of the TP program. Appendices A thru E provide a sample checklist, a list of potential documents to be reviewed, a list of equipment focus areas, a sample list of questions to be asked during the interviews, and TP degradation indicators.

3.1 Expected Benefits of a Self-Assessment

A TP program self-assessment is an excellent tool for the TPE to improve the TP program at the plant by identifying strengths and weaknesses in the program and communicating suggestions for improvement.

A self-assessment will examine the TP program and its interfaces with other plant departments, programs and processes, compare it to industry best practices, and provide recommendations for program improvements.

Benefits to be expected from the self-assessments include:

- Make relevant departments, personnel and management aware of the importance of TP and its effect on plant cycle efficiency, capacity factor and profitability.
- Evaluate plant TP program and its effectiveness with the management objectives, and to provide accurate monitoring of plant TP.
- Compare plant TP program with industry norms and best practices, and provide recommendations to enhance the program.
- May identify causes for lost MWe.

3.2 Scope of Assessment

The scope of the assessment needs to be established at the time the commitment is made to perform the assessment and should be defined clearly prior to the initiation of the assessment. The assessment may include the program assessment only, or may include a more in-depth assessment of megawatt losses if plant output is lagging the baseline output for unaccounted reasons.

3.3 Objective of the Assessment

The objective of the assessment is to evaluate the effectiveness of the existing TP program. It should also provide recommendations for program improvement. Objectives should be established in consultation with the plant TPE or management with responsibility for the performance and success of the assessment.

The objectives of the assessment are to ensure:

1. Effective implementation of a TP program with the attendant program procedures/guidelines and procedural compliance, and process technical rigor of the TP program.
2. The TP program makes efforts to drive for continuous programmatic improvement.
3. Completeness and accuracy of the TP program documentation (for example, Notebooks) and qualifications.
4. Effective identification of degraded performance and tracking to completion of corrective actions. Assess if the program effectively monitors and trends actual performance against that predicted by the baseline models.
5. Reconciliation of losses and gains from design output to the daily actual output, and corrective actions that capture the status of efforts to "recover" identified megawatt losses.
6. Effective reporting of findings, trends and results to Management, System Engineer(s) and Plant Engineering Manager (or Program Engineering Manager) and others as appropriate and in a timely manner.
7. The TP program is effective in reducing MWe losses, maximizing capacity factor and improving unit cycle efficiency.
8. Improving equipment reliability by interfacing with other plant programs to improve equipment performance, reduce unplanned load reductions and detect and prevent equipment-related failures.
9. The effectiveness of Core Thermal Power (CTP) monitoring and alternate monitoring to assure CTP is accurate and within licensed limits.

3.4 Conduct of Program Assessment

The following are considerations in performing the assessment. Appendix A of this report provides an assessment guideline/checklist, which is generic and written with the intent that it will be modified by the audit team for the specific plant that is being assessed. Listed below are typical assessment activities:

- Pre-assessment:
  - Develop the assessment plan
  - Selection of assessment lead and assessment team members
  - Briefing of the assessment team (one half day)
  - Review of plant and TP program documentation (as needed by each individual, up to two full days)

- During assessment:
  - Entrance meeting with plant management
  - Interview sessions
  - Team reviews activities of each day
  - Final document gathering, if needed
  - Follow-up interviews, as necessary
  - Team compiles strengths, weaknesses and observations by area
  - Team evaluates plant relative to industry best practices
  - Team scores plant in each TP program area
  - Team develops and prioritizes recommendations
  - Results assembled for presentation to management
  - Final presentation to management produced
  - Exit meeting and presentation with plant management
  - Discussion of recommendations with management
- Post-assessment:
  - Final draft assessment report completed and issued
  - Plant response reviewed
  - Follow-up activities scheduled as needed and final report issued to the plant

3.4.1 Assessment Plan

The identified assessment team leader should develop an assessment plan in consultation with the plant TPE and consider including the following aspects in the development of the assessment plan.

Assessment Scope and Objectives. The assessment scope and objectives should be finalized with the plant TPE and clearly defined in the assessment plan. The scope should include a review of station TP elements such as program procedures, performance goals, station compliance with program requirements, baseline documentation, configuration control, effectiveness of root cause determinations and corrective actions, effectiveness of program reporting and communications, use of appropriate tools and techniques, program staffing, and TPE qualification and continuing training. For each stated objective, the assessment should identify measurable goals and measurement criteria, references and supporting analysis and methodology. The assessment plan should identify specific attributes and elements to be reviewed for each functional area.

Management Involvement. Management involvement is essential for the success of the assessment as well as for the implementation of the assessment recommendations after the assessment is completed. The entrance meeting between the assessment team and station management should be scheduled to familiarize management with the scope and approach of the assessment. The exit meeting should be scheduled to brief management on the conclusions and major recommendations of the assessment and to answer any questions management may have.

Operating Experience. Recent operating experience related to the TP program should be reviewed and a list of relevant issues should be compiled to identify how well the plant is knowledgeable and addressing their impact on the plant.

Previous Assessments. The assessment team should include a review of previous TP assessments, as well as other assessments for TP issues, and assess plant progress in addressing previous recommendations, identifying any open issues. This review also highlights repeat issues so that suitable recommendations may be made for long term solutions.

Corrective Action Program and Maintenance Backlog. Plant databases should be reviewed to identify outstanding thermal-performance-related work orders or corrective action items and how long they have been outstanding. They should be reviewed to identify trends and repeat problems. A sample of components should be checked to determine if PM/PdM and testing are being implemented.

Interviews with Plant Personnel. Interviews should be scheduled with relevant department personnel to determine their awareness of TP program objectives and ownership, as well as their role in maximizing TP.

Field Observations. TP program-related activities such as lost megawatt search and recovery (inspections, testing or maintenance) or periodic performance evaluation activities should be observed and reviewed.

3.4.2 Assembling the Assessment Team

The team leader should be knowledgeable of, but not currently involved in the TP program under assessment. Enlisting qualified TPEs from other plants should be considered. Note that some companies/plants require that the plant program owners (TPE) lead their respective assessments. It is recommended the assessment team be composed of peer plant TPEs, EPRI representatives and its consultants, and other select subject matter experts. Independent experts should be chosen based on their knowledge of the subject matter and industry expertise. The assessment team may typically consist of four to eight persons, potentially including two TPEs from peer plants (or corporate office) and two to three industry experts. At least some of the assessment team members should have participated in TP assessments in the past.

3.4.3 Briefing of the Assessment Team

The individuals selected for the assessment need to be briefed on the responsibilities of team members, common objectives, and methodology.

The briefing should include the scope and objectives as agreed with the plant TPE/management. The assessment plan should be discussed and the team members should understand their roles and responsibilities and the overall schedule, including detailed steps to be taken by each team member during the site visit and afterwards. Any clarifications that may be required should be resolved prior to the assessment.

3.4.4 Reviewing Plant Information

All team members should be familiar with the plant heat balances, turbine cycle design and recent MWe recovery efforts. The TPE of the plant should provide as a minimum: (1) a 100% power design heat balance from the thermal kit and station baseline heat balance, (2) a copy of any procedure(s) relating to the plant's TP program, (3) a copy of any report(s) sent to management on TP, and (4) recent plant data.

TP program implementation documents compare the relationships of the TP program elements with relevant plant processes and procedures, and how TP elements are integrated with them. Program infrastructure is assessed such that the organizational structure and available resources are sufficient to ensure program success. These documents should be reviewed by the team members prior to the assessment.

3.4.5 Site Visit

The assessment typically lasts for one week on-site. The site visit time should be chosen that is convenient for the plant personnel and the assessment team members. Outage periods should be avoided as the plant personnel are typically busy and may not be able to devote the time necessary for interviews, and so on.

3.4.6 Site Visit Entrance Meeting

The TP program assessment involves various plant departments and divisions. Therefore, the TP assessment requires a notification of assessment to the plant departments and a pre-assessment management briefing. The plant TPE may inform relevant departments of the assessment team and solicit their cooperation.

The assessment team should plan to attend a management briefing on the first morning of the assessment week. A short briefing to the management and the affected department supervisors (Maintenance, System Engineering, Operations, Chemistry, and so on) and other TPEs should include the purpose of the assessment, an introduction of the assessment team, objectives of the assessment, proposed schedule and a summary of the potential assessment outcomes.

3.4.7 Field Observation

If possible, a plant tour or review of photos may be helpful to allow the team members to get a feel of the material condition of plant systems and components, and may even include observation of TPE work activities in performing a cycle isolation study or taking instrument data collection.

3.4.8 Interviews

Interviews should be conducted with individuals that have a stake in the TP program. Individuals selected will vary with the plant and existing program structure. Below is a guideline for selecting potential interviewees, to include:

- TPE
- Plant Manager
- Engineering Managers (Design Engineering and Systems/Program Engineering)

- Operations Manager/Control Room Operators
- Maintenance Manager/Maintenance Supervisors
- Work Control/Outage Manager
- Turbine Cycle System Engineers
- Component Engineers – Turbine Cycle Components

Interviews should be performed as early as possible during the site visit to allow enough time to conduct any follow-up interviews.

The TPE should consult with the various interviewees of their availability and schedule prior to the assessment team arrival and preferably finalize the schedule in consultation with the assessment team lead prior to the team site visit.

Prior to the interviews, the team should strategize how to get the most from the interviews. Each assessment interview team preferably consists of two members familiar with the areas of the personnel being interviewed. The team should then divide up the interviews to make best use of their respective subject matter expertise and experience.

Each team should have a lead assessor who will pose questions. The other team members may seek clarification of points made. One of the reviewers, other than the lead, should take notes of the interview. After the lead assessor has completed their list of questions, other assessors can ask questions for additional information. The assessment members should ask questions that elicit information for a complete understanding of the practices of the interviewee's area. Finally, the interviewee should be asked to make any additional comments related to the TP assessment scope and objectives.

Immediately following the interview, the notes should be reviewed, clarified, and areas that are not clear should be marked for a follow-up interview. Results that indicate a potential strength, weakness or other significant observation in any of the assessment areas should be identified and recorded at this time.

The following is a list of general questions designed to gauge the vertical and horizontal communication and understanding of the TP Monitoring Program:

- Tell us your understanding of the TP Monitoring Program at your plant and your interface with the TPE.
- What is your role in monitoring and optimizing plant TP?
- What are the largest MW or availability losses in the plant right now? What is being done to address them?
- Are there any future MW improvement/recovery initiatives being planned?

The team members should interview the TPE about all aspects of TP including, but not limited to, management support, how the TPE came up with circulating water temperature correction curves, the plant process computer system, routine data gathering, analysis and reporting, and the TPE's interface with the system engineers, Maintenance, Operations, Chemistry, Management, and so on.

System Managers, Operations personnel, Maintenance personnel, PM/PdM coordinator(s), and so on, should be interviewed. At the end of each day the assessment team should convene for debriefing and discussion. Each interview should be verbally summarized for the entire group. Each team member has the opportunity to question, comment or suggest a potential observation, strength or weakness. The keeper of the interview documentation should record significant results of the discussion. Throughout these discussions, other significant observations may evolve unrelated to a specific interview.

Questions will inevitably arise that require further investigation. Resolution of these questions should be assigned to individuals, who will report the results at a later debriefing session. These sessions should also identify additional interviews needed. These secondary interviews should be scheduled in the block of time set aside for follow-up interviews.

The follow-up interviews should focus on resolving questions and issues that came up during debriefing. Interviewees should be informed of this focused intent. However, interviewees should still be invited to ask any questions and comment within the assessment scope. The results of the follow-up interviews should be recorded in the same manner as the primary interviews.

3.4.9 Plant Database and Document Review

Potential plant documents that may be reviewed are identified in Appendix B. In general the following steps may be used in reviewing plant documents:

1. Review documents, computer databases, files, and so on, used as TPE monitoring tools and routine monitoring files of plant performance.
2. Review a sample of plant data and TP tools used by the station for periodic monitoring against the TP procedures.
3. Review management support to the TP program, and if enhancements to improve implementation are supported by management (for example, upgrades in system monitoring equipment, test equipment, or software), including opportunities/efforts to initiate or expand the parameter monitoring.
4. If gaps are identified in the adequacy of program compliance or program health, check if an action plan has been formulated and is being executed in a timely manner.
5. Verify if the TPE is calculating the net and gross outputs, all losses and gains from baseline output to the daily actual output, and provide Operations with baseline vs. actual output and summary of losses.
6. Verify if the TPE is routinely reviewing with appropriate system managers the System Health Reports for those systems that may impact TP. Attention should be given to adequate intrusiveness into system and component risks of generation loss, and to timely and early planning of resolution actions.
7. Verify if a TP action plan that captures the status of efforts to “recover” identified megawatt losses or improves the TP program is being generated.

8. Review if program deficiencies identified are documented in the station Corrective Action Program, and are properly prioritized and resolved in a timely manner, consistent with their significance and are tracked to closure.
9. Review TP-related corrective action items created for resolution of TP issues and the appropriate disposition of the related issue(s). The TP action plan should be reviewed to identify current issues, together with confirmation that appropriate actions are in process.
10. Check if the results of the program are made visible to management through plan-of-the-day, daily or weekly reports, and so on. Check if the TPE appropriately notifies management proportionately to the importance of identified issues.
11. Check management response to the identified issues and the corrective actions initiated by the management.
12. Identify examples of opportunities and actions that demonstrate that the goal of continuous programmatic improvement is a focus for the station's TP program.
13. Verify that cost effective material condition TP-related improvements are being identified and pursued, as documented in TP action plans.

3.4.10 Assessment Team Consensus and Closure

From the interviews and reviews, the assessment team should identify by consensus strengths, weaknesses and observations in each aspect of the TP program. The effectiveness of the TP program should be assessed through an objective scoring of each functional area or attribute. For example, the program status in each area can be determined by a voting of the assessment team members on a scale of 0 to 10. The score is intended to estimate the percentile ranking of the plant in that attribute, with a score of 10 representing the 100th percentile. The following scoring may be used:

- Score 0 to 1 – Does not exist or close to non-existence, deficient
- Score 2 to 4 – Not effective with significant improvements required
- Score 5 to 7 – Effective with significant opportunity for improvement
- Score 8 to 9 – Best Practice, may have some room for improvement
- Score 9 to 10 – Best that can be implemented and no cost-effective improvements can be identified

A radar chart can be utilized to show the scores in a graphical depiction. Figure 3-1 represents the assessment areas as radial lines on a radar screen. Each radial line is graduated with a scale from zero to ten.

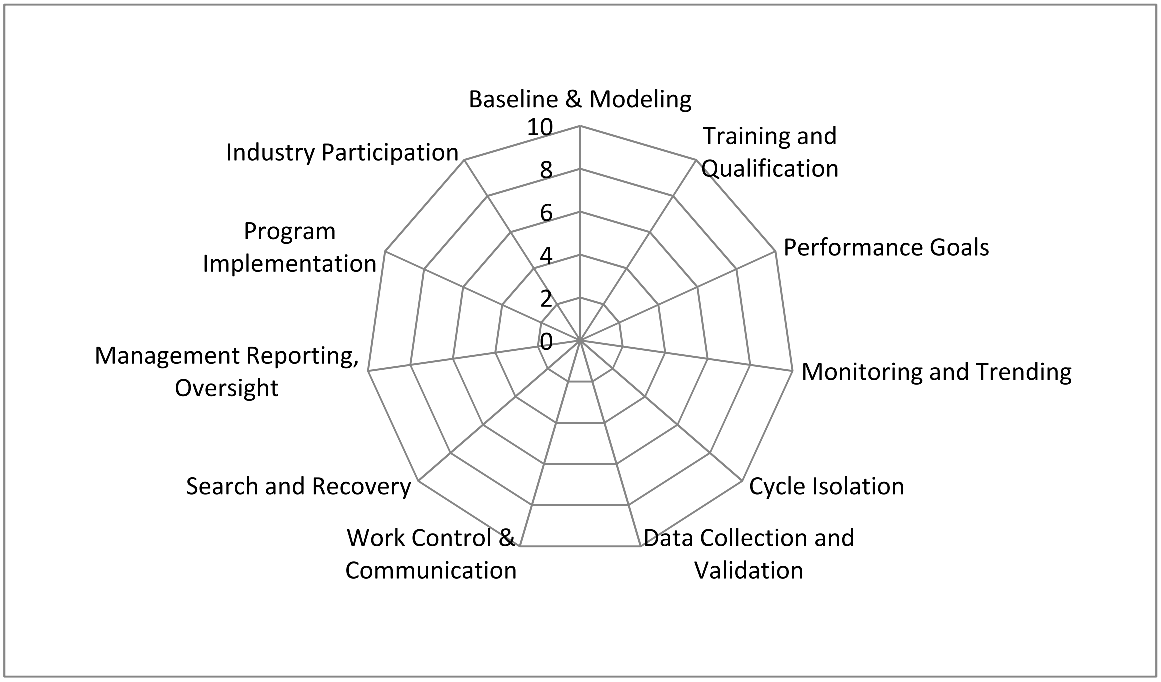

Figure 3-1
Blank Radar Chart

Area 1: Baseline and Modeling

Area 2: Training and Qualification

Area 3: Performance Goals

Area 4: Monitoring and Trending

Area 5: Cycle Isolation

Area 6: Data Collection and Validation

Area 7: Work Control and Communication

Area 8: Search and Recovery

Area 9: Management Reporting

Area 10: Program Implementation

Area 11: Industry Participation

The following guidance may be used in scoring various attributes of the program and evaluating the results of the scored radar chart.

Area 1: Baseline and Modeling

10	Industry Best – Testing and/or modeling is performed to reconcile losses and gains from baseline models to the daily actual output before and after significant plant modifications. The plant maintains a thorough, accurate and validated model of the turbine/condenser/feedwater cycle using TP modeling software. Modifications require signoff by TPE for evaluation of impact on thermal performance.
5	Compliance– Baseline has been defined, but has not been kept up to date. Thermal systems are modeled, but model has not been updated to reflect latest modifications. TPE is aware of upcoming modifications and has assessed their applicability to the TP.
0	Needs Improvement – No baseline data is available. Thermal systems have not been modeled using a software program. TPE does not review modifications for thermal performance impact.

Area 2: Training and Qualification

10	Industry Best – TPE is fully qualified and a program of continuing training exists. Backup TPE is fully qualified and proficient in the TP Monitoring program. The TPE demonstrates experience and expertise in all elements of the TP monitoring program. The TPE achieves continuing training through industry forums, peers reviews, evaluations of other stations and/or specific industry courses.
5	Compliance – TPE is fully qualified. Backup is assigned. Some additional training attended.
0	Needs Improvement – TPE is not fully qualified. No backup assigned.

Area 3: Performance Goals

10	Industry Best – The performance goals, e.g., Capacity Factor, FLR, Program Health and other required indicator data as are accurately calculated and reported to all relevant departments in the plant. Goals are achievable, proactive and consistent with operational, maintenance and modification costs. A long time strategy for MWe improvement or uprate is established.
5	Compliance – Performance goals are calculated.
0	Needs Improvement – No goals calculated or do not reflect present configuration.

Area 4: Monitoring and Trending (including trending software and tools)

10	Industry Best – Performance parameters are identified, and performance monitoring of systems is performed on a periodic basis and controlled by work instruction or procedure. Software data management and analysis tools are effectively used. Appropriate parameters are corrected for certain operating conditions before they are trended. The program effectively monitors and trends actual performance against baseline models. Ranges of trends are appropriately set to identify changes in unit performance over time. Trends are reviewed at least weekly (preferred daily).
6	Compliance – Performance parameters are identified, performance monitoring occurs on a periodic basis using ad hoc procedures. Trends are reviewed infrequently.
1	Needs Improvement - Performance monitoring occurs when requested by other site groups. Long standing thermal performance issues persist.

Area 5: Cycle Isolation

10 Industry Best – High energy valves and steam traps are identified, instrumented and monitored on a frequent basis, and Condition Reports are written and followed through when deficiencies are identified. Computation algorithms are automated, accurate and calculate economic impact of leakages. Monitored losses are divided into avoidable and unavoidable losses flow paths.

5 Compliance - High energy valves and steam traps are identified, some are instrumented, others measured manually. Parameters monitored on a periodic basis.

0 Needs Improvement – High energy valves are not identified or not monitored on a periodic basis.

Area 6: Data Collection and Validation

10 Industry Best – Valid data points are identified. Thermal systems are mostly instrumented, and those that are not instrumented are periodically tested. Data is collected from the plant computers and automated for easy trending. BOP instrument calibration specifications are evaluated and frequencies are appropriate. Data validation techniques are programmatically controlled and automated. House loads are monitored, trended and evaluated for possible optimization/reduction.

5 Compliance – Thermal systems are instrumented to some extent and data is trended using software.

0 Needs Improvement – Very little accurate data is available for monitoring. Available data from installed instruments is collected but not periodically reviewed for abnormalities. Instrument calibrations are not periodically checked.

Area 7: Work Control and Communication

10	Industry Best – The TPE has very effective and periodic communication/interface with Design Engineering, Maintenance, Operations, Systems, FAC, Reactor Engineering, Project Management and Chemistry, and attends their group meetings. These groups are very familiar with plant TP and prioritize TP issues. Performance objectives and goals, key parameters/trends and O&M strategies are effectively communicated for program success. Maintenance and outage work to address thermal performance deficiencies is effectively and appropriately prioritized.
5	Compliance – TPE has good working relations with interfacing groups, identifies TP priorities and follows up on TP issues.
0	Needs Improvement – TP issues, identified to the plant groups, are communicated as schedules allow. Plant departments have little consideration for TP. Managers in other departments do not know the TPE.

Area 8: Search and Recovery

10	Industry Best – The plant has a structured formal search and recovery process that has been found successful in identifying and recovering MWe losses. Search and recovery actions are triggered by key parameters with established thresholds, and use a proactive approach beginning with component level performance data. O&M practices and plant modifications are implemented to achieve thermal performance goals.
5	Compliance – The plant has a standard search and recovery process, and losses are identified and recovered.
0	Needs Improvement – Plant has no established search and recovery process.

Area 9: Management Reporting/Oversight

10	Industry Best – TPE issues periodic, timely reports and identifies TP issues and causes of losses to immediate supervision, system managers and senior management via reports and presentations. Corrective actions are initiated for performance deficiencies and tracked to completion. The TP program is visible to management through Plant Health Committee presentations and critical Program Health Reports. TP Program enhancements are supported by management and adequate resources are dedicated.
5	Compliance – TPE issues periodic reports identifying TP issues and causes of losses to the management.
0	Needs Improvement – Reports are issued infrequently, no presentations are made or no meetings are held with management to discuss TP issues. Management is not briefed on TP issues in a timely manner and does not support TP Program enhancements.

Area 10: Program Implementation (including procedures and documentation)

10	Industry Best – A formal program exists with program procedures, well defined division of responsibilities, clear communication lines, and TPE and backup responsibilities delineated. Gaps in program compliance or program health are promptly identified and action plans are executed. Program Health Reports indicate programmatic excellence. Documented guides with checklists and logs are utilized to conduct routine performance monitoring and reporting, and to troubleshoot thermal performance issues.
5	Compliance – A formal program exists with TPE and backup identified and division of responsibilities defined.
0	Needs Improvement – No formal program exists, and the TPE is either full time or part time with no backup identified.

Area 11: Industry Participation

10	Industry Best – The TPE holds a major role in the industry organizations. The TPE is invited to participate in both internal and external TP program assessments. Includes industry peers in plant program assessment and factors in OE. Industry issues are known and mitigation plans are established.
5	Compliance – TPE participates in industry programs and supports plant TP program self-assessment. OE is reviewed and TPE is aware of generic industry issues.
0	Needs Improvement – TPE does not participate in industry groups and no self-assessments have been performed. OE is not reviewed.

For areas that need improvement, a list of observations may be prepared along with recommendations. The recommendations can be prioritized by a voting of the assessment team members on a scale of 0 to 10. An effective means of prioritization is for each reviewer to distribute 10 voting points among the alternatives in any way he or she chooses with the following constraints:

- Each participant must distribute his or her voting points on at least three candidate enhancements.
- Each participant may vote no more than five points on a single recommendation.

3.5 Assessment Report

The assessment team report should include:

1. List of assessment team members
2. List of interviewees and other contributors
3. Assessment objectives and scope
4. Measurement criteria and methodology for evaluating each assessment area and objective
5. Strengths, weaknesses, and other significant observations by assessment area
6. Summary of findings and metrics for each functional area/attribute, with quantification of results plotted on the radar chart
7. Identification and prioritization of TP program enhancements and areas for improvement or deficiencies
8. Recommendations for actions to address highest priority TP enhancements

The assessment team should then present the results of the assessment at a briefing to plant management and appropriate plant staff. The briefing should restate the objectives of the assessment and should summarize items 5 through 8 above.

The draft of the assessment should be provided to the TPE and should incorporate comments and results of follow-up activities identified in the management briefing. Upon completion of the assessment, the TPE and the Lead Assessor should prepare and issue a summary report outlining the assessment results and recommendations.

4
REFERENCES

1. *Plant Engineering: Thermal Performance Engineering Handbook, Volume 1: Supersedes TR-107422-V1*. EPRI, Palo Alto, CA: 2013. 3002000560.
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3. *Thermal Performance Engineering Handbook, Volume 3*. EPRI, Palo Alto, CA: 2015. 3002005346.
4. *Plant Engineering Heat Cycle Isolation Valve Leakage Identification and Quantification*. EPRI, Palo Alto, CA: 2012. 1025264.
5. Plant Performance Enhancement (P2EP) Technical Library.

A
SELF-ASSESSMENT CHECKLIST

Attached is a sample checklist and interview questions, which may be utilized in conducting assessments of nuclear plant TP programs. The checklist and the questions may be modified based on scope of the assessment.

THERMAL PERFORMANCE PROGRAM ASSESSMENT

Station Name: ________________________________ Unit No. ______________

Completed By: ________________________________ Date: ________________

Team Lead

Approved By: _________________________________ Date:_________________

Sponsoring Manager

SELF ASSESSMENT CHECKLIST

Date: ______________________________

Thermal Performance Engineer (TPE): __________________

I. Assessment Team Members (List name, title, company, and plant name)

Name	Position/Title	Company	Plant Name

II. Plant Personnel Interviewed

Name	Position/Title	Department

III. Assessment Objectives/Functional Areas

List Objectives: ____

____

____

Functional Areas (Identify the areas that are being assessed):

- ☐ Baseline and Modeling
- ☐ Training and Qualification
- ☐ Performance Goals
- ☐ Monitoring and Trending
- ☐ Cycle Isolation
- ☐ Data Collection and Validation
- ☐ Work Control and Communication
- ☐ Search and Recovery
- ☐ Management Reporting
- ☐ Program Implementation
- ☐ Industry Participation

IV. Prior TP Program Assessment Documentation/Evaluations

List the relevant documents reviewed during the assessment.

IV.1 Regulatory Inspection Reports

III.2 Internal Audits

III.3 Industry Evaluations

III.4 Incident Reports

III.5 Plant Procedures

V. Assessment Questions

1. Baseline and Modeling

1.1 Has a plant thermal performance baseline been established? What sources and methods were used to establish the baseline?

1.2 Is the thermal cycle modeled in TP modeling software?

1.3 Is the turbine cycle model thorough, accurate and validated? How is the validation documented?

1.4 Does the baseline model reflect the current plant configuration? Has it been updated to reflect major equipment modifications/upgrades? How has the baseline model been calibrated and what data were used?

1.5 Are there any outstanding modifications that have a potential impact on TP? (Provide examples of recent modifications reviewed by the TPE.)

Remarks:

2. Training and Qualification

2.1 Describe the qualification, experience and expertise of the TPE and backup TPE. What training has been conducted?

2.2 Is TP included in the training of system engineering, maintenance, operations?

2.3 Are training opportunities being identified to increase the technical knowledge of program personnel?

Remarks:

3. Performance Goals

3.1 What are the performance goals of the TP program? Are the goals reasonable and achievable?

3.2 Is the performance accurately calculated and reported? (for example, Capacity Factor, Forced Loss Rate (FLR), Program Health and other required indicator data as required.)

3.3 If the performance is not per expectation, are corrective actions taken for improvement such as preventive maintenance, refurbishment, replacement, or modifications? Give examples.

3.4 Are performance goals aligned with station business plans?

3.5 Is there a long-term strategy for MWe improvement or uprate?

Remarks:

4. Monitoring and Trending

4.1 Are the critical systems and components or program parameters that require trending identified and being monitored?

4.2 Are monitoring and trending tools are in place to monitor key performance indicators for major system components that impact generation?

4.3 Does the program effectively monitor and trend actual performance against that predicted by the baseline models?

4.4 Are the range of trends are adequate to identity changes in the performance of the unit(s) over time (typical range of trend = 6 month)?

4.5 How frequently are the data trends monitored and reviewed? (Expect at least weekly, preferably daily. Objective recommendation required if trend review is less frequent than twice per week.)

4.6 Is software utilized for data evaluation and trending?

4.7 If the power output is not as expected, are lost megawatts being identified? Does the thermal performance balance report reconcile all losses and gains from the design baseline to the actual output?

4.8 Which systems, structures, or components in the program are currently classified as degraded?

4.9 Are the records/readings stored for later retrieval?

Remarks:

5. Cycle Isolation

5.1 Is there a formal cycle isolation monitoring program in place?

5.2 Are high energy valves instrumented for identifying leak through?

5.3 Are steam traps being monitored for steam leaks?

5.4 Where have deficiencies in cycle isolation been found, and what actions were taken to mitigate them?

5.5 Are cycle isolation leakages quantified and trended? (Review past trend data.)

Remarks:

6. Data Collection

6.1 Describe methods of data collection and trending. (Review list of measured parameters with TPE.)

6.2 Are BOP instruments available, functional and calibrated on an appropriate frequency? Are there anomalies in acquired operating data due to erroneous readings?

6.3 Is adequate instrumentation permanently installed?

6.4 Is temporary or portable instrumentation available and utilized?

6.5 Are the thermal systems and components instrumented and being monitored or tested to identify the cause of any losses?

6.6 Are operator walkdowns and inspections credited in program implementation to identify faults or degrading conditions? Are the operators trained and knowledgeable on the bases for these inspections?

6.7 Are plant walkdowns (Operator walkdowns, System Engineer/TPE walkdowns) effective in identifying various performance problems such as dump valves not reset, steam trap leaks, valve leak-through to the condenser, miscellaneous steam leaks, oscillating feedwater level control, and so on? Are the following testing methods utilized and reviewed?

6.7.1 Infrared surveys (valve leak-through, poor/loose insulation, through wall leaks)

6.7.2 Ultrasonic testing (through wall leaks, valve leak-through)

6.7.3 Eddy current testing (feedwater heater, other heat exchangers, and steam generator and tube leaks)

6.8 Are feedwater heater terminal temperature difference (TTD) and drain cooler approach (DCA) accurately computed and trended based on operating data?

6.9 Is there an established program or process for monitoring, detecting and quantifying condenser in-leakage? (Review air in-leakage trends with TPE and actions taken to minimize air in-leakage.)

Remarks:

7. Work Control and Communication

7.1 Describe the lines of communication and interfaces between the TP program owner and other station groups (for example, Operations, Systems Engineering). Are the interfaces of TPE with other affected groups effective? How frequently do meetings occur?

7.2 Does Operations monitor plant thermal performance and notify TPE of issues?

7.3 Is the TP related maintenance prioritized?

7.4 Is the TPE involved in reviewing potential modifications for their effect on plant TP?

7.5 Is the TPE involved in reviewing FAC issues, high energy leak issues and AOV issues with Engineering?

7.6 Is the TPE aware of Water Chemistry issues that could cause corrosion or fouling?

Remarks:

8. Search and Recovery

8.1 Is there a structured search and recovery process? (Review a recent lost MWe search and recovery action plan with the TPE.)

8.2 Is the process successful in identifying and recovering MWe losses?

8.3 Are thresholds for key parameters established as trigger points?

8.4 When performance deficiencies are identified, what search and recovery actions are taken? (for example, corrective actions, troubleshooting plans, quantify and track deviations to resolution)

8.5 Have there been repeat TP problems at the station? What actions were taken to prevent recurrence?

Remarks:

9. Management Reporting/Oversight

9.1 Describe the periodic reporting tools and action plans utilized in the TP program.

9.2 Are program deficiencies properly identified, prioritized consistent with their significance, documented in the station Corrective Action Program and tracked to closure?

9.3 Is the Delta Generation, which can be used as a tool to evaluate whether the unit output is as expected or not, included in plant daily status reports, serving as a Daily Megawatt Reporting Tool?

9.4 Does the program report findings, trends and results to immediate supervision, System Manager(s) and Senior Manager Plant Engineering (or Program Engineering Manager), as appropriate and in a timely manner?

9.5 Is the TPE routinely reviewing with appropriate system managers the System Health Reports for those systems that may impact the thermal performance of each unit? (Attention should be given to adequate intrusiveness into system and component risks of generation loss, and to timely and early planning of resolution actions.)

9.6 Are monthly reports/Program Health Report issued, listing long-term generation impacts with associated work orders, IDs, MW losses, the responsible organization, estimated completion date and issue status? (Unidentified losses should also be identified based on corrected plant output and expected gross generation that accounts for circulating water inlet temperature. Corrected generation and expected generation should be graphically displayed for the given month.)

9.7 Are reports critical and reflective of programmatic issues identified or being addressed during the period?

9.8 Is the program visible to management through plant periodic meetings presentations and critical Program Reports? Are gaps and/or enhancements to improve implementation supported by management (for example, upgrades in system monitoring equipment, test equipment or software)? (Review documentation and discuss with management.)

9.9 Are program improvement actions and recommendations from Corporate Engineering reviewed and implemented at the station-level?

Remarks:

10. Program Implementation

10.1 Does a formal program exist?

10.2 Is there a formal program basis document describing the purpose of the program and its expected benefit to the station?

10.3 What document(s) provides the expectation for program performance at the station? Are the Thermal program instructions/guidelines established with clear lines of responsibilities and duties and reporting requirements?

10.4 How are TP program related modifications, preventive maintenance and inspections integrated with plant work scheduling to ensure that work proceeds as scheduled?

10.5 Who is assigned the responsibility at the plant for the TP program? Is a TPE assigned to the Program?

10.6 Are the TPE and backup TPE up-to-date with Industry TP knowledge?

10.7 Does the TPE have concurrent duties? How often does the program owner get assigned to other emergent issues not related to the program? (Other activities occupied ____% of his time during the last quarter.) Is sufficient time provided to the TPE to perform all the necessary program tasks?

10.8 Are personnel assigned to backup TPE for program implementation?

10.9 Do others have responsibilities within the TP program? How are the responsibilities defined? Are they (for example, system engineers) involved in establishing program inputs?

10.10 Is a TP program Notebook or other similar documentation maintained containing pertinent examples of plant monitoring spreadsheets with overview instructions for backup, vendor manuals, data sheets and TP modeling software user's manual?

10.11 Do other station organizations support implementation and execution of TP program activities, including adequate resource dedication?

10.12 Are cost effective material condition improvements being identified and pursued, as documented in Action Reports?

10.13 When was the last program assessment performed? What was the scope of the most recent assessment? What other station organizations were involved in the most recent assessment?

10.14 Were industry peers involved in the most recent assessment? Has the program been benchmarked against similar plants? What types of benchmarking have been performed recently on the program?

10.15 What were the findings of the most recent assessment? How were the findings integrated into the program? What is the status of any corrective actions?

Remarks:

11. Industry Participation

11.1 Does the TPE participate in industry forums (for example, EPRI P2EP), peer reviews or have taken industry specific training courses?

11.2 Is the TPE aware of the generic Industry issues?

11.3 How is industry operating experience (OE) factored into the program (for example, periodic review of industry experience)?

Remarks:

____
____
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____

VI. Summary

For each assessment objective/functional area, document below the findings and conclusions. Consider each attribute as listed in Appendix B with an objective result for each. Develop an overall score (1-10) for each functional area and present graphically (for example, using radar chart).

VI.1 Overall Rating

Excellent: _______Adequate: ______ Needs Improvement: _________

VI.2 Assessment Analysis

VI.3 Strengths:

____
____
____

VI.4 Opportunities for Improvement:

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____

VI.5 Deficiencies/Barriers to Improvement:

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VI.6 Recommendations:

VII. General Comments:

B
SUGGESTED DOCUMENTS TO BE REVIEWED

The following is a general list of documents suggested to be reviewed for the various attributes of the TP monitoring program.

A. **Baseline Modeling**. The baseline provides the optimum performance that the plant should try to achieve and the megawatt output of the plant when all systems are working as designed.

Attribute	Document(s) to be Reviewed
Baseline is established	Heat Balance, Vendor Thermal Kit, Design Performance, Predicted Performance
Achievable performance is used to set program goals	Business Plan Performance Measures
Baseline vs. Achievable differences are characterized as non-correctable or correctable	Lost MW recovery plans
Thermal Performance model use is optimized for prediction, assessment and analysis of plant data	Heat Balance Program, cycle models, model output usage
Cost-Benefit analysis of correcting differences is available	Lost MW recovery plans, strategic plan
Goals are consistent with operational, maintenance, and modification costs and trade-offs	Lost MW recovery plans, strategic plan
Long Term Strategy for MW improvement/Uprate is established	Plant Strategic Plans

B. **Performance Goals**. Goals should be established for thermal performance, and they should be based on the best achievable performance (BAP) of the plant.

Attribute	Elements Reviewed
Baseline reference values are established and documented for overall cycle efficiency	Baseline data
Plant-specific goals should be established for thermal performance	Plant Business Plan Performance Measures

C. **Monitoring and Trending**. Having established both the actual unit performance and the BAP, areas of potential cycle efficiency degradation should be identified by tracking the deviation from BAP.

Attribute	Elements Reviewed
Key parameters are identified for trending and monitoring	Trend plots
Additional component parameters are identified for trending and monitoring	Trend plots
Appropriate parameters should be corrected for certain operating conditions before they are trended	Trend plots, thermal kit

D. **Component-Specific Monitoring**. Evaluate current monitoring, trending, analysis and calculations, and action thresholds.

Component(s)	Elements Reviewed
Condenser and Auxiliaries	Condenser duty, cleanliness, SJAE monitoring, Condensate Depression, Scaling/Microfouling, non-condensable gasses, macrofouling
Cooling Towers	Range, approach, duty/capability, water distribution, fill condition, fouling
Feedwater Heaters	Plugged tubes, heater level, erosion, temperature differentials
Steam Turbine	First Stage pressure, HP turbine enthalpy drop efficiency

E. **Search and Recovery**. The process of returning the plant to its baseline thermal performance in a cost-effective manner.

Attribute	Elements Reviewed
Triggered by key parameters with established thresholds	Trend plots, Lost MW Recovery plans
Potential remedial actions to correct conditions that cause MWe losses are developed	Lost MW Recovery plans, Performance Engineering Report
Operational and Maintenance practices and plant modifications needed to achieve thermal performance goals are implemented	Lost MW Recovery plans, Performance Engineering Report, Program Health Reports

F. **Communication**. Adequately communicating the objectives, responsibilities, and results of the Thermal Performance Monitoring Program (TPMP) helps ensure the success of the station as a whole.

Attribute	Elements Reviewed
Performance objectives and the benefit to the plant	Performance Engineering Monthly Report, Business Plan Performance Measures, Program Health Report
Performance goals and changes to the goals	Performance Engineering Monthly Report, Business Plan Performance Measures, Program Health Report
Key parameters and their trends	Performance Engineering Monthly Report, Business Plan Performance Measures, Program Health Report
Operational and maintenance requirements and responsibilities that are required to make the program work	Performance Engineering Monthly Report, Business Plan Performance Measures, Program Health Report
Program successes	Performance Engineering Monthly Report, Business Plan Performance Measures, Program Health Report

G. **Procedures and Documentation**. Formal and/or informal guides that can used to conduct routine performance engineering tasks and reports and to troubleshoot thermal performance problems.

Attribute	Elements Reviewed
Program objectives	Plant TP Program manuals, procedures
Data sheets	Desk Instruction
Expected range of sample data	Desk Instruction
Key parameters and trends	TPE Desk Instruction
Instrumentation List	TPE Desk Instruction
Calibration curves and specified calibration period identified	TPE Desk Instruction

H. **Training and Qualification**. Job-specific initial and professional development training designed to ensure competency in the TPE position.

Attribute	Elements Reviewed
Knowledge of Engineering Fundamentals	Engineering Training and Qualification
Knowledge of Baseline and Modeling	Engineering Training and Qualification
Knowledge of Monitoring and Trending	Engineering Training and Qualification
Knowledge of Search and Recovery methods	Engineering Training and Qualification
Knowledge of program communications methods	Engineering Training and Qualification

I. **Cycle Isolation Monitoring**. Monitoring of actual and potential steam and heated water flow paths that bypass all or part of the turbine cycle and can decrease turbine efficiency. These can be divided into avoidable and unavoidable flow paths.

<u>Unavoidable Flow Paths</u>:

Attribute	Elements Reviewed
Turbine Control Valve leakage	Heat Balance, Cycle Model, trend plots
Turbine Shaft Seal leakage	Heat Balance, Cycle Model, trend plots
MSR Scavenging Steam	Heat Balance, Cycle Model, trend plots
Feedwater Heater continuous vent valves	Heat Balance, Cycle Model, trend plots, Process Books

Avoidable Flow Paths:

Attribute	Elements Reviewed
Turbine Bypass Valves	Trend Plots, Process Books
FW Heater EDL Leakage	Trend Plots, Process Books
RFP Recirculation Valves	Trend Plots, Process Books
Cleanup Valves	Trend Plots, Process Books
Main Turbine Drain Valves	Trend Plots, Process Books
Startup Drains	Trend Plots, Process Books
Relief Valves	Shiftly Rounds, Process Books

AOVs/MOVs:

Attribute	Elements Reviewed
Impact on Cycle Isolation evaluated	Trend Plots, Process Books
AOV/MOV program includes TPMP insights in scoping and prioritization	Trend Plots, Process Books

Alternative Leak Detection Technologies:

Attribute	Elements Reviewed
Infrared Inspection	Work History, Logs, Downpower Plans
Ultrasonic Leak Detection	Work History, Logs, Downpower Plans

Loss Quantification:

Attribute	Elements Reviewed
Parameter Selection	Work History
Loss Estimate Algorithms	Work History
Software Use	Work History
Economic Impact	Work History

Instrumentation:

Attribute	Elements Reviewed
Location of Sensors	Work History
Calibration	Work History
Data Management	Work History

J. **Data Collection and Validation**. In order to make accurate calculations of thermal performance, the thermal performance engineer needs a set of valid data points and parameters for the plant.

Data Requirements:

Attribute	Elements Reviewed
Electrical Power Metering	Spreadsheets
Main Steam Pressure	Spreadsheets
Feedwater Flow Rate	Spreadsheets
Heater Drain Flow	Spreadsheets
Feedwater Temperature	Spreadsheets
Condenser Performance	Spreadsheets
Feedwater Heater Performance	Spreadsheets

Data Validation:

Attribute	Elements Reviewed
Gross Instrument or Sensor Failures	Spreadsheets
Analytical redundancy calculations	Spreadsheets
Limit Checking	Spreadsheets
Calibration	Spreadsheets
Statistical Methods	Spreadsheets
Comparison with Heat Balance	Spreadsheets

House Loads:

Attribute	Elements Reviewed
Monitor and trend unit house loads	Spreadsheets, Watt-hour meter readings
Evaluate Methods of house load reduction	Spreadsheets

C
COMPONENT FOCUS AREAS

The following components may be evaluated for current monitoring, trending, analysis and calculations, and action thresholds using EPRI Plant Engineering Handbook guidance as a baseline.

C.1 Condenser and Auxiliaries

Attribute
Condenser Duty (Q)
Cleanliness Factor (CF)
SJAE Monitoring
Condensate Depression
Scaling/Microfouling
Non-Condensable Gases
Macrofouling

C.2 Cooling Towers

Attribute
Range
Approach
Duty/Capability
Water distribution
Fill condition
Fouling

C.3 Feedwater Heaters

Attribute
Terminal Temperature Difference (TTD)
Drain Cooler Approach (DCA)
Plugged Tubes
Heater Level
Erosion

C.4 Steam Turbine

Attribute
Turbine First Stage Pressure
HP turbine enthalpy drop efficiency

C.5 Moisture Separator Reheaters

Attribute
Heater Terminal Temperature Difference (TTD)
Reheater Log Mean Temperature Difference (LMTD)

C.6 Cycle Isolation

Minimization of steam and heated water flow paths that bypass all or part of the turbine cycle.

Unavoidable Flow Paths:

Attribute
Turbine Control Valve Stem Leakage
Turbine Shaft Seal Leakage
MSR Scavenging Steam
Feedwater Heater Vent Valve

Avoidable Flow Paths:

Attribute
Turbine bypass valves
Feedwater Heater EDL Leakage
RFP recirculation valves
Cleanup valves
Main Turbine drain valves
Startup vents
Relief valves

Air-Operated Valves:

Attribute
Impact on cycle isolation evaluated
AOV program includes Thermal Performance program insights in Scoping and prioritization
AOV diagnostic testing link to TP Program

Instrumentation:

Attribute
Location
Calibration
Data management

Alternative Technologies:

Attribute
Infrared detection
Acoustic detection

Loss Quantification:

Attribute
Parameter selection
Loss estimate algorithms
Software use
Economic impact

C.7 Data Validation

Data Requirements:

Attribute
Electrical Power Metering
Main Steam Pressure
Feedwater Flow Rate
Heater Drain Flow
Feedwater Temperature
Condenser Performance
Feedwater Heater Performance

Validation:

Attribute
Gross instrument or sensor failures
Analytical redundancy calculations
Limit checking
Like-sensor comparison
Calibration
Statistical methods
Comparison with Heat Balance Program

C.8 MS/MSR Outlet Moisture

Attribute
Reheater Energy Balance Method
Shell Drain Flow Method

C.9 House Load

Attribute
Monitor/Trend unit's loads
Evaluate methods of power reduction

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