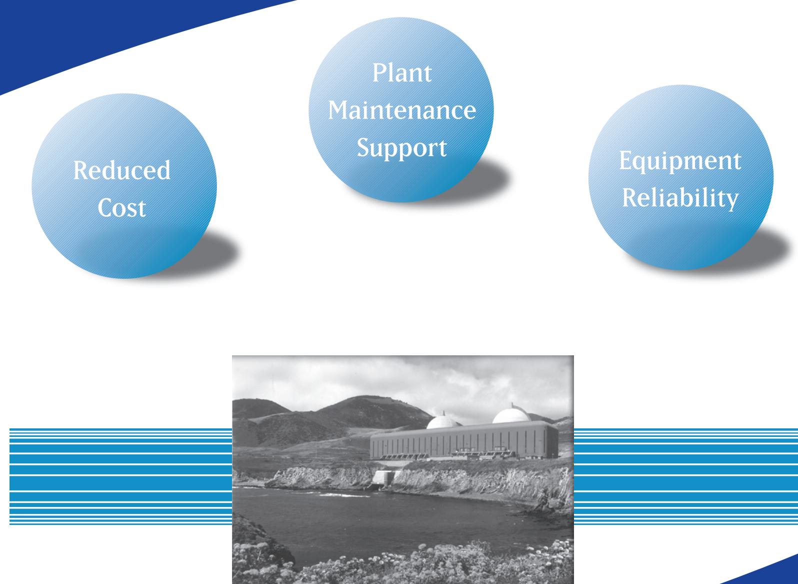
ELECTRIC POWER RESEARCH INSTITUTE

2011 TECHNICAL REPORT

Nuclear Maintenance Applications Center: Preventive Maintenance Program Guideline



Nuclear Maintenance Applications Center: Preventive Maintenance Program Guideline

This document does NOT meet the requirements of 10CFR50 Appendix B, 10CFR Part 21, ANSI N45.2-1977 and/or the intent of ISO-9001 (1994)

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Abstract

Over the years, the Electric Power Research Institute (EPRI) has developed many technical documents to aid in developing effective preventive, predictive, and condition monitoring maintenance programs to ensure equipment reliability and availability. The industry has drawn on this information to establish or enhance preventive maintenance (PM) programs. However, not all PM program processes have been implemented, leaving some programs marginally effective and vulnerable to failure.

The purpose of this report is to provide guidance to plant engineering and maintenance personnel to enhance the effectiveness of their existing PM programs. It identifies key attributes of a living PM program and how they relate to one another; identifies existing EPRI technical documents that might be candidates for revision or update; compiles living PM program information into a single point of reference that can be applied to all EPRI nuclear member plants; and presents a living PM program flowchart.

This report provides an effective means for maintenance directors and engineering managers to evaluate the structure of their existing PM programs to ensure that they have the necessary elements to implement and continuously improve an effective PM program. It identifies the most effective activities to ensure continued equipment reliability, thus reducing equipment failures that typically result in immediate, widespread, costly repairs and loss of generation.

A living PM program should change to reflect work process changes, plant modifications, and continuous improvements. A rigid or stagnant program will leave equipment vulnerable to failure. The industry's aging engineering and maintenance work force is being replaced with less-experienced personnel; therefore, knowledge and awareness of information for living PM programs must be addressed. This report provides a single point of reference for that information.

Keywords
Engineering
Equipment reliability
Maintenance
Preventive maintenance
Work planning

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Section 1: Introduction

1.1 Purpose

The purpose of this report is to provide guidance to plant engineering and maintenance personnel to enhance the effectiveness of their existing PM program. This report:

- Identifies key attributes of a living PM Program and how they relate to one another
- Identifies and review applicable existing EPRI technical documents, identifying documents that may be candidates for updating and revision
- Compiles the living PM Program information into one document, referencing existing information as necessary
- Develops a living PM Program Flow Chart

This report provides an effective means for the maintenance directors and engineering managers to evaluate the structure of their existing PM Program to ensure that they have the necessary elements to implement and continuously improve an effective living PM Program.

- It provides the end user with a single point of reference
- The information can be applied to all EPRI Nuclear member plants
- This report identifies the most effective activities that should be in place to ensure continued equipment reliability, thus reducing equipment failures which typically result in immediate and wide-spread costly repairs and loss of generation

1.2 Background

Over the years, the Electric Power Research Institute (EPRI) has developed many technical documents for the industry to aid in the development of effective maintenance (preventive, predictive, and condition monitoring) programs to ensure equipment reliability and availability. The industry has drawn on this information to establish Preventive Maintenance (PM) Programs or enhance existing programs. However, in some cases not all PM Program processes have been implemented, and subsequently leave some programs marginally effective and vulnerable to failure. A PM Program is designed to be a living program in that it should change as plant work processes change, plant modifications are made, and to continuously improve. If the program is rigid and/or becomes stagnant, it will leave equipment vulnerable to failure.

The industry's engineering and maintenance work force is aging and being replaced with less-experienced personnel. Their knowledge and awareness of EPRI technical information regarding the implementation of a living PM Program needs to be addressed.

The relevant research related to establishing and improving a plant's PM Program needs to be readily available to the plant staff, which can be accomplished by compiling it into one reference source that contains all of the attributes of a living PM Program.

1.3 Report Scope and Contents

Figure 1-1 illustrates the scope and contents of this report.

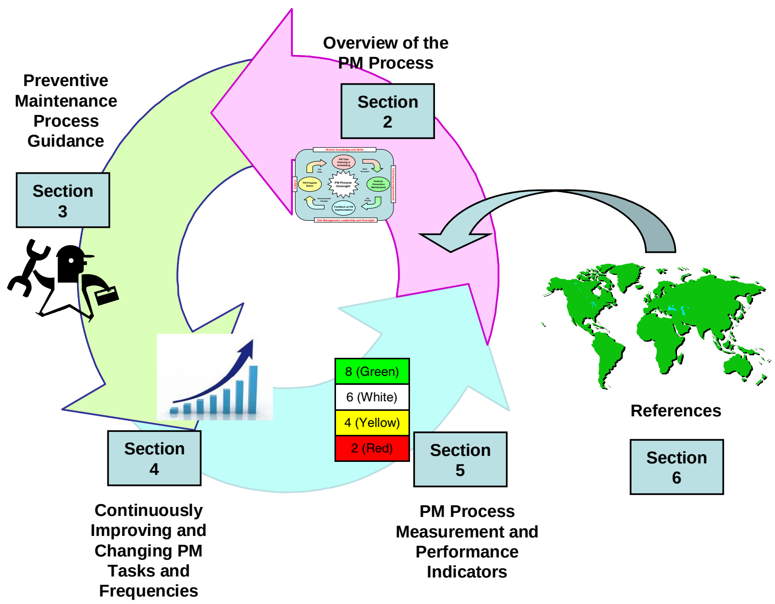

Figure 1-1
Report Scope and Contents

Following the introductory material provided in this section, an overview of the PM process is provided in Section 2. The primary focus of the report is the detailed implementation guidance provided in Section 3, which delves into each quadrant of the process flow chart and discusses means through which the PM process can continuously improve and be dynamic (i.e., a living program). Section 4 provides guidance to facilitate continuous improvement of the process, as well as means for regularly changing PM tasks and frequencies. PM process measurement and performance indicators are discussed in Section 5, and

Section 6 provides the user a comprehensive list of references, grouped by major process element, that can provide more detailed implementation guidance for many of the areas supporting the PM process.

1.4 Definition of Key Terms and Acronyms

1.4.1 Definitions of Key Terms

The following definitions are based on INPO AP-928 Revision 3[1] and INPO AP-913, Revision 3[1]. The user is advised to ensure the definitions used in PM and work planning program documents and procedures are consistent with the most recent revision of the INPO guideline.

1.4.1.1 Preventive Maintenance

Preventive maintenance (PM): includes predictive (condition-based) and periodic/planned (time-based) actions taken to maintain a piece of equipment within design operating conditions and to extend its life. Do not use a PM task to address corrective/deficient/other maintenance without identifying it as one of those categories.

- Grace period preventive maintenance is any preventive maintenance task that is to be performed beyond its original due date but prior to the late date for that activity. Normally, this period (due date to late date) is an additional 25 percent of the original schedule interval for the PM task. No engineering evaluation is required. The grace period is provided as reasonable flexibility to allow for alignment with surveillance activities and functional equipment group bundling and to better manage station resource use. Preventive maintenance tasks are expected to be scheduled based on their due dates.
- A deferred preventive maintenance task is a preventive maintenance task that exceeds its original late date with an approved engineering evaluation that determines the acceptability for extension to a new due date before the original late date is exceeded.
- A deep-in-grace task is a preventive maintenance task whose scheduled date has or will exceed 50 percent of the grace period.
- A delinquent (overdue) preventive maintenance task is a preventive maintenance task that exceeds its late date (grace period) without sufficient technical basis. A sufficient technical basis shall meet the criteria outlined in INPO AP-913[1] for conducting PM deferrals. In addition, the applicable system/component or program engineer should be knowledgeable of all PMs that have been deferred, including understanding the aggregate risk associated with multiple PM deferrals, on a given system or component. Delinquent/overdue PMs are tracked separately from PM deferrals that have a sufficient technical basis, so that station management is informed of the risk associated with multiple late/delinquent PMs.

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[1] Access to INPO reports and materials is restricted to organizations authorized by INPO. The information is confidential and for the sole use of the authorized organization.

The distinction between predictive maintenance and periodic maintenance is presented below, as per the definitions provided in INPO AP-913, Revision 3[2].

Predictive Maintenance

Predictive maintenance is a form of preventive maintenance performed continuously or at intervals governed by observed condition to monitor, diagnose, or trend SSC functional or condition indicators. Results indicate current and future functional ability or the nature of and schedule for planned maintenance.

Examples of predictive maintenance are found below.

- Vibration analysis (includes spectral analysis and bearing temperature monitoring), lube oil and grease analysis are used to monitor rotating equipment.
- Check valve testing (non-intrusive)
- Infrared surveys (thermography)
- Oil analysis (tribology)
- Motor operated valve diagnostic testing
- Air operated valve testing

Periodic Maintenance

Periodic maintenance is a form of preventive maintenance consisting of servicing, parts replacement, surveillance, or testing at predetermined intervals of calendar time, operating time, or number of cycles.

Periodic maintenance may be performed to prevent breakdown and can involve servicing such as lubrication, filter changes, cleaning, testing, adjustments, calibrations, and inspections. Periodic maintenance can also be initiated because of the results of predictive maintenance, vendor recommendation, or experience. Examples of periodic maintenance are shown below.

- Scheduled valve re-packing because of anticipated leakage based on previous experience.
- Replacement of bearings or pump realignment as indicated from vibration analysis and/or lubrication oil analysis.
- Major or minor overhauls based on experience factors or vendor recommendations.

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[2] Access to INPO reports and materials is restricted to organizations authorized by INPO. The information is confidential and for the sole use of the authorized organization.

1.4.1.2 Corrective Maintenance

Corrective maintenance are actions that restore—by repair, overhaul, or replacement—the capability of a failed SSC to function within acceptance criteria.

Corrective maintenance is restoration of equipment or components affecting nuclear or personnel safety or plant reliability that have failed, degraded or do not conform to their original design, configuration, or performance. As a rule, if the specific component requiring maintenance is substantially degraded (for example, packing or bearing degradation) or failed, the action required to repair it is classified as corrective maintenance.

To be considered corrective maintenance, the SSC must have failed such that it cannot meet its intended functions, or for degradation identified during a PM, the component will reach this state before the next scheduled PM interval. There may be cases where corrective maintenance could include standing Preventive Maintenance orders/procedures specifically invoked to correct anticipated component degradation. If the degradation does not meet these criteria, it should be considered elective maintenance.

An SSC should be considered failed or significantly degraded if the deficiency is similar to any of the following examples:

- It is removed from service because of actual or incipient failure
- Significant component degradation that affects system operability – The SSC may be determined operable by engineering assessment, but the degradation is significant and requires immediate corrective action. This normally includes any deficiency that requires a basis for continued operation as defined in NRC Generic Letter 91-18, and should be considered as corrective maintenance.
- It creates the potential for rapidly increasing component degradation (for example, leaks of borated water, steam leaks where cutting degradation is possible).
- It releases fluids that create significant exposure or contamination concerns (or has the potential to under postulated accident conditions) – Minor leaks that can be controlled and managed by simple drip catch containments would not be included here.
- It adversely affects controls or process indications that directly or indirectly impair operator ability to operate the plant or that reduce redundancy of important equipment.
- Significant component degradation identified from the conduct of predictive, periodic, or Preventive Maintenance which, if not resolved, could result in equipment failure or significant additional damage prior to its next scheduled Preventive Maintenance period.

Note – Based on the severity of the failures noted above, some may not warrant corrective maintenance, and may be considered elective maintenance.

1.4.1.3 Planned Maintenance

Planned maintenance is a form of preventive maintenance consisting of refurbishment or replacement that is scheduled and performed to preclude failure of an SSC.

1.4.1.4 PM Optimization

Preventive Maintenance Optimization (PMO) is a process appropriate site personnel take to optimize the preventive maintenance tasks associated with plant equipment, the frequency with which they are performed, and the resources/staff associated with performing them. The ultimate goal of PMO is to cost-effectively increase the reliability of plant equipment. Benefits of an effective PMO process may be any of the following:

- Improved forced loss rate and higher capacity factors
- Reduction of intrusive maintenance activities
- Reduction of maintenance-induced failures
- Elimination of non-value-added maintenance work
- Better balance between on-line maintenance tasks and outage-driven maintenance tasks
- Reduction in maintenance task support services such as engineering, work management, operations, material and parts services
- Improved industry and regulatory reviews, and evaluations and audits

1.4.1.5 Reliability Centered Maintenance

Reliability Centered Maintenance (RCM) has traditionally been a "static" approach to measuring the reliability of equipment and then directing resources to the failure modes that have the greatest impact on the correct operation of equipment. (Reference EPRI 1002126).

1.4.2 Acronyms

ALARA – As Low As Reasonably Achievable

ANII – Authorized Nuclear Inservice Inspector

ANSI – American National Standards Institute

CFR – Code of Federal Regulations

CM – Corrective Maintenance

ECM – Equipment Condition Monitoring

EFE – Equipment Failure Evaluation

EPIX – Equipment Performance Information Exchange

EPRI – Electric Power Research Institute

EPSS – Electrical Performance Support Systems

ER – Equipment Reliability

ERI – Equipment Reliability Index

ERWG – Equipment Reliability Working Group

FEG – Functional Equipment Group

FME – Foreign Material Exclusion

FMEA – Failure Modes Effect Analysis

FSAR – Final Safety Analysis Report

HIT – High Impact Team

HVAC – Heating, Ventilation and Air Conditioning

IER – INPO Event Report

INPO – Institute of Nuclear Power Operations

IR – Infra-Red

JIT – Just In Time

M&D – Monitoring & Diagnostics

NEIL – Nuclear Electric Insurance Limited

NMAC – Nuclear Maintenance Applications Center

NP – Nuclear Power

NRC – Nuclear Regulatory Commission

O&M – Operations & Maintenance

O&MR – Operations & Maintenance Reminder

OLM – On-line Monitoring

PdM – Predictive Maintenance

PM – Preventive Maintenance

PMBD – Preventive Maintenance Basis Database

PMCG – Preventive Maintenance Coordinators Group

PMOC – Preventive Maintenance Oversight Committee

PMT – Post-Maintenance Testing

PPE – Personnel Protective Equipment

PRA – Probabilistic Risk Assessment

PSE – Plant Support Engineering

RCM – Reliability Centered Maintenance

RP – Radiation Protection

RTF – Run-To-Failure

RTV – Room Temperature Vulcanizing

SEN – Significant Event Notice

SET – Significant Event Report

SOER – Significant Operating Experience Report

SSC – Structure, System or Component

TR – Technical Report

UFSAR – Updated Final Safety Analysis Report

1.5 Key Points

Throughout this report, key information is summarized in "Key Points." Key Points are bold lettered boxes that succinctly restate information covered in detail in the surrounding text, making the key point easier to locate.

The primary intent of a Key Point is to emphasize information that will allow individuals to take action for the benefit of their plant. The information included in these Key Points was selected by NMAC personnel, consultants and utility personnel who prepared and reviewed this report.

The Key Points are organized according to the four categories: O&M Costs, Technical, Human Performance, and Supervisory Observation. Each category has an identifying icon, as shown below, to draw attention to it when quickly reviewing the guide.

Key O&M Cost Point
Emphasizes information that will result in overall reduced costs and/or increase in revenue through additional or restored energy production.

Key Technical Point
Targets information that will lead to improved equipment reliability.

Key Human Performance Point
Denotes information that requires personnel action or consideration in order to prevent personal injury, equipment damage, and/or improve the efficiency and effectiveness of the task.

Key Supervisory Observation Point
Identifies tasks or series of tasks that can or should be observed by Maintenance First Line Supervisors to improve the performance of the Maintenance Staff and improve the reliability of the component.

The Key Points Summary section (*Appendix A*) of this guide contains a listing of all key points in each category. The listing restates each key point and provides a reference to its location in the body of the report. By reviewing this listing, users of this guide can determine if they have taken advantage of key information that the writers of this guide believe would benefit their plants.

Section 2: Overview of the PM Process

The purpose of this section is to provide an overview of the PM process, how it fits into the overall process for ensuring equipment reliability, and how it can be structured to ensure it remains vibrant and capable of facilitating continuous improvement, innovation and change.

2.1 Equipment Reliability Process

Figure 2-1 illustrates the top level equipment reliability process as depicted in INPO AP-913, Revision 2, "Equipment Reliability Process Description"[3]. One of the six functional areas of this process is Preventive Maintenance (PM) Implementation, which for the purposes of this report, is highlighted in blue.

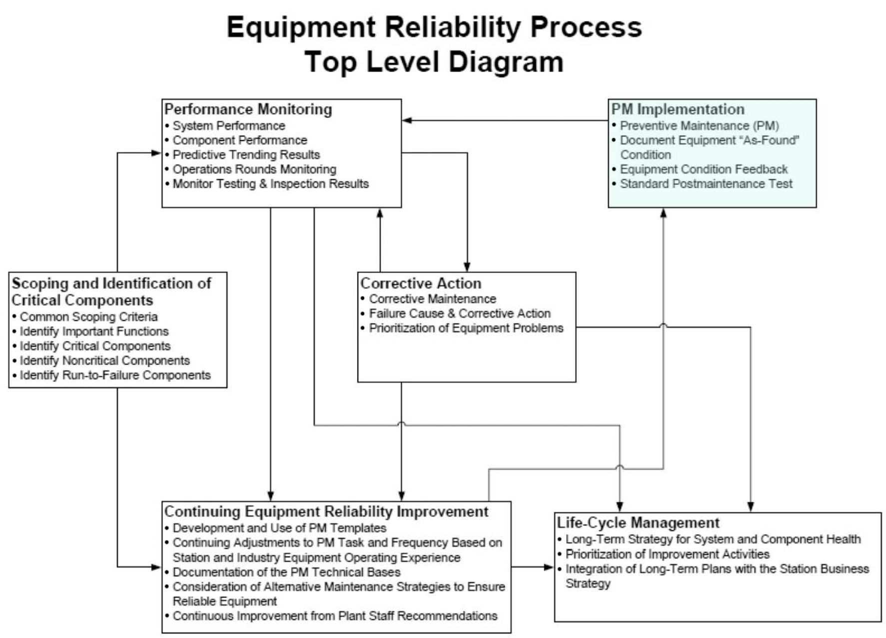

Figure 2-1
Elements of the Equipment Reliability Process (Figure Courtesy of INPO AP-913, Rev 3[2])

[3] Access to INPO reports and materials is restricted to organizations authorized by INPO. The information is confidential and for the sole use of the authorized organization.

Key Technical Point

PM implementation should be a dynamic process that continually improves and adjusts to accommodate the age of the equipment, design modifications of plant structures/systems/components, and the results and lessons learned from performing maintenance over the life of the equipment.

2.2 The Living Preventive Maintenance Process

Figure 2-2 illustrates four key elements that should be implemented to make the PM program dynamic and living – one that not only maintains high equipment reliability, but continually improves so as to optimize the cost and effectiveness of the Preventive Maintenance tasks being performed and their frequencies.

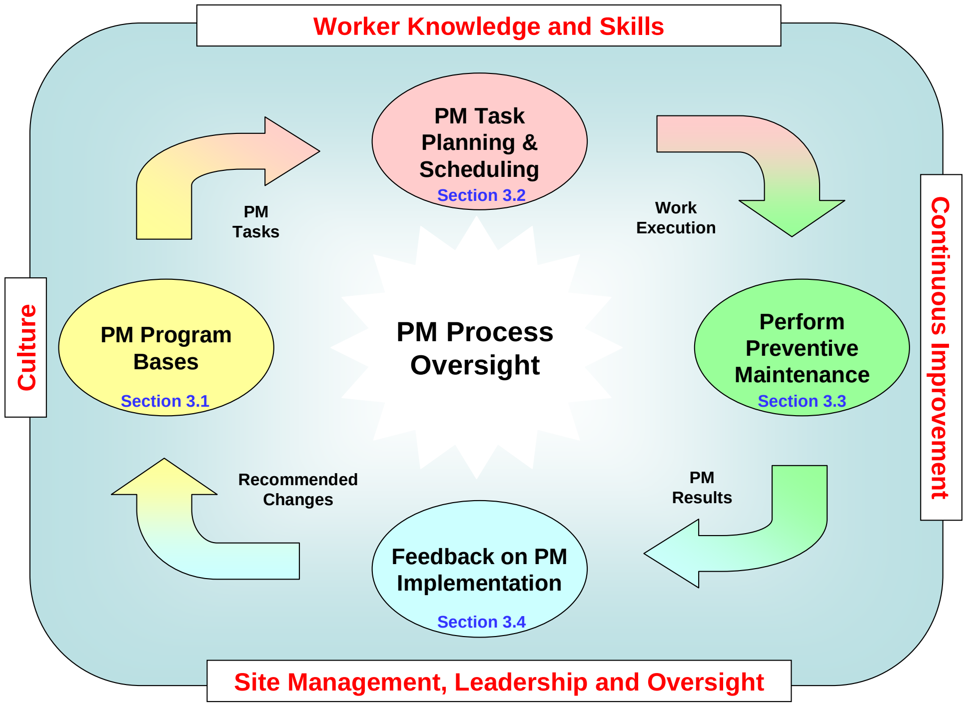

Figure 2-2
Elements of the Living PM Process

Figure 2-2 is based on guidance provided by INPO. The original diagram was simplified to create the figure shown above and enhanced through the efforts of the Technical Advisory Group who facilitated the development of this technical report. As noted on Figure 2-2, each of the four main elements of the process is cross-referenced to the respective section where detailed implementation guidance is provided (e.g. Section 3.1, 3.2, 3.3 or 3.4). Figures 2-3 through 2-6 provide a preview of the detailed components associated with each of the four main process elements.

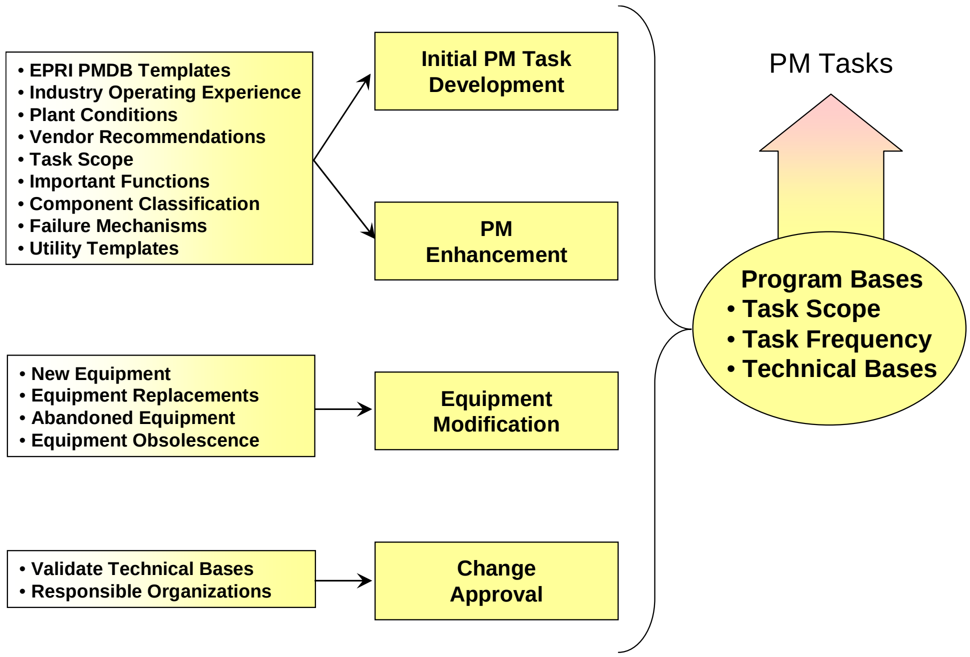

Figure 2-3
PM Program Bases (Reference Section 3.1)

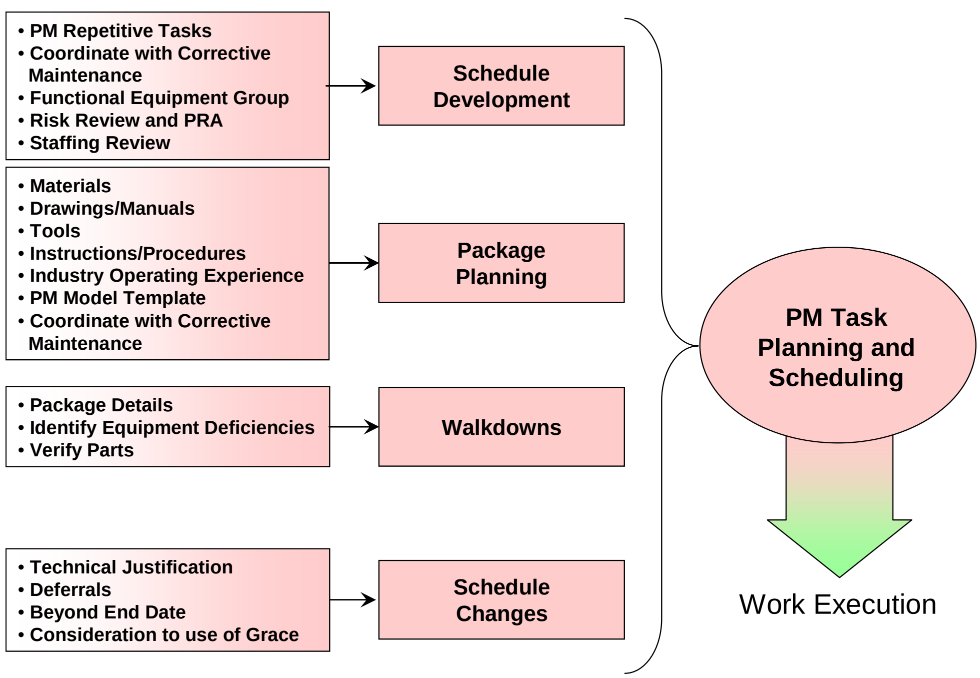

Figure 2-4
PM Task Planning and Scheduling (Reference Section 3.2)

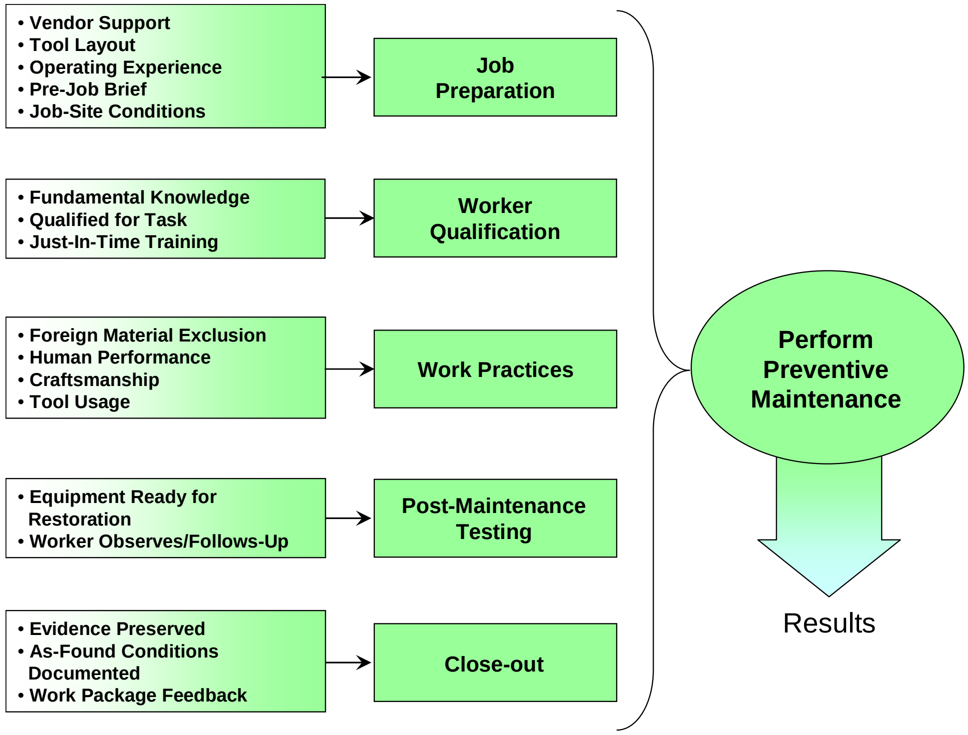

Figure 2-5
Performing Preventive Maintenance (Reference Section 3.3)

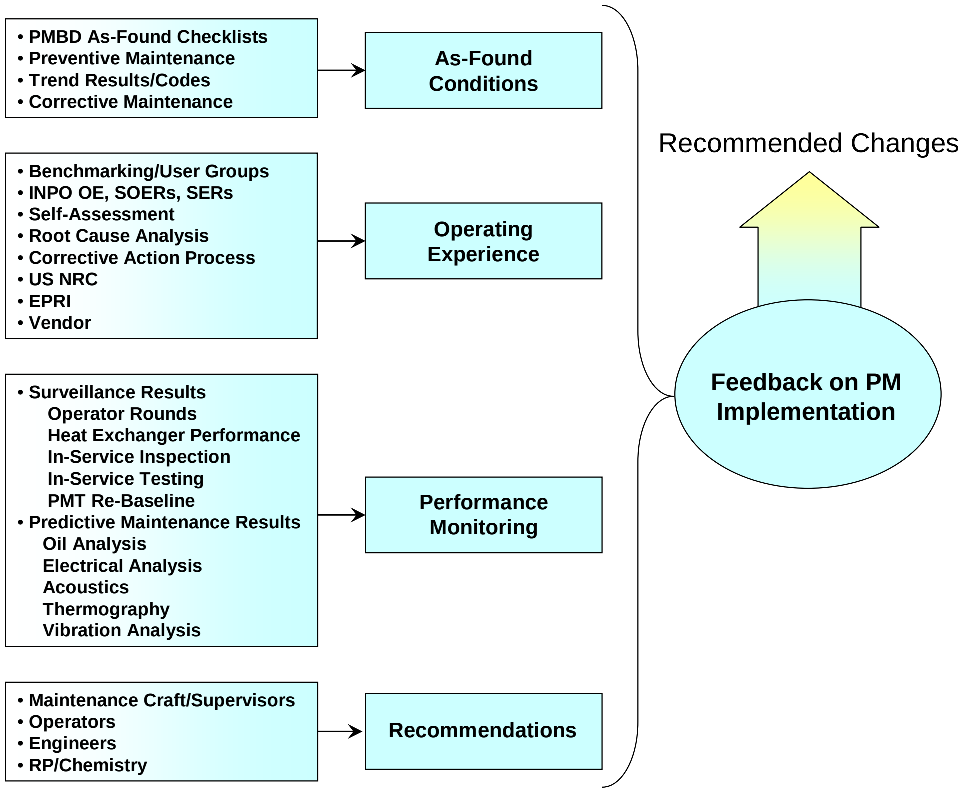

Figure 2-6
Feedback on PM Implementation (Reference Section 3.4)

The following are some key points regarding the living PM process illustrated in Figure 2-2:

1. The following four key elements comprise the process, which are inter-related and repeatedly performed in the order depicted (note the colored arrows that move in a clockwise direction and transition from one element to the next).

   - PM Program Bases
   - PM Task Planning& Scheduling
   - Performing Preventive Maintenance
   - Providing Feedback on PM Implementation

2. Enveloping the PM Process are four key supporting elements that facilitate its ability to change and live:

   - A plant culture that encourages change and strives for excellence
   - Leadership and oversight from site management because of the cross-disciplinary and cross-departmental nature of the process
   - A desire to continuously improve the PM process and subsequently the reliability of plant equipment
   - Excellent worker knowledge and skills

3. The effectiveness of the process is measured and benchmarked through regular assessment and program oversight, which may be performed on one or more of the four process elements.

EPRI 1023209, "Preventive Maintenance (PM) Program Guideline: Composite Flowchart", is a poster-sized composite of the elements of the PM program described in this section.

2.3 Preventive Maintenance Coordination

Key O&M Cost Point
Each site should have a person or team that drives and coordinates the implementation of the PM process.

Depending on the organizational structure at each site, this coordinating function may be performed by an individual (often referred to as the PM Coordinator or PM Engineer), or by a team of people/stakeholders in the PM process. Whether the coordination is done by one person at a site or a team of individuals is not important; but the following key points should be considered regarding the effectiveness of the PM coordination:

- Technical personnel are preferred in lieu of an administrative/clerical person, commensurate with the responsibilities defined by each site
- Coordinator(s) should ensure PM changes get implemented in a timely manner
- Coordinator(s) should ensure feedback is being compiled, trended, analyzed and used to change PM bases
- On-going support from plant management is critical
- Buy-in/support from plant engineering, maintenance and work control
- Coordinator(s) should be considered as the PM program subject matter expert (SME)
- Coordinator(s) should understand that the goal is to ensure appropriate equipment reliability with the optimal PM scope and frequency is applied and continuously reviewed and enhanced as needed
- Coordinator(s) should ensure the appropriate maintenance is being performed at the optimal interval to achieve reliability of the units at a reasonable cost
- Coordinator(s) should lead the PM process assessments

Key Human Performance Point
Although the roles and responsibilities of the PM Coordinator(s) will vary from site to site, the two functions that tend to be common to any nuclear utility are:

- Leading the PM change process
- Conducting PM process assessments

Appendix B of this report provides examples of job descriptions for PM Coordinators, as well as describing typical roles and responsibilities.

Section 3: Preventive Maintenance Process Guidance

The purpose of this section is to discuss means for optimizing and continuously improving PM process implementation. In this section, each of the four key elements of the PM Process model depicted in Figure 2-2 is described in detail.

3.1 PM Program Bases

The first element of the PM process that is typically performed during the initial development of PM tasks and frequencies is establishment of the PM Program Bases.

3.1.1 Detailed Aspects of this Process Element

Figure 3-1 illustrates a more detailed view of the first PM process element, and implementation guidance is provided in the sections immediately following the figure.

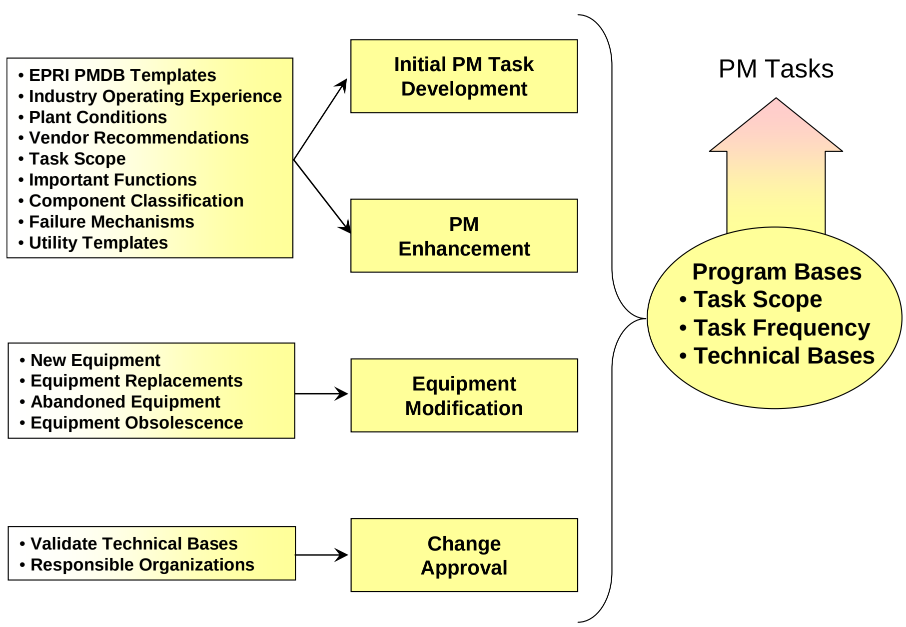

Figure 3-1
PM Program Bases

3.1.2 PM Program Bases Implementation Guidance

The intent of this section is to provide detailed implementation guidance for implementing this key element of the PM process model, and how to optimize interfaces with other elements outside of the PM sector.

3.1.2.1 Initial PM Task Development

Key Technical Point
One of the key factors considered during the initial development of PM task scope and frequency is the component classification and functional importance.

The correct classification for each component is extremely important to managing the overall size of the PM Program and hence the workload of the maintenance department. If classification criteria are applied in too conservative a manner, the end result will be too many PM tasks which do not contribute to the improvement of equipment reliability while distracting the maintenance workforce from more important work.

INPO AP-913[4] provides guidance for classifying equipment as critical, non-critical, or run-to-failure. This classification is not just used for establishing PM guidance however, as it is a fundamental element affecting many equipment-related activities such as performance monitoring, corrective action, work management, procurement, long-range planning, and system health reporting. Both INPO AP-913[4] and PM Basis Database follow the same logic to determine the functional importance and criticality of components. However, the PM Basis Database terminology for "non-critical" is different than that used by INPO. The PM Basis Database uses Minor in the place of Non-Critical. As shown on Table 3-1, this classification is referred to as Criticality Type in the EPRI PM Basis Database template, and can be either Critical or Minor, as shown on the top row of the template.

Key Technical Point
Classification not only considers the deterministic safety classification of the equipment but the classification from an equipment reliability perspective.

Table 3-1
Factors Affecting PM Task & Frequency Development

Criticality Type:	**Critical**				**Minor (See Note)**			
Duty Cycle:	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**
Service Condition:	**Severe**		**Mild**		**Severe**		**Mild**	
PM Tasks:	Frequency Interval							

Note: The term "Minor" encompasses non-critical categorized equipment

This effort has for the most part been accomplished by site engineering personnel for the vast majority of the equipment in their plants. Aside from regulatory requirements, many sites also consider economics when establishing the treatment of classified equipment, including maintenance requirements. Sites have also recognized varying levels of engineering conservatism when component

[4] Access to INPO reports and materials is restricted to organizations authorized by INPO. The information is confidential and for the sole use of the authorized organization.

classification was performed. Once equipment has been classified, engineers need management support of their classifications and equipment performance expectations.

Also shown in Table 3-1, the PM Basis Database templates also takes into consideration Duty Cycle (high or low) and Service Condition (severe or mild operating environment) that can affect the frequency in which PM tasks should be performed.

Appropriate site personnel should ensure that PM activities address:

- Impact on resources and scheduling
- Accurate and appropriate plant configuration/plant conditions
- Parts availability (reviews and order lead times)
- Planning needs (drawings, procedures, etc.)
- Component classification is correct
- Plant risk from task performance

The PMBD component templates are developed using the Reliability Centered Maintenance (RCM) analysis philosophy. The component is broken down into its individual piece parts and a Failure Modes Effect Analysis (FMEA) is performed and the associated task that can identify or monitor the degradation leading to failure. The PMBD also takes into consideration potential stressors such as heat, humidity, vibration, contamination, and fluid quality, that can affect the component's reliability. The PM task scope should be based to eliminate the *most common* failure mechanisms/modes, and should also consider the criticality of the component. Other factors that should be considered when developing PM tasks and frequencies include the following:

- Vendor recommendations
- Industry operating experience (external and internal, INPO SOER's, etc.)
- Maintenance history
- Regulatory and other commitments, such as:
  - Insurance (e.g., NEIL, ANII, etc.)
  - FSAR or UFSAR
  - Technical Specifications
  - Equipment Qualification (seismic and environmental)
  - State inspections/commitments
- EPRI PMBD templates
- Fleet/plant-specific templates
- Life cycle management issues and concerns
- Design basis
- Engineering evaluation and study

- Instrument calculations
- Codes and standards
- Maintenance Rule
- Task effectiveness as determined by the PMBD vulnerability tool

Key O&M Cost Point
The PM task scope should be based to eliminate *most common* failure mechanisms/modes, and should also consider the criticality of the component.

Site procedures should ensure that PM evaluations establishing PM task and frequencies integrate an appropriate level of technical review, and involvement by maintenance personnel. These two organizations working in concert with one another should assure a high level of quality when initially developing PM tasks. Many plants have used the PMBD Templates as a reference to develop their fleet and site specific component templates used to document their maintenance strategy and basis.

3.1.2.2 PM Enhancements

Many sites have initiated optional PM enhancement project(s) to improve process efficiency, cost effectiveness and subsequently equipment reliability. PM enhancement projects may include or result from any of the following efforts:

- High Impact Team (HIT) assignment
- PM optimization; including improvements in the PM challenge process
- Reliability Centered Maintenance (RCM)
- Component reclassification
- Regulatory and other commitments (e.g., NEIL)
- Power uprates and large plant design modifications

Similar to the initial development of PM tasks and frequencies, enhancements typically consider the following factors:

- Industry operating experience (external and internal, INPO SOER's, etc.)
- EPRI PMBD Templates
- Fleet / Plant-specific templates
- Task Effectiveness using the EPRI PMBD Vulnerability tool
- Life cycle management
- License extension
- PM feedback

Key Technical Point
A key factor affecting the living PM program is accurate documentation of the actual equipment currently installed in the plant.

3.1.2.3 Equipment Modification

This can change over time as equipment is replaced due to obsolescence, to enhance system performance, or simply for life cycle management. In some cases, new equipment is installed either as a result of a design modification or a power uprate. Other times equipment is abandoned in place (installed but not used). All of these scenarios affect the accurate documentation of the actual equipment installed and subsequently the accuracy and effectiveness of the PM program.

3.1.2.4 Initial/Change Approval

Key Technical Point
Each site should have a procedure for approving the PM technical basis that resulted in clearly defining PM tasks and respective interval frequencies.

Some licensees use a group of individuals to approve PM bases. These committees may be referred to as a Preventive Maintenance Oversight Committee (PMOC) or Just-In-Time (JIT) Committee. In either case, the group approves the PM bases through consensus and during the time the group convenes.

Some sites take a different approach to approving the PM Technical Basis by ensuring stakeholders have an opportunity to review the basis individually. In this scenario stakeholders typically include any or all of the following individuals:

- System engineers
- Component owner/engineer
- Maintenance supervision/management
- Operations personnel
- Planning & scheduling personnel
- Work control/management personnel

3.2 PM Task Planning & Scheduling

The second element of the PM process that follows once PM tasks and frequencies are developed is task planning and scheduling.

3.2.1 Detailed Aspects of this Process Element

Figure 3-2 illustrates a more detailed view of the second PM process element, and implementation guidance is provided in the sections immediately following the figure.

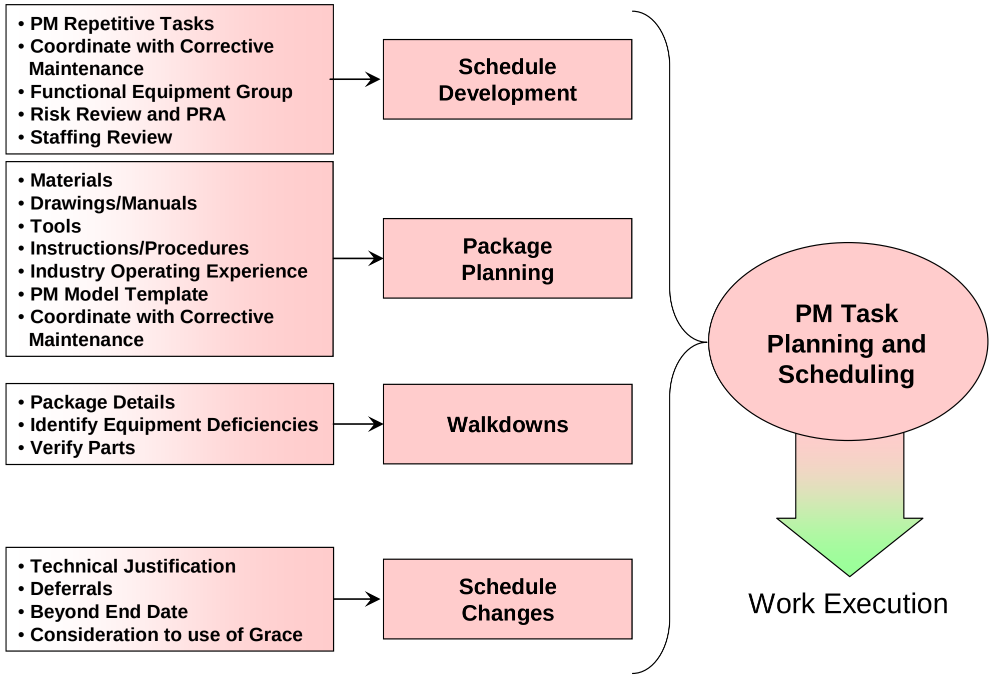

Figure 3-2
PM Task Planning & Implementation

3.2.2 PM Task Planning & Scheduling Implementation Guidance

The intent of this section is to provide detailed implementation guidance for implementing this key element of the PM process model, and how to optimize interfaces with other elements outside of the PM sector.

3.2.2.1 Schedule Development

Typically the first activity regarding the development of a PM schedule is to establish functional equipment groups (FEG). This grouping of equipment enables site personnel to analyze the long-term cycle plan and determine how best to use grace to consolidate work activities.

Another key element of schedule development is to ensure first-time PM activities have addressed the following issues:

- Validation of need for the task
- Impact on resources
- Ensure appropriate plant configuration
- Parts availability review
- Determine planning needs
- Training

Key O&M Cost Point
By examining PM tasks with compatible frequencies, work can be efficiently bundled to optimize costs, minimize equipment out-of-service time, and efficiently use maintenance resources.

- Equipment criticality
- Plant risk

Additional guidance is provided in the following documents:

- Equipment Reliability Process Description. INPO, Atlanta, GA: March 2011. AP-913, Revision 3.[5] (Available only to INPO members.)
- Work Management Process Description, Appendix H. INPO, Atlanta, GA: June, 2010. INPO AP-928, Revision 3.[5] (Available only to INPO members.)

Key O&M Cost Point
Once PM scope and schedule are identified, staffing reviews can commence to ensure the most effective use of available resources.

Inherent to the scheduling process should be the implementation of appropriate risk reviews and the identification (and grouping) of repetitive tasks. Preventive Maintenance should be coordinated with other types of maintenance activities (e.g., corrective, elective, tool pouch, surveillance, etc.) to ensure efficiency, to avoid duplication of activities, and to optimize the use of maintenance resources. In parallel with this, schedulers should identify and review plant health issues and criticality classifications, as needed.

3.2.2.2 Package Planning

Detailed guidance regarding the methodology for developing and planning a work package is provided in EPRI 1011903, "Maintenance Work Package Planning Guidance", and is summarized below as it would apply to the planning of PM tasks.

Perform Initial Review of the PM Task

In many systems, the work planner can perform this task by validating and updating the work description. The PM task description should validate the scope of the work being performed. The work planner may also be required to validate and update the task description panel, if needed.

If possible, the task description should include the discipline doing the work, the component tag being worked (or affected), and the task work scope. In some cases, the task description may be the same as the title of the PM task.

The work planner should review the work management database to determine if any existing active PM tasks already address the task without duplication. They should also validate the newly created PM task. This validation should include a walkdown, which verifies the following:

- Equipment tag number
- Nameplate data of the component
- Location

[5] Access to INPO reports and materials is restricted to organizations authorized by INPO. The information is confidential and for the sole use of the authorized organization.

- Parts that have been identified for the PM task
- Scaffold and insulation requirements
- Required permits
- ALARA
- Resources, including support staff
- Special and necessary tools
- Work area conditions and potential hazards
- Personnel protective equipment
- Required plant configuration needed for task execution

Many plants already have standing procedures describing the requirements associated with performing field walkdowns, and if this is the case, they should be referenced and followed. The walkdown can be waived if it would result in unnecessary radiation exposure, requires entry into a confined space, is a priority task, or is not required by the nature of the reported problem as determined by the work planner, or as a result of the application of a graded walkdown procedure. Some plant procedures require the craft to perform a walk down, which often includes drawing out the required parts. This happens prior to work execution as prescribed in INPO AP-928[6]. This activity is valuable because it affords an opportunity for the craft to provide feedback on the work package prior to work commencing, and if necessary get it changed prior to performance of the work activities.

The following general guidance regarding walkdowns should be considered:

- A PM task planning field walkdown checklist should be considered as a means of ensuring consistency, and be used to assist in planning the work activities
- If assistance is required to perform a walkdown, the work planner should notify the respective group performing the walkdown that support will be needed
- If the walkdown reveals an energy release may be necessary, the work planner should make a note in the precautions/prerequisites section, while referencing the appropriate plant procedure. (Note that implementation of the energy release would typically be the responsibility of operations personnel and not the work planner. Walkdowns are more often performed by maintenance craft than planners.)
- Photographs and/or digital images should be included in the PM task for clarity and pre-job briefs whenever possible.

[6] Access to INPO reports and materials is restricted to organizations authorized by INPO. The information is confidential and for the sole use of the authorized organization.

Key Human Performance Point
The work planner should generate separate tasks for support activities to ensure PM task completion.

PM Task Development

Preventive Maintenance tasks should be based on pre-planning activities and are generally subdivided by crew or the discipline performing the task. In addition, tasks may be further segregated based upon implementation of the task sequence. For example, a task which would normally be divided in the schedule into one or more activities, may be broken up into the corresponding number of sub-tasks, as determined by the planner (based on complexity and scope of the work).

Note that this may not necessarily apply to PMs or work orders that utilize equipment lists. Development of work instructions associated with complex jobs should be coordinated with other discipline planners to ensure appropriate PM tasks have been properly identified. The work planner initiating a sequential support task should typically notify the work week manager/scheduling when initiating activities.

Develop the Work Instructions

The work planner should determine the availability and applicability of existing work instructions before developing new ones.

Identification of Necessary Parts

Key Supervisory Observation Point
The planner should be careful when using a Bill of Material parts list that the most current part number is used for needed parts.

The planner should retrieve the bill of material information when building a material request for a PM task, and care should be taken to use the most current and approved revision of vendor drawings and catalog information.

Some plants leave part revision history in the BOM resulting in the use of potentially incorrect information if the parts list is not carefully reviewed. When a bill of material is determined to be inadequate to positively identify the correct part/replacement item, the planner should initiate appropriate action.

Miscellaneous Task Planning

Depending on the type of information system used at the plant, there are a number of miscellaneous actions that may need to be communicated to the personnel implementing the work package. Examples of this type of information may include the following:

- Instructions to manually set/change flags and requirements (if not automatically populated)
- Ensuring accounting codes are correct
- Ensuring PM task skill codes are correct
- Ensuring process panels of the information system are addressed
  - Task profile
  - Document reference
  - Resource
  - Requirements/permits

- Nuclear safety concerns
- Task scheduling
- Hold processing
- Address cross-reference

Administering the PM Task Approval Process

Key Human Performance Point
Preventive Maintenance work instructions are written for maintenance activities that do not change the design of the plant, and are not subject to 10CFR50.59. As such, a technical review is appropriate, in lieu of the review process described in the regulation.

The technical reviewer is the individual assigned to review the work package content and quality. A technical review is typically required when approved procedures/pre-approved instructions do not exist. This technical review is to adequately reviewing the following:

- Work instructions containing complex or unique step-by-step instructions on critical equipment (Note that safety-related documents require review and approval by a knowledgeable individual prior to initial use in accordance with Regulatory Guide 1.33.)
- Work instructions posing a risk of unit/generator trip, plant transient or lost generation

When the planner has completed entering the planning details and other appropriate information on the PM task, the planner should then develop the appropriate routing list and submit the task for approval. In many cases (e.g., ISI, coatings work, EQ, welding, etc.) electronic review and approval may be desirable. The work planner may add other organizations or individuals such as radiation protection, quality control, engineering, etc. for approval.

3.2.2.3 Craft Walkdowns

Another key element of the planning and scheduling element of the PM program is the conduct of craft walkdowns. Many sites take a graded approach to this activity and vary the rigor of the walkdown based on the following criteria:

- Criticality of components
- Risks
- First-time performance
- Complexity of the task, frequency of performance
- Strength of existing procedures

During or immediately after the craft walkdown, the appropriate maintenance and work planning personnel should perform the following activities:

- Verify availability of the correct parts
- Identify equipment deficiencies
- Review work package content and details
- Look for opportunities to bundle work or take credit for recent maintenance

- Look for discrepancies regarding resource loading
- Identify/review clearances
- Report any unidentified support activities

3.2.2.4 Schedule Changes

Schedule changes may be necessary to support the execution of a PM task. EPRI Report 1014798 and INPO AP-928[7] address causes and effects of schedule changes and include metrics for measuring the impact on program performance. The measurement criteria used by the each plant should be commensurate with either each site's own specific criteria or criteria generally in use within the industry, or as supplied by other organizations, i.e., INPO, ERWG, etc. As noted above, the information provided is from EPRI Report 1014798 published in December 2007. Users of this information should check the EPRI database for more recent revisions. The following describes four performance metrics associated with schedule changes.

- Percentage or Number of PM Deferrals
- Delinquent (Late) PMs
- PMs Completed Deep into the Grace Period
- PM Revision Backlog

3.3 Performing Preventive Maintenance

The third element of the PM process subsequent to the planning and scheduling of maintenance activities is the actual performance of the PM tasks.

3.3.1 Detailed Aspects of this Process Element

Figure 3-3 illustrates a more detailed view of the third PM process element, and implementation guidance is provided in the sections immediately following the figure.

[7] Access to INPO reports and materials is restricted to organizations authorized by INPO. The information is confidential and for the sole use of the authorized organization.

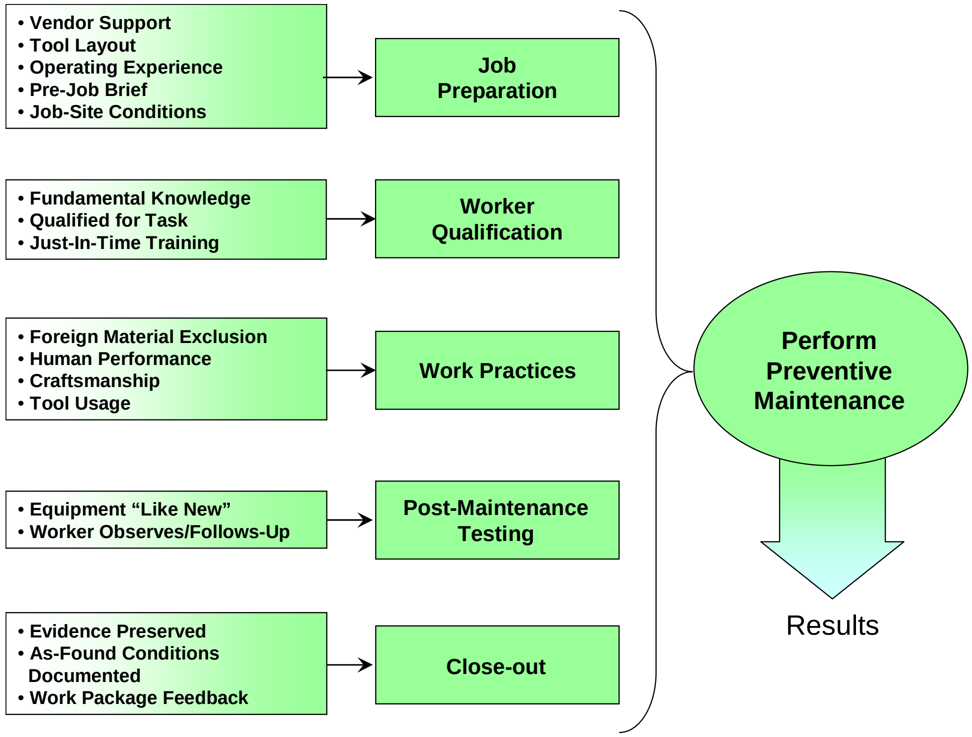

Figure 3-3
Performing Preventive Maintenance

3.3.2 PM Program Bases Implementation Guidance

The intent of this section is to provide detailed implementation guidance for implementing this key element of the PM process model, and how to optimize interfaces with other elements outside of the PM sector.

3.3.2.1 Job Preparation

To ensure safe and effective performance of PM tasks, maintenance craft personnel typically prepare for the job by conducting the following activities:

- Attend a pre-job brief (graded approach), which should take into account plant operating experience and include any appropriate human performance tools
- Conduct a walkdown of clearance tag configuration
- Physically identify and obtain parts/materials
- Identify personal protective equipment (PPE) needed for the work
- Note current job site conditions (ambient, radiation level, confined space, and current system conditions)
- Ensure any necessary vendor support has been coordinated
- Verify worker qualification are current

- Layout tools anticipated for the work activities
- Ensure start-work permissions/approvals are in place and documented
- Verify required support activities have been accomplished (e.g., scaffolding, RP support, hot work permit, etc.)

3.3.2.2 Worker Qualification

The basic discipline-specific skill sets that are commonly assumed among craft labor are often referred to as the "Skill-of-the-Craft". These work skills are accumulated knowledge from basic craft experience, or those skills resulting from training required to obtain independent qualification, or enhanced basic journeyman skills. The essential skills of the craft are typically maintained through involvement in an accredited training program.

Skill-of-the-craft skills are considered to be standard industry practices and may not require step-by-step instructions or an approved procedure in hand for work to proceed or be effectively accomplished. As noted in this report, error tolerance and the possible effects to plant operations should be used as considerations when assessing the need for work instructions or procedure.

Key Human Performance Point
The use of skill-of-the-craft in the performance of a job is not considered to be a change of work scope, providing it is confined to the job covered by the work package and that all other work done is in agreement with approved procedures.

Table 3-2 illustrates typical skills of the craft that in most cases can be established as the minimum skills possessed by any craft laborer in their particular discipline. Most craft laborer's skills exceed those listed below, but for the purposes of establishing a minimum baseline in this report, the following tables should be used as a benchmark.

Table 3-2
Minimum Expected Skills of the Craft (Typical) (Reference EPRI 1011903)

Work Activity	Mechanical	Electrical	I&C	Service	HVAC
Air filter, motor – Replace	X				X
Bolts – Tighten	X	X	X		X
Cable raceways - Adjust or replace screws		X			X
Calibration (Electrical meters/transducers, pneumatic timing tools)			X		X
Circuits – Check voltage and current measurements		X	X		X
Computer inks, paper, recorders, etc. – Replace			X		X
Conduit covers, brackets and screws – Replace, grease and lubricate		X			X
Corrosion (abrasive or chemical) – Remove	X			X	X

Table 3-2 (continued)
Minimum Expected Skills of the Craft (Typical) (Reference EPRI 1011903)

Work Activity	Mechanical	Electrical	I&C	Service	HVAC
Crimp connectors – Install or remove		X	X		X
Doors (non-security/fire protection) – Replace or repair knobs, locks, hinges, closures, flushbolts, etc.	X			X	
Drains – Blow-out, clear	X			X	X
Extension cords – Plug in and use	X	X	X	X	X
Fasteners – Cut to length	X	X	X		X
Fencing – Rework or replace	X			X	
Filters – Replace/clean	X	X	X		X
Gaskets – Replace	X	X	X		X
Grating and grating clips – Rework and replace	X			X	X
Greasing	X	X			
Handrail barriers – Rework or replace	X			X	
Handwheels – Replace or rework	X				X
Housekeeping, general-cleaning, inspection	X	X	X	X	X
Instrument fittings – Replace			X		X
Instrument isolation valves – Rework or replace handwheels	X		X		X
Instrument tubing – Rework or replace support clips, screws, spring washers, shims	X		X		X
Instrument tubing – Tighten	X		X		X
Electrical insulation – Check resistance		X	X		X
Insulation – Rework and replace screws/ bands				X	X
Lenses and caps - Replace		X	X		X
Light bulbs – Replace		X	X		X
Lubrication	X	X			
Masonry – Rework	X			X	
Non-skid applications	X			X	
NSR bolts – Replace with identical item only	X				
NSR convenience outlets – Rework or replace		X			X

Table 3-2 (continued)
Minimum Expected Skills of the Craft (Typical) (Reference EPRI 1011903)

Work Activity	Mechanical	Electrical	I&C	Service	HVAC
NSR Fuses – Replace with identical item only		X	X		X
NSR Junction Boxes – Replace gaskets, covers or screws, latches		X	X		X
NSR Light fixtures – Rework or replace		X		X	X
NSR Nameplates, tags, cover-plates, inspection plates – Replace		X	X		X
O-rings – Replace	X	X	X		X
Pipe flanges – Tighten to stop leakage	X				X
Plug-in components – Replace		X	X		X
Pumps/Motors – Add oil or grease	X	X			X
Pumps – Adjust packing	X				X
Refrigerant – Trim charge		X		X	X
Refrigeration – Remove oil from refrigeration plants		X		X	X
Roofing – Rework, non-fire barrier-asphalt, metal, etc.				X	
Seals – Replace	X				X
Soldering (piping and wiring)	X		X		X
Stairs – Rework (nosings, steps, handrails)	X			X	
Telephone/Plant paging system – Rework or replace handles, knobs, switches		X			
Threads – Clean (mechanical means)	X				X
Tubing – Install (except on seismic restraints), fitting, makeup	X		X		X
Turbine diaphragms – Seal with RTV to stop in-leakage	X				
Valve lapping	X				X
Valve packing (manual) – Adjust	X				X
Valve stems (manual) – Lubricate	X				X
Walls (non-fire barrier-gypsum, plaster, metal, concrete) – Rework				X	
Welding/Brazing	X				
Wire wrapping – (except on printed circuit boards)		X			X

Key Human Performance Point
Using human performance tools by maintenance personnel should be in compliance with their individual site procedures, many of which are based upon INPO guidelines.

Use of human performance tools is mandatory in most plants and must be reviewed during pre-job briefs. While INPO provides guidance on what each tool is and how it is applied, each maintenance organization should determine how the maintenance craft make use of them during the execution of work.

Maintenance personnel are encouraged to familiarize themselves with training offered by INPO that addresses Generic Human Performance Tools. These techniques can help them minimize the chances of human error as they perform many of the functions needed to conduct PM activities.

- Peer Checking
- Phonetic Alphabet
- Placekeeping
- Pre-job Briefing
- Procedure Use and Adherence
- Questioning Attitude
- Self checking
- Three-Way Communication
- Print Reading

Maintenance managers should also consider the benefits of Just-In-Time training to fill in any gaps that might exist and to provide extra assurance that the personnel are capable of performing PM activities. Care should also be taken to ensure compliance with the Fatigue Rule (10CFR Part 26).

Key Supervisory Observation Point
Work practices exercised during PM activities should exemplify high standards of quality and workmanship.

3.3.2.3 Work Practices

Maintenance personnel should be aware of the following work practices when performing PM tasks:

- Foreign Material Exclusion (FME) prevention techniques and requirements
- Appropriate use of human performance techniques
- Proper usage of assigned tools
- Pride and proficiency in craftsmanship demonstrated
- Housekeeping and as-left conditions
- Industrial safety
- Radiological Safety
- Nuclear Safety
- Awareness risk and/or impact to the plant resulting from performance of the PM task

Key Technical Point
Standardized PMT procedures and instructions should be used whenever possible.

Key Supervisory Observation Point
When a PMT needs to be prepared, the planner should select the appropriate test scope from a PMT matrix.

3.3.2.4 Post-Maintenance Testing (PMT)

Post-maintenance testing is often an integral part of PM tasks and should be conducted in strict accordance with site maintenance instructions and implementing procedures.

Maintenance personnel should observe the test, record test results when required, and take the necessary follow-up actions depending on the results of the tests.

Post-maintenance testing (PMT) verifies that components and systems are capable of performing their intended functions when returned to service following maintenance and ensures any original deficiencies have been corrected. Certain inspections and checks that satisfy some PMT requirements follow the activities conducted during the maintenance phase. These inspections, verifications, or checks are usually an integral part of the maintenance procedures. After the maintenance is completed, the additional verifications and tests performed ensure that the component or system is ready for operations. The PMT activities should be designed and scoped to assure that the functionality of the component is verified through a series of progressive testing steps, but to avoid duplicate testing.

If a test is not available, the planner should contact the engineering organization for determining the most appropriate functional test, and/or the operations organization for the most appropriate operability test.

The difference between "operable" and "functional" as it relates to post maintenance testing is as follows. Operability is strictly defined within each station’s licensing documents. Functionality is defined as the component being able to perform its design functions.

EPRI Report 1009709, “NMAC Post Maintenance Testing Guide, Revision 1”, provides licensees with suggested activities comprising the scope of the PMT for many different types of equipment. Most licensees have adopted these tests and incorporated them into their respective plant procedures. The report defines post-maintenance testing as:

> “Any appropriate combination of inspections, checks, and testing performed following maintenance to verify that a particular piece of equipment or system performs its intended function based on its design criteria and verification that the original deficiency has been corrected”.

3.3.2.5 Close-Out

The final, yet one of the most important, element of performing PM tasks is the close-out of the work activity. The scope of close-out activities may vary from plant to plant, but a thorough and well-documented close-out of each task is fundamental to ensuring necessary revisions to the PM program are communicated and acted upon.

Typically the close-out will ensure the following activities are addressed:

- As-found conditions are documented (codes plus comments), communicated, analyzed, trended and acted upon
- Work summary is documented in accordance with licensee procedures
- Feedback on work package quality is provided to work planners in a timely manner
- Post-job briefs are attended and used to communicate close-out information
- Following corrective maintenance and/or troubleshooting, evidence is preserved (e.g., worn/replaced parts) in accordance with licensee procedures
- Appropriate and necessary corrective actions are identified, documented, and communicated in accordance with licensee procedures

3.4 Feedback on PM Implementation

The fourth element of the PM process resulting from the performance of PM tasks is the compilation and evaluation of feedback on PM implementation, which ultimately should result in recommended changes to the PM program technical basis, thus closing the cycle of the four key process elements.

3.4.1 Detailed Aspects of this Process Element

Figure 3-4 illustrates a more detailed view of the fourth PM process element, and implementation guidance is provided in the sections immediately following the figure.

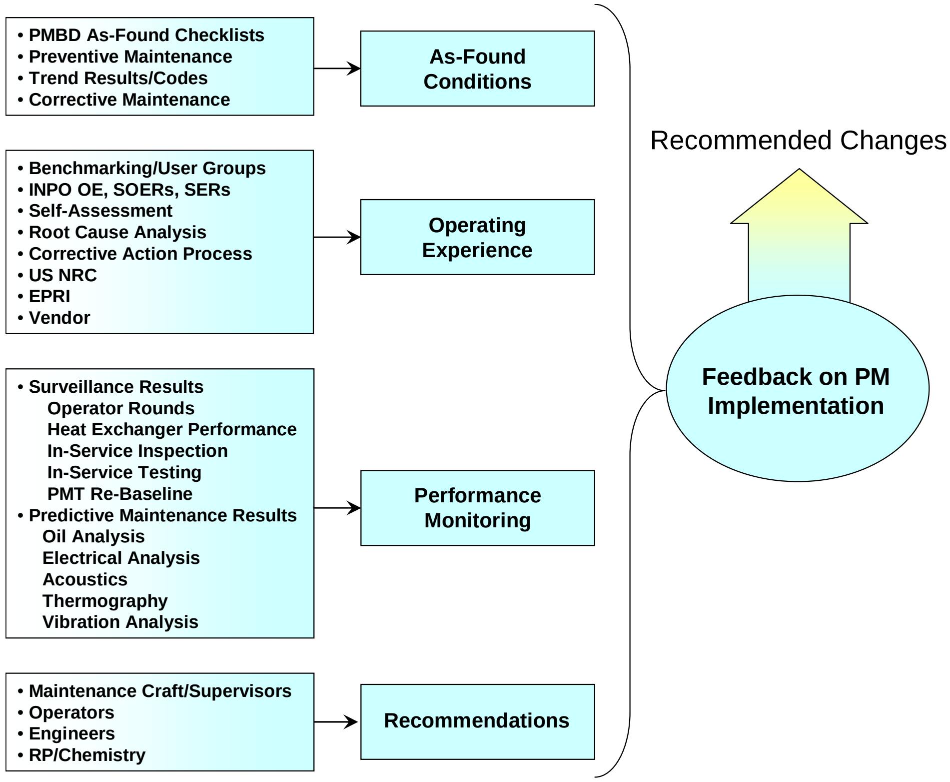

Figure 3-4
Feedback on PM Implementation

3.4.2 Guidance Regarding Feedback on PM Implementation

The intent of this section is to provide detailed implementation guidance for implementing this key element of the PM process model, and how to optimize interfaces with other elements outside of the PM sector.

3.4.2.1 As-Found Conditions

The Institute of Nuclear Power Operations (INPO) AP-913[8] calls for the use of an as-found equipment condition monitoring process.

It is this condition information, and the associated determination of component degradation, that can directly influence future PM task activities and intervals. With this in mind, several factors should be considered in designing the process for capturing information and providing feedback:

Key Technical Point
The capture and review of relevant component condition information during the performance of a specific Preventive Maintenance (PM) task is a crucial step in the ongoing refinement of the overall PM program.

[8] Access to INPO reports and materials is restricted to organizations authorized by INPO. The information is confidential and for the sole use of the authorized organization.

- Consistency. The process must allow for multiple users working on numerous similar components, providing consistent collection of data with minimal reliance on the interpretive skills of the craftsperson performing the PM task.
- Retrievability. The data collected must be in a format suitable for entry into a database for review and trending. It must minimize the use of handwritten dialogue.
- Simplicity. Feedback data collection must not unrealistically impact and burden the PM process or create a negative attitude toward its use.
- Relativity. The capture of information about a component's material condition must address the relative levels of degradation, if such information is definable. It should also consider the mechanisms of component deterioration.
- Applicability. The component condition feedback information requested during the performance of a specific PM task must be applicable to the task, focus on only what is addressed in the task, and be discernable through the activities performed.
- Resolution. This is the key step in closing the loop with the originator, thus promoting the quality and amount of feedback.

In consideration of these factors, the feedback information collection process should be developed, based on the use of applicable checklists of unique component degradation mechanisms. Although not intended to be used as designed forms, these checklists for the collection of feedback information have been logically created with the appearance of a form.

An As Found checklist is available for use for the tasks that are being performed and are located with the PMBD templates task descriptions in the PM Basis Database. These task As Found checklists are directed at the components failure locations and reportable conditions that the task protects against.

As-found conditions should consider the state of equipment immediately preceding both preventive and corrective maintenance activities. Each site should establish appropriate codes for trending maintenance results and as-found conditions. In general, the feedback should be used to evaluate for additions, deletions, and scope and frequency changes. If proactively used, it can be the impetus for timely changes and keep the PM program vibrant and dynamic. When feedback is only acted upon during the Just-in-Time (JIT) or PM challenge meetings, (i.e., done during the PM Task Planning & Scheduling process), it becomes a last resort to affect changes to the PM activities. The living process requires that the evaluation of the as-found data is an on-going process that the owners of the PM Technical Basis update throughout the full length of the planning process. The JIT or PM Challenge meeting should be used only as a last opportunity to identify potential PM scope or interval changes prior to scheduled performance.

EPRI 1002935, "Guideline for As-Found Reporting - A Process for a Living Preventive Maintenance Program" provides detailed guidance regarding the collection and use of as-found data, and should be considered when developing or implementing an as-found program.

In parallel with the development of this report, EPRI was developing a supplemental guideline providing the collection and evaluation of as-found information, and how to effectively use that data to affect changes to PM work activities and frequency. This supplemental report was targeted for publication in 2012.

3.4.2.2 Operating Experience

Key Technical Point
In addition to as-found conditions, operating experience is another key feedback input to facilitate change to the PM task scopes and frequencies, and in a generic sense, keep the process dynamic and living.

Operating experience for a given component or piece of equipment can be obtained through plant-specific experience, self-assessment, benchmarking (e.g., user groups/industry meetings), or root cause/corrective action process. It may also be obtained through the experience of the industry in general. The following sources of industry OE should be considered:

- Original Equipment Manufacturer (OEM)
- EPRI
- NRC
- INPO OE, SER's, SOER's, O&M's
- International experience

3.4.2.3 Performance Monitoring

Another key source of feedback regarding the effectiveness of current PM tasks and frequencies is performance monitoring regularly conducted by maintenance, operations and engineering personnel. The results of predictive maintenance activities are one primary source of equipment performance feedback that can lead to changes in PM activities. Typically, predictive maintenance activities can include any of the following:

- Vibration analysis
- Electrical analysis
- Thermography
- Acoustics measurement and analysis
- Oil sampling and analysis

Other direct sources providing results of equipment performance monitoring may include any of the following:

- Surveillance results
- Operator rounds
- Heat exchanger performance
- In-service inspections

3.4.2.4 Recommendations

Key O&M Cost Point
Recommendations for initiating changes to PM tasks and frequencies should be encouraged and come from as many organizations involved with the reliability of the equipment as possible.

Organizations initiating changes typically include (but not limited to) the following:

- Engineering personnel (system, reliability, component, design)
- Radiation Protection (RP)
- Chemistry personnel
- Operations
- Maintenance craft and supervisors
- Work management (planners, cycle managers, work week managers, schedulers, etc.)

Recommendations provided by original equipment manufacturers should also be considered.

Section 4: The Process for Continuously Improving and Changing PM Tasks and Frequencies

The purpose of this section is to describe the process for continuously improving and changing PM tasks and frequencies. The PM process model described in Sections 2 and 3 is designed to ensure the PM program remains vibrant and living; and one that is capable of facilitating changes as recommended by key maintenance and engineering personnel. However, a key step in this process is effectively incorporating and implementing the recommendations provided (as discussed in Section 3.4 of this report).

This key aspect includes an expectation regarding the acceptance of a certain degree of risk associated with making changes. Experience suggests that this one element was the largest contributor to the failure of as-found programs.

Key Human Performance Point
A key aspect of ensuring the success of any "model" is to make certain that the owners of the PM Technical Basis are in line with management's clearly defined expectations regarding changes to PM scope and frequency.

4.1 Inputs for Recommendations to Change PM Task & Frequencies

As noted in Section 3.4 of this report, the following key inputs shape the recommendations for change to PM tasks and frequencies:

- As-found conditions
- Operating experience
- Performance monitoring

Operating experience is collected over a long period of time and needs to be assessed to determine its applicability to a particular plant component or system. However, the as-found conditions and performance monitoring provide real-time, component-specific information that should be translated into clear recommendations for changing applicable PM task scope and/or and frequencies, and cause those changes to occur. Both are necessary to provide input to cause those changes to occur and assure a vibrant living PM program. As such, processes and guidance for using as-found conditions and the results of performance monitoring to change PM tasks and frequencies are provided in the following sections.

4.2 Effective Use of As-Found Information

4.2.1 Outline of the Process

A simplified version of the decision process is shown in Figure 4-1. This simplified version is not for practical use but rather is intended to show the conceptual basis of the procedure. In the complete procedure (shown in Figure 4-2), there are more options than those shown in the simplified process.

Key Technical Point
Industry experience suggests that if condition codes are going to be used they should be low in number (no more than 5 with 3 being good) with very clearly defined definitions.

The craft should be frequently briefed on what constitutes each of the conditions for the components they most often interface with. Additionally, photographs of components displaying each of the different codes in use should be placed in the shops for ready reference. Training should include a session on application of as-found codes during craft continuing training with, if possible, actual components displaying the conditions attributable to each of the codes. Additional examples of as-found condition coding are provided in INPO AP-913[9] and should be considered.

For example, unacceptable conditions may not lead to shortening the interval if they are low impact items for this task and if a different task would be more effective in addressing them. Another example may occur when the observation of a stable trend would permit task deferral, even if certain marginal conditions had been observed, provided the condition would not become unacceptable before the task was ultimately performed.

The boxes in Figure 4-1 address three commonly encountered situations:

- **Condition Acceptable.** The condition of the equipment is good enough that it is possible to judge there was no need to have performed the PM task when the equipment was observed (although the task was indeed performed), and that equipment performance would have continued to be satisfactory even if the task had been deferred until the next scheduled implementation. The current task interval should be stated at the head of the condition feedback documents to assist in this judgment. The designation acceptable thus actually means acceptable until the next time, suggesting that a frequency change to the task interval might be considered. Typically engineers require a number of consecutive occurrences of the PM found in this condition prior to agreeing to make interval changes (typically 3 times).
- **Condition Marginal.** Some deterioration exists. This deterioration is, however, anticipated and should give no cause for alarm. The degradation is indicative of normal wear, resulting from exposure to anticipated service conditions. The degradation would normally be corrected at this time, either during the PM task or possibly by a separate CM work order (if the PM is covering the need to replace parts due to normal wear there should not be a need for a CM work order, which are tracked and reported under a different set of performance criteria). This case is considered marginal because action

[9] Access to INPO reports and materials is restricted to organizations authorized by INPO. The information is confidential and for the sole use of the authorized organization.

is taken to improve the condition, either because it would become unacceptable before the next time or because it is unclear if the condition would progress to unacceptable by the next time the task is performed if it were not corrected at this time. Marginal degradations indicate that the task content and interval may be appropriate. The key issue is whether the condition would become unacceptable by the next time if no action were taken now.

- **Condition Unacceptable.** There exists a degraded condition that is judged to be unacceptable at this time. The unacceptable condition does not have to be equivalent to a failure, but it should cast doubt on the ability of the equipment to function satisfactorily over the current interval of time if the same degradation were to be repeated in the future (that is, it may have been fortunate to have avoided a failure on this occasion, but there is no guarantee that the same will happen in the future). The designation of unacceptable suggests that the exposure or risk is too high for comfort and that corrective action should have been taken at an earlier time. It raises the question of whether the task content should be modified or the interval reduced to avoid a repeat of the situation in the future.

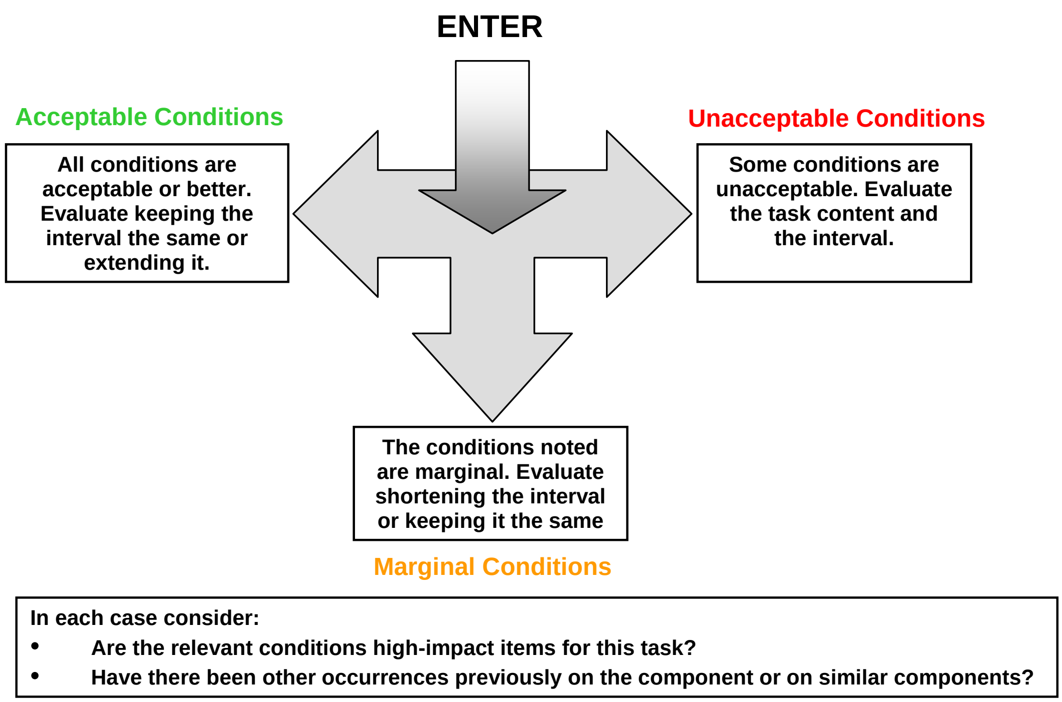

Figure 4-1
Conceptual Basis of the Decision Process [1002935]

In following this process, the simplistic design of Figure 4-1 becomes more complex as it takes into consideration two basic questions:

- Are the observed conditions particularly relevant in some way for this task (that is, do they have high impact)?
- Have the conditions been observed on previous occasions or for other similar equipment?

The flow chart in Figure 4-2 shows an outline of the complete process as it is applied for an individual PM task. This task may be one for which the interval is in question. It may also be any other task thought to be relevant to observed equipment degradation in a process that seeks to change task content or interval for any task that would most effectively address the observed conditions. The tasks ultimately changed may or may not include the task during which the equipment condition had originally been observed.

The decision process consists of the following:

1. The entries on the feedback documents are used to decide which shaded area on Figure 4-2 is applicable.
2. A decision is made about what the action should be, if any.

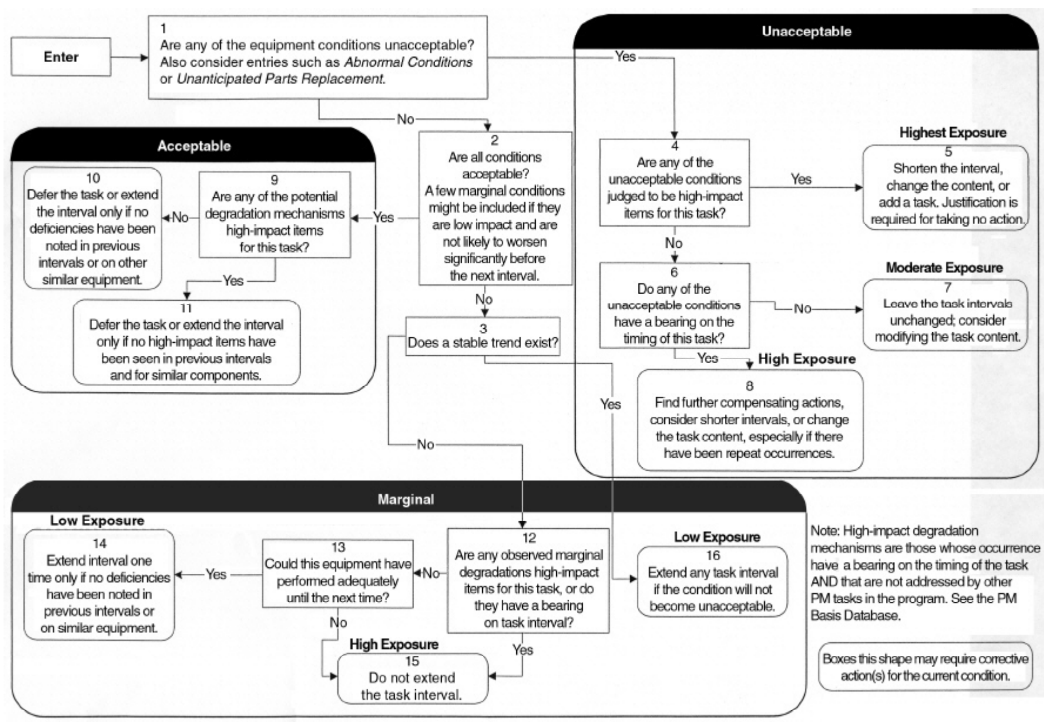

Figure 4-2
Summary Process Chart

Before addressing Figure 4-2 in detail, the impact data and some important features of the feedback documents will be described.

4.2.2 Important Features of the Feedback Documents

The data provided by this project consists of a database of condition information customized to each PM task for major equipment types. The database is presented as a series of checklists. A complete set of as-found reportable conditions specific to each PM task and each component type is obtainable from the EPRI PM Basis Database. These checklists can be viable tools when debriefing craft personnel after an unsatisfactory condition was flagged. The checklists are obtained by pressing the As-found Checklist button on the PM Basis form for the task in question.

4.2.3 As-Found Condition Evaluation Process Using EPRI PM Basis Database

The following procedure assumes that the assignments of acceptable, marginal, and unacceptable can be determined from the information available. If this is not the case, the information is not capable of supporting decisions relating to PM tasks and intervals. The existence of stable trends in condition, if any, should be considered. Extrapolation of such trends can provide the answer to items below.

The general procedure for using as-found data follows.

First of all, it is necessary to identify the applicable PM task that best addresses the degradation mechanism(s) underlying the condition information of interest. This may not be the task during which the condition was noticed and reported.

As an example, two applicable tasks are an overhaul at 15 years and an inspection every 3 years. The 3-year inspection results in an unacceptable condition report involving a degradation mechanism that seems to develop over a time span of approximately 10 years. This observation may have little impact on whether the inspection interval should be 2, 3, or 4 years. On the other hand, the failure-free period might be very significant to whether the overhaul interval should be changed from 15 years to 8, 10, or 12 years.

If the failure-free period is not known and cannot be estimated, it may be better to rely on the inspection to find and monitor the progress of the degradation. In this case, the equipment condition still does not provide direct insight on the inspection interval.

An applicable PM task is one that is designed to address the degradation mechanisms being evaluated. These aspects of the as-found condition are the relevant ones for the applicable task.

For time-directed tasks (in contrast to condition-monitoring activities), the degradation mechanisms being evaluated must be of the wear-out kind if the appearance or absence of the degradation is to have an influence on the task interval. Mechanisms of the wear-out kind have an expected failure-free period and a Time Code in the database that includes the letter W, as in W5-7, or UW3. (To see the time code values, press the Cause Evaluation button on the

Source form.) Failing this, the condition information is not relevant to adjusting the task interval. Therefore, one must beware of drawing conclusions about time-directed task intervals from equipment conditions that are related to randomly-timed degradation mechanisms. In other words, users must have some confidence that the findings on equipment condition point systematically to a conclusion about task intervals.

- If one or more relevant aspects of equipment condition are unacceptable, this will generally indicate that the interval for the relevant task should be shortened. This is especially true if the condition has been seen before, has occurred on similar equipment, or is a known frequent cause of failures in industry experience.
- If all aspects of equipment condition are consistently acceptable, the interval should be lengthened. An intermediate step would be to defer the task one time and to reassess the condition.
- If some aspects of equipment condition are acceptable and none are unacceptable, there is no need to change the interval or defer the task. However, it may be appropriate to modify task content or procedures in relation to unnecessary activities.

The database can provide assistance in guiding these choices. In particular, the Custom Statistics form will show how well the degraded condition is expected to be addressed by the combination of tasks employed. It will also show which other degradation mechanisms are addressed by each task (use the Show Color, Most Likely Degraded Conditions, Most Likely Failure Causes, and Task Effectiveness buttons). The Degradation form will show explicitly which other tasks address the degradation mechanism in question. See the description of the vulnerability evaluation in PM Task Evaluation or Interval Evaluation in the database for further information on how these tools can be used.

The Cause Evaluation and Degradation forms will also show, in the Time Code column, whether a degradation mechanism is expected to possess a failure-free period. Such cases are characterized by a time code containing a "W" or "UW" followed by an expected failure-free period in years (such as W3) or a range of years (such as 5-10, meaning five to 10 years). Note that such a range shows uncertainty about when the failures might first show up. It does not indicate the range of times during which failures will be observed, which can be much longer than the expected failure-free period. Time codes containing an "R" indicate random failures, which can literally occur at any time (that is, with no expectation of an extended failure-free period).

4.2.4 Alternative Process for Evaluating As-Found Data

This section describes an alternative process for evaluating as-found data as depicted in Figure 4-2.

4.2.4.1 Deciding Which Shaded Area Applies (Boxes 1 to 3)

Box 1: The reviewer should make a judgment on whether any of the noted conditions are unacceptable, meaning they are unacceptable at the time they were discovered. Any equipment conditions already noted by the craft personnel in the unacceptable column of the three-column format should probably be considered to be in the unacceptable category, although the reviewer is able to make an alternative designation.

The results of tests and measurements are usually compared to numerical thresholds or ranges to determine the need for action. However, the need for action does not necessarily mean that there is unacceptable risk or exposure. Unacceptable means that action should have been taken before this time. "Unacceptable" flags the need for shortening the interval.

Other Deteriorations and Abnormal Conditions also represent degraded conditions that, if in existence, probably require corrective action. Many of these degradation mechanisms can be anticipated conditions, which the PM task is designed to identify and correct. They may or may not already be unacceptable at the time they are observed. Similarly, if parts need to be replaced that are not scheduled for replacement, there is an indication of a degraded condition that may or may not be unacceptable.

It is a matter of judgment as to which of the above conditions qualify as sufficiently risky that future repeat occurrences would represent too much exposure to be acceptable. In such cases, there would be a willingness to modify the PM program to avoid them on future occasions. The reviewer is acting as a filter to identify events that plant management would not want to see repeated, even though equipment may not have failed. Such conditions are unacceptable and should be further considered in Box 4.

Any unacceptable equipment conditions take precedence over other conditions that might be only marginal or acceptable. Unacceptable conditions require action, although the most effective action may not concern the task in which the unacceptable condition was observed. If there are no unacceptable conditions, the flow passes to Box 2.

Box 2: This box looks for feedback that indicates all noted equipment conditions are acceptable, meaning acceptable until the next time the task is performed. The implication is that the interval might be extended or the task deferred. In reviewing what is acceptable, it is not strictly necessary that the condition should avoid degrading to unacceptable before the next scheduled implementation of the same task, because some intermediate task performance interval could be more practical and still offer beneficial cost reduction. Typically, this would involve task interval extension until the next opportunity to address the condition, which might be during a different task.

The EPRI PM Basis Database suggests that, when a task interval of several years is extended, the extensions should be no larger than 25% of the existing interval up to a maximum of two years. For practical reasons, a short task interval may need to be extended by amounts that could be up to 100% of the existing interval.

Extending the interval for one time means that the task interval is not permanently changed to the new value until the results of further one-time extensions have been experienced. In this report, deferral of the task means that the task is not performed until the next time the same task is scheduled, effectively doubling the interval. Task deferral is a one-time event.

In practice, it is unlikely that all conditions noted would be in the acceptable category, and logic flow would then proceed to Box 3. However, it may be possible to proceed to Box 9 even if a few conditions are marginal, providing that these are all low-impact items and are judged by a wider group of knowledgeable personnel (system or component engineers) to be unlikely to become unacceptable at a longer interval.

Low impact means that the degradation mechanism is one whose occurrence meets all of the following criteria in relation to the other PM tasks that are performed on this equipment:

- Is not common in the industry
- Does not carry implication for the task interval
- Is not heavily relied on to detect or to prevent the condition

The reviewer is responsible for making a personal judgment of the relevance of these factors.

The EPRI PM Basis Database Task Effectiveness form addresses these factors. Low-impact degradation mechanisms are marked with an "X" in the EPRI impact data for the task. Items marked with a "c" (commonly occurs), with a "T" (influences time interval), with an "R" (task is relied on), or with a combination of these, are NOT low-impact items.

Box 3: Box 3 addresses mainly marginal conditions and asks if a trend exists, either quantitative or qualitative, that is stable and predictable. Many forms of deterioration become progressively more severe over time. The existence of a trend implies that the condition has appeared in the past, so that past condition feedback information must be consulted or a numerical value can be separately trended. Unless the trend is approaching an unacceptably degraded or unacceptable condition, there may be a possibility to extend the task interval, depending on the time history and stability of the trend. These cases are addressed in Box 16.

If a trend does not exist, the situation is much less predictable, and a separate judgment needs to be made on whether the task interval could be extended. These conditions are addressed in Boxes 12 to 15.

4.2.4.2 Unacceptable Conditions (Boxes 4 to 8)

Box 4: Box 4 addresses at least one condition judged to be unacceptable, whether this comes directly from conditions noted to be unacceptable by craft personnel, from other deteriorations or other abnormal conditions, from results of measurements or tests, or from unanticipated parts replacements, all of which are judged to be unacceptable by the reviewer. If there is more than a single unacceptable condition, it is recommended that the process first be worked for each condition separately before a judgment is made on the combination. If any of the unacceptable conditions are high-impact items, the objective should be to modify the PM program by changing the task content, improving the task implementation, or decreasing the interval.

High impact means that the degradation can influence the task interval. The PM program should reliably detect or prevent such degradation. The reviewer is responsible for making a personal judgment of these factors. Assistance can be obtained from the EPRI impact data. High-impact degradation mechanisms are marked with a "TR" or "TCR" in the EPRI impact data for the task.

Items marked with a "T," "R," or "c," or with combinations of these other than "TR" or "TCR," are NOT considered high-impact items in this evaluation process. However, utility personnel are encouraged to modify what they believe should qualify as high impact. Before using the data, it is necessary to check that the degree of reliance on the task for addressing the unacceptable conditions is as indicated by the impact data, considering the PM program in effect at the utility.

Box 5: Box 5 develops actions to improve PM performance. The EPRI PM Basis Database Most Likely Degraded Condition and Most Likely Failure Cause analysis, in conjunction with the suggested task scope listed at the end of each task, provide possibilities for additional PM activities that might be added to the scope of the task. The PM Task Basis text outlines the key focus of the task, its timing, and the main influences on each. Taken together with vendor recommendations, industry operating experience, relevant problem reports, and associated root cause analyses, it should be possible to decide how to modify the task to obtain improved performance.

As a last resort, modifications to the equipment may be justified if enhanced maintenance cannot compensate for a design weakness or if the cost of enhanced PM, CM, and equipment outages is too high.

In general, the need for changes of some kind will be dependent on the number of independent unacceptable conditions, the degree of functional importance of the equipment, whether the unacceptable conditions have occurred previously, and whether they have also occurred on other examples of the same type of equipment. Situations that end up in Box 7 should have written justification if no action is taken.

Box 6: If there are no high-impact items (see Box 4 for an explanation of high impact) for the current task among the unacceptable conditions, these conditions can still have a bearing on the timing of the task. A "T" in the impact data suggests degradation mechanisms of this kind. If none of the conditions have a bearing on the timing of the task, there is less incentive to change the task interval. Therefore, changing it might be a mistake. This situation is considered in Box 7. If the appearance of unacceptable conditions carries some implication for task timing, this is considered further in Box 8.

The degree of reliance placed on the task in addressing the unacceptable conditions should be independently considered in the light of the other PM tasks in effect for the equipment. The generic case assumes a PM program equivalent to that in the EPRI PM Basis Database. If fewer tasks are performed at the utility, some additional items might need to be upgraded to an "R" status.

At this point, the reviewer would do best to consider other tasks that also address the unacceptable conditions, if there are any, because some of these can be high impact and be more effective in addressing the condition.

If no other tasks provide a higher potential impact, the evaluation should be continued for the current task. Even if changes to other tasks provide a higher impact, the evaluation should still be closed for the current task to complete the options available.

Box 7: Unacceptable conditions may not have any direct bearing on decisions affecting the task interval. In this case, the task interval should not be changed. For example, a frequently performed task such as a yearly inspection is not significantly impacted by the observation of a condition that develops slowly, such as corrosion of HVAC ducting. However, it may be appropriate to change the task content, for example, by including less accessible areas of the ducting in the inspection.

Box 8: Unacceptable conditions have been observed that carry some implication for the timing of this task, even though there can be other PM tasks in the program that address the issue. If changes to other tasks appear more likely to effectively address the issue, the current task interval should not be changed. However, if this task offers the best way to address this equipment condition, the task interval should be shortened or the task content modified.

The need for changes of some kind will generally be dependent on the number of independent unacceptable conditions, the degree of functional importance of the equipment, whether the unacceptable conditions have occurred previously, whether they have also occurred on other examples of the same type of equipment, and whether they are high-impact items for another task. The situation is similar to that for Box 5, but the incentive to change the current task is likely to be less, and more options may be available.

4.2.4.3 All Conditions Acceptable (Boxes 9 to 11)

Box 9: If all aspects of the equipment condition appear to be acceptable for some time beyond the current implementation of the task, this would seem to be an invitation to extend the task interval. However, the advance of degradation mechanisms in time and the occurrence of failures are notoriously variable in many instances; therefore, it is necessary to apply a significant level of conservatism in the approach to interval extension or eventual task elimination.

The first level of caution should take account of the degree to which this task is sensitive to any of the potential degradation mechanisms (including ones that have not yet been observed). A high-impact mechanism is dependent on the task for its detection; no other line of defense is available from other tasks that are in the program (see Box 4 for an explanation of high impact).

A high-impact mechanism is also one that, if it were to occur, would likely have a bearing on the task interval (that is, it is a "TR" or "TCR" in the impact data). If none of the degradation mechanisms addressed by this task are of high impact, it should be possible to extend the task interval with very little risk or exposure. This situation is considered in Box 10. In the more likely case where at least some of the degradation mechanisms are of high impact, somewhat more caution is indicated in Box 11.

The degree of reliance placed on the task in addressing all the possible degraded conditions should be independently considered in the light of the other PM tasks in effect for the equipment. The impact tables assume a PM program equivalent to that in the EPRI PM Basis report. If fewer tasks or different combinations of tasks are performed at the utility, some additional items might need to be upgraded to an "R" status.

Box 10: Situations that end up in this box should carry the expectation that the task interval might either be deferred on this occasion or extended in general. No kind of task interval extension should be implemented unless the equipment was restored to good condition at the last implementation of the task. In addition, if deficiencies were observed on either of the previous three occasions or for other similar equipment, there is no justification for either deferring the task one time or for increasing the task interval. Previous condition reports and other similar equipment should be checked. If the condition consistently appears to be acceptable, the task can be deferred or the interval extended, especially if deficiencies that have occurred historically are effectively addressed by at least one other task.

Interval extension should be implemented carefully and not by doubling the current interval if this is already several years. This is especially true if some condition deficiencies have been noted historically or in industry experience, or if the current interval is already longer than that recommended in the EPRI PM Basis Database. If parts have repeatedly been replaced unnecessarily, it might be possible to eliminate these unnecessary replacements provided the interval stays the same. If the interval is extended, the parts replacements at the longer interval should be retained until experience is gained at the longer interval.

Box 11: Extra caution should be applied in this case because high-impact degradation mechanisms exist for this task. No kind of task interval extension should be implemented unless the equipment was restored to good condition at the last implementation of the task. Task deferment or interval extension should be dependent on whether the previous three condition reports for the same task and other reports for similar equipment have indicated all equipment conditions to be acceptable for an extended period. In particular, if equipment condition deficiencies that had shown up previously are high-impact items, the task should not be deferred or the interval extended unless corrective action is known to have eliminated the root cause.

As noted in Box 10, interval extension should be implemented carefully and not by doubling the current interval if it is already several years. This is especially true if similar condition deficiencies have been noted historically or in industry experience, or if the current interval is already longer than that recommended in the EPRI PM Basis Database.

4.2.4.4 Marginal Conditions (Boxes 12 to 16)

Box 12: This box addresses feedback information showing equipment conditions that are not judged to be unacceptable but are not so acceptable as to be an invitation to interval extension (that is, in this case some noted conditions were marginal). Since no stable trend is evident, it would appear that if any of the marginal conditions are high-impact items for this task (see Box 4 for an explanation of high impact) or would have a bearing on the task interval (a "T" in the impact data), it would be unwise to extend the task interval in any way, as indicated in Box 15. If none of the marginal conditions are high impact, and none are likely to influence the task interval, the case is considered further in Box 13.

Box 13: If there is no undue impact on this task from the marginal degraded conditions, a judgment must now be made as to whether the equipment could operate for an extended period of time without the condition becoming unacceptable. If the answer is no, there is obviously no justification for extending the task interval in any way, as indicated in Box 15. To assist in answering this question, information from previous condition forms and from other tasks that address the same condition should be considered.

If, in the judgment of the reviewer, the equipment could continue to operate without the condition becoming unacceptable, consideration can be given to extending the task interval one time, as in Box 14.

Box 14: Condition items that reach this box reveal marginal conditions that are not particularly relevant for decisions affecting this task. It has been judged that the specific condition(s) most recently observed would not have become unacceptable at an extended interval. However, the occurrence of the marginal conditions on previous occasions might be significant. It is advisable to extend the task interval on one occasion if the condition was restored at the last condition report, but only if this or other marginal degradations have not shown up on any of the three previous occasions or for other similar components. If the condition was not restored at the last condition report, there is no basis for a one-time interval extension. In any case, the interval should not be changed permanently until further experience is gained from one-time extensions.

Box 15: This box simply indicates the task interval should not be extended if marginal conditions that do not exhibit a trend that can either have an impact on the task interval or could become unacceptable before the next time.

Box 16: Marginal conditions that exhibit a trend provide an opportunity to extend the task one time with little risk unless the condition has advanced to the point where it might become unacceptable before the next time. The task interval can be extended one time, or even deferred one time if this is not the case, even if the condition is a high-impact item for the task. Alternatively, the task can be performed the next time to restore the condition and extended one time after that. If the trend is confirmed by new experience, the task interval could eventually be extended permanently.

In the case where a trend is stable, there may also be support for increasing the task interval. Assuming that no deferrals will take place when close to unacceptable conditions, the stability of the trend over several past performances of the task suggests that the interval might be increased.

4.2.5 High Impact or Low Impact

As noted above, the two factors that influence the majority of decisions are whether the relevant equipment conditions are high-impact conditions for the task in question and whether the conditions have been observed previously for this equipment (or for other equipment of the same type with the same functional importance, duty cycle, and service conditions). The impact that the observation of the degradation has on decisions affecting the task is described in the following text.

There are many ways equipment condition can degrade. The feedback documents can provide information on all of them, but the information is not uniformly important to each PM task. A key to evaluating the significance of this information is to realize that the relevance of equipment condition depends on the task being evaluated.

For example, a PM program consists of an overhaul at 15 years and an inspection every 2 years. A degradation mechanism that develops steadily over a time span of 10 years is observed during one of the inspections, but it has little impact on whether the inspection interval should be 1, 2, or 3 years. On the other hand, its observation might be very significant to whether the overhaul should be changed to 8 or 10 years.

Furthermore, if the PM program contains two tasks being done much more frequently than the overhaul, both of which are capable of detecting the above unacceptable condition, the risk of exploring overhaul intervals in the range of 10 to 20 years is much less than if the condition had been detectable only by the overhaul.

If a degradation mechanism can initiate randomly with no warning and has a significant chance of occurring in 2 to 5 years, its observation has little impact on decisions affecting the overhaul interval (for example, at 10 years), but it might be very significant for the more frequent inspections.

Considerations like these lead to the concept that the appearance of various equipment degraded conditions carries very different levels of significance, depending on the task and interval being considered. An aid to making these judgments can be derived from the EPRI PM Basis Database that contains information supplied by utility maintenance personnel on the most important reasons for doing each PM task.

4.3 Effective Use of Performance Monitoring Results

Use of performance monitoring results can be an effective input for improving the PM process if it is continuously tracked and trended.

As noted on Figure 3-4, performance monitoring should include results from operator/engineer surveillances as well as predictive maintenance activities. The two contributing elements may include input from any of the activities/programs listed in Table 4-1.

Key Technical Point
Performance monitoring results should supplement the documentation of as-found conditions and operating experience.

Table 4-1
Contributing Elements of Performance Monitoring

Surveillance Results	Predictive Maintenance Results
• Operator Rounds	• Oil Analysis
• Heat Exchanger Performance	• Electrical Analysis
• In-Service Inspection	• Acoustics
• In-Service Testing	• Thermography
• PMT Re-Baseline	• Vibration Analysis

4.4 Examples of PM Feedback

The purpose of this section is to illustrate examples of how PM feedback can be scored and incorporated into the process to continually improve and optimize PM task scope and frequencies.

Tables 4-2 through 4-7 illustrate examples of how one site collected and scored PM feedback for various activities associated with valves and valve operators. These examples are provided for illustrative purposes only and as such each user of this report should determine the extent to which these examples should be used to enhance existing site/fleet procedures.

Table 4-2
PM Feedback Codes for AOV Testing

Value	Conditions
"A" – SUPERIOR	Superior Like New (Comment Required) All Criteria met by "as-found" test no adjustments needed, no actuator leakage Smooth Stroke
"B" – SAT	Satisfactory As Expected data except **minor** adjustments/ wear/ air leaks. Function/ control not affected.
"C" – IMPROVE	Sat With Improvement Possible Any suggestions for improvement
"D" – ABNORMAL	Abnormal Wear/Degraded (Comment Required) "As-found" Acceptance Criteria failed. Function/ control may be affected but correctable by adjustments only. Sluggish/Jerky Motion
"E" – EXTREME	Extremely Degraded (Comment Required) "As-found" Acceptance Criteria failed **significantly** Valve function/ control affected Valve Motion extremely jumpy, jerky Unexpected parts replacements/ overhaul required.

Table 4-3
PM Feedback Codes for AOV Packing

Value	Conditions
"A" – SUPERIOR	Superior Like New (Comment Required) Valve Packing found > 80% of predicted drag Valve Packing loads found close to last AOV test values
"B" – SAT	Satisfactory as Expected Nominal Adjustment/ retorque required only (typically 3-6 flats) Valve Packing found between 60% and 80% of predicted drag
"C" – IMPROVE	Sat With Improvement Possible Any suggestions for improvement
"D" – ABNORMAL	Abnormal Wear/Degraded (Comment Required) Significant Retorque required (ie many flats) Valve Packing found between 40% and 60% of predicted drag
"E" – EXTREME	Extremely Degraded (Comment Required) Valve Packing Found LEAKING Very Significant Adjustment, Repack or Rework required Valve Packing Found < 40% of predicted drag

Table 4-4
PM Feedback Codes for AOV Actuator Overhauls

Value	Conditions
"A" – SUPERIOR	Superior Like New (Comment Required) Actuator found in "like new" condition <1 psi. "as-found" drop test All elastomers soft, undamaged, o-ring/ seal lube not dry Non-elastomers (stem, piston, cylinder) good shape (no scoring etc)
"B" – SAT	Satisfactory as Expected Function/ control not affected <5 psi. as-found pressure drop Standard Elastomers/ lube/ regulator replacement ONLY required
"C" – IMPROVE	Sat With Improvement Possible Any suggestions for improvement
"D" – ABNORMAL	Abnormal Wear/Degraded (Comment Required) <10 psi "as-found" pressure drop Very noticeable degradation of elastomers and lubricants (i.e., dry) Minor non-elastomer rework Minor Function/ control degradation noted
"E" – EXTREME	Extremely Degraded (Comment Required) Function/ control affected >10 psi as-found pressure drop Elastomer failure/ damage significant Major non-elastomer damage/ rework required.

Table 4-5
PM Feedback Codes for Manual Valve Packing

Value	Conditions
"A" – SUPERIOR	Superior Like New (Comment Required) No signs of leakage, bolting in good shape little nut turn on packing re-torque Consideration to extending the PM Frequency
"B" – SAT	Satisfactory as Expected No signs of leakage, bolting in good shape 2-4 flats nut turn on packing re-torque If large population, few if any problems found
"C" – IMPROVE	Sat With Improvement Possible Any suggestions for improvement
"D" – ABNORMAL	Abnormal Wear/Degraded (Comment Required) Signs of leakage More flats then excepted required to achieve Packing Torque value
"E" – EXTREME	Extremely Degraded (Comment Required) Valves found leaking Packing found with little load, significant re-torquing required

Table 4-6
PM Feedback Codes for Check Valves

Value	Conditions
"A" – SUPERIOR	Superior Like New (Comment Required) Check Valve found in excellent condition, Little if any signs of wear or flutter, or body contact Little if any build up of scale, mud or rust
"B" – SAT	Satisfactory as Expected Check valve found in good operating condition No surprises found, after restoring, check valve is good till next PM
"C" – IMPROVE	Sat With Improvement Possible Any suggestions for improvement
"D" – ABNORMAL	Abnormal Wear/Degraded (Comment Required) Check valve would still operate proper Significant wear, damage, etc, part replacement required Unexpected wear or damage
"E" – EXTREME	Extremely Degraded (Comment Required) Check Valve found just operable or damage/broken/inoperable Unacceptable wear or damage Check Valve broken

Table 4-7
PM Feedback Codes for Safety/Relief Valves

Value	Conditions
"A" – SUPERIOR	Superior Like New (Comment Required) Found in excellent condition No adjustment required
"B" – SAT	Satisfactory as Expected Lifted at setpoint +/- 3% in general Minor adjustment requirement, Little debris etc found in inlet piping
"C" – IMPROVE	Sat With Improvement Possible Any suggestions for improvement
"D" – ABNORMAL	Abnormal Wear/Degraded (Comment Required) Lifted outside of +/- 3% Adjustment required Some debris found in inlet piping
"E" – EXTREME	Extremely Degraded (Comment Required) Failed to lift near set pressure or found leaking Unable to readjust Inlet blocked or significantly filled with debris mud, etc.

Table 4-8
PM Feedback Codes for Other Valves

Value	Conditions
"A" – SUPERIOR	Superior Like New (Comment Required)
"B" – SAT	Satisfactory as Expected
"C" – IMPROVE	Sat With Improvement Possible Any suggestions for improvement
"D" – ABNORMAL	Abnormal Wear/Degraded (Comment Required)
"E" – EXTREME	Extremely Degraded (Comment Required)

Section 5: PM Process Measurement and Performance Indicators

The purpose of this section is to provide a means to measure the effectiveness of the living PM process.

5.1 Introduction to PM Program Self-Assessment Metrics

Table 5-1 illustrates the three major program attributes discussed in EPRI 1014798 and which major program attributes can be measured by using a combination of the various metrics noted. The user of this report should recognize that there are several metrics shown on Table 5-1 that address the vibrancy of the program and ensuring that it remains a living program that changes PM tasks and frequencies as necessary over time.

Four metrics are associated with Major Program Attribute 1, and are related to scheduling PM activities as previously discussed in Section 3.2.2 of this report. Seven metrics are associated with Major Program Attribute 3, and are related to measuring the effectiveness of a living PM program.

Table 5-1
PM Major Program Attributes and Related Performance Metrics

	Major Program Attributes	Related Performance Metrics
1	The PM Program as a Work Management Process	See Section 5.2 of this report for detailed guidance regarding the four (4) metrics recommended for measuring the work management process within the PM program. • Percentage or Number of PM Deferrals • Delinquent (Late) PMs • PMs Completed Deep into the Grace Period • PM Revision Backlog
2	The Infrastructure of the PM Program	See EPRI 1014798 for detailed guidance regarding the six (6) metrics recommended for measuring the infrastructure of the PM program. • Staff Capabilities and Experience • PM Living Program Procedures • Documented Program Health, Assessments and Benchmarking • Training • Technical Evaluations of PM Deferrals • PM Basis Documentation
3	The PM Program as a "Living Program"	See Section 5.3 of this report for detailed guidance regarding the following seven (7) metrics recommended for measuring the infrastructure of the PM program. • Amount of Craft Feedback • Quality of the Craft Feedback • Ability to Evaluate Craft Feedback • Feedback Response Time to Craft Feedback • Just In Time (JIT) PM Review Process • Template Development and Implementation • Integration of Industry Data into PM Templates

5.2 Major Program Attribute 1: The PM Program as a Work Management Process

The information provided in this section and Section 5.3 is from EPRI Report 1014798 published in December 2007. Users of this information should check the EPRI database for more recent revisions. The measurement criteria used by each plant should be commensurate with either each site's own specific criteria or criteria generally in use within the industry, or as supplied by other organizations, i.e., INPO, ERWG, etc.

This major assessment attribute should measure how well site personnel are getting the work done in the field. To measure this major program attribute, site personnel should consider the following four (4) performance metrics:

Percentage or Number of PM Deferrals – A percentage of the current number of orders deferred divided by the total number of PM Tasks performed during the same period. Deferred orders are not counted until the order is past its grace period late date. Also orders on equipment that are broken and "out of service" where the PM scope will be completed prior to returning to service do not need to be counted. (Note 1)

Basis – Deferred orders are a direct measure of PMs that are not being performed when scheduled, and indicate a breakdown in the planning/scheduling and subsequent execution of PM activities. The following metrics were consistent with those established by the ERWG Equipment Reliability Index (ERI) at the time the EPRI report was published. The user should ensure the most current ERI is used, which may be found at www.INPO.org/.

Score (Color)	Rating	Percentage of PM Deferrals	Number of PM Deferrals per Unit per Quarter (Note 2)	Number of PM Deferrals per Unit per Quarter (Note 3)
10 (Green)	Industry Best	< 0.1% PM Deferrals	1	2
8 (Green)	Industry Strength	PM Deferrals > 0.1% to < 0.25%	2	4
6 (White)	High	PM Deferrals > 0.25% to < 0.5%	6	12
4 (Yellow)	Medium	PM Deferrals > 0.5% to < 1.0%	7 - 10	13 - 20
2 (Red)	Low	PM Deferrals > 1.0%	≥ 10	≥ 20

Notes:
1) A brief discussion regarding industry guidance on deferrals is provided in Appendix D of EPRI 1014798. Deferrals typically do not apply to very short frequency PM (i.e., weekly/monthly) since they almost immediately come due again, are difficult to track, and are typically more of an inspection/check versus a task which affects equipment reliability.
2) Recommended metrics are suggested for critical equipment, as determined by each site per INPO AP-913
3) Recommended metrics are suggested for non-critical equipment, as determined by each site per INPO AP-913

Delinquent (Late) PMs – Number of PMs that are found to have exceeded their grace period without an approved deferral in place on the date it exceeded the late date. Note that a given PM could include a number of components. If this is the case, the count should represent the number of PMs, not the total number of components affected.

Basis – Delinquent/late orders are another direct measure of PMs that are not being performed when scheduled and have exceeded their grace period. These orders indicate a breakdown in the planning/scheduling and subsequent execution of PM activities.

Score (Color)	Rating	Number of Delinquent PMs
10 (Green)	Industry Best	No delinquent PMs per unit per year
8 (Green)	Industry Strength	No delinquent PMs per unit per year
6 (White)	High	1 delinquent PM per unit per year
4 (Yellow)	Medium	2-4 delinquent PMs per unit per year
2 (Red)	Low	> 4 delinquent PMs per unit per year

PMs Completed Deep into the Grace Period – "Deep into the Grace Period" is defined as an order having greater than 50% of the grace period used prior to the work being completed. (Note that some utilities are using 60% as an alternative measure.) This is a calculated average of all orders completed within the defined date range. This average is generally calculated anywhere from the previous quarter (12 or 13 weeks), year, or over the previous refueling cycle duration, whichever is most appropriate.

Basis – Orders completed deep into the grace period indicate another type of breakdown in the planning/scheduling and subsequent execution of PM activities. This is considered a proactive early indicator of potential performance decline in the work management process. A high percentage indicates that PM work is not performed when originally scheduled, and allowed to slip beyond the half-way point of the designated grace period. The following metrics were consistent with those established by the ERWG Equipment Reliability Index (ERI) at the time the EPRI report was published. The user should ensure the most current ERI is used, which may be found at www.INPO.org/.

Score (Color)	**Rating**	**Percentages of PMs Completed Deep Into the Grace Period**
10 (Green)	Industry Best	No orders completed "deep into the grace period".
8 (Green)	Industry Strength	>0% but <10% orders completed "deep into the grace period"
6 (White)	High	>11% but <15% orders completed "deep into the grace period"
4 (Yellow)	Medium	>15% but <20% orders completed "deep into the grace period"
2 (Red)	Low	>20% orders completed "deep into the grace period"

Notes:
Care should be taken not to imply that there is a direct correlation between when the work is performed during the grace period and subsequent equipment failures.
The scope of equipment and the type of activities that allow PMs to be performed during a grace period varies from plant to plant.
A brief discussion regarding industry guidance on using a grace period is provided in Appendix D of this report. Typically PM activities performed on environmentally-qualified equipment have little or no grace and are excluded for this metric. Surveillance tests are excluded from this metric because they are typically not considered in the PM program. Short frequency PM activities (i.e., weekly/monthly) are excluded from this metric, because they almost immediately come due again and often are difficult to track.

PM Revision Backlog – This is the number of individual PM change requests that are created and not approved for implementation. Currently this indicator is set up to be a direct count rather than a percentage.

Basis – PM revisions should be promptly reviewed and approved. Excessive backlogged PM revisions indicate a breakdown in the PM program.

Score (Color)	Rating	Number of Backlogged PM Revisions
10 (Green)	Industry Best	PM Revisions < 20
8 (Green)	Industry Strength	PM Revisions > 20 but < 40 revisions
6 (White)	High	PM Revisions > 40 but < 100 revisions
4 (Yellow)	Medium	PM Revisions > 100 but < 200 revisions
2 (Red)	Low	PM Revisions > 200 revisions

Notes:
In the context of this metric, PM change requests should constitute revisions to PM scope, frequency, and basis, and should not include administrative changes to PMs.
Each site has the option to integrate the age or criticality of backlogged PM revisions into this metric, if warranted.
The recommended metrics in this table are shown on a per-unit basis and can be modified to take into account bundling of units/trains into one change form.

Key O&M Cost Point
Management personnel should appreciate that pop-up (unplanned and unannounced) training or stand-downs can have a devastating effect on schedule and PM implementation.

Maintenance and work planning personnel should recognize that management has the discretion of overriding an existing schedule based on extenuating circumstances that may be caused by emergent plant issues.

5.3 Major Program Attribute 3: The PM Process as a "Living Program"

This major assessment attribute should measure continuous improvement and optimization of work activities and frequencies. To measure this major program attribute, site personnel should consider the following seven (7) performance metrics:

Amount of Craft Feedback – This is a measure that site craft is consistently engaged at providing "as-found" condition feedback.

Basis – The ability of craft labor to consistently provide "as-found" condition data provides critical input to the PM program to assess adequacy of PM scope and frequency.

Score (Color)	Rating	Amount of Craft Feedback
10 (Green)	Industry Best	100% of PM orders contain "as-found" condition data
8 (Green)	Industry Strength	100% of PM orders contain "as-found" condition data
6 (White)	High	>95% of PM orders contain "as-found" condition data
4 (Yellow)	Medium	>85% of PM orders contain "as-found" condition data
2 (Red)	Low	<85% of PM orders contain "as-found" condition data

Quality of Craft Feedback – This is a measure of the quality of "as-found" condition feedback provided by craft labor including the accuracy of the feedback and the level of detail it contains.

Basis – "As-found" condition data provided by craft labor should be accurate and detailed so as to allow PM work planners and engineering to adjust the PM activities and frequencies according to the conditions found on the equipment.

Score (Color)	**Rating**	**Quality of Craft Feedback**
10 (Green)	Industry Best	More than 95% of craft feedback is technically accurate, detailed enough to adjust PM bases without extensive follow-up, and is provided in a timely manner.
8 (Green)	Industry Strength	More than 90% of craft feedback is technically accurate, detailed enough to adjust PM bases without extensive follow-up, and is provided in a timely manner.
6 (White)	High	More than 75% of craft feedback is technically accurate and provided in a timely manner, but some of the feedback is not detailed enough to adjust PM bases without extensive follow-up,
4 (Yellow)	Medium	Most craft feedback is technically accurate and provided in a timely manner, but more than half of the feedback is not detailed enough to adjust PM bases without extensive follow-up,
2 (Red)	Low	Most craft feedback is technically inaccurate and not provided in a timely manner. Little of the feedback contains sufficient detail to adjust PM bases without extensive follow-up,

Ability to Evaluate Craft Feedback – This is a measure how effective the site is at evaluating "as-found" condition feedback and that processes exist to use it.

Basis – Processes should allow the PM owner and engineering to evaluate and subsequently adjust the PM activities and frequencies according to the conditions found on the equipment.

Score (Color)	**Rating**	**Ability to Solicit and Use Craft Feedback**
10 (Green)	Industry Best	Craft feedback is evaluated and adjustments consistently are being made to the PM process based on this input. The effectiveness of this process is measured and publicized.
8 (Green)	Industry Strength	Craft feedback is evaluated and an appropriate number of adjustments are being made to the PM Process based on this input.
6 (White)	High	Craft feedback is evaluated and some adjustments are being made to the PM Process based on this input.
4 (Yellow)	Medium	Some data is being evaluated and implemented but it is not considered a significant contributor to the PM Living Program Process.
2 (Red)	Low	No documented or publicized method is recognized by site Craft or Engineers of its contribution to changes to the PM Process.

Response Time to Craft Feedback – This is the average time in days between when a work order is closed and when all craft feedback regarding "as found" conditions is appropriately addressed (actions initiated and craft is informed).

Basis – It is important to engage craft into the feedback process by providing a quick turnaround to their input and being able to initiate action in a timely manner while the issues are relatively fresh in everyone's minds. This implies that there is some means to document and track craft feedback action items to assure all feedback is properly evaluated and feedback items don't just "fall through the cracks".

Score (Color)	**Rating**	**Average Feedback Response Time**
10 (Green)	Industry Best	< 7 days
8 (Green)	Industry Strength	>7 days but <14 days
6 (White)	High	>14 days but <30 days
4 (Yellow)	Medium	>30 days but <90 days
2 (Red)	Low	> 90 Days

Just-In-Time (JIT) PM Review Process – A regular review conducted on PM activities well before upcoming performance dates (i.e., between T26 to T8) and adjustments are made to the PM Process from this review.

Basis – This is integral to the living PM process and is an industry-recognized practice that provides continual self-assessment on a PM-by-PM basis.

Score (Color)	**Rating**	**Effectiveness of the Just-In-Time PM Review Process**
10 (Green)	Industry Best	A formal team exists to review upcoming PMs between T-26 to T-8. The process is guided under a documented procedure and performance measures are collected on the success of the review. An appropriate number of adjustments are being made to the PM process. At least five (5) of the following characteristics are being evaluated: 1. Crediting PMs from past corrective orders as appropriate 2. Bundling PMs with other functional equipment group work for more efficient work productivity 3. Evaluating "As-Found" condition codes or trends 4. Flagging and evaluating outstanding PM Revision Requests for incorporation prior to performance 5. Validating the documented PM basis (scope and frequency) 6. Assessing the availability of parts and evaluating obsolescence issues. 7. Validating the accuracy of the component criticality classification
8 (Green)	Industry Strength	A formal process is implemented and four of the seven characteristics are met
6 (White)	High	A formal process is implemented and three of the seven characteristics are met
4 (Yellow)	Medium	A formal process is implemented and two of the seven characteristics are met
2 (Red)	Low	No formal PM review process exists.

Template Development and Implementation

Basis – Documentation of the PM basis is easily retrievable. PM templates should exist and be equivalent to industry standards. The PM program has been evaluated against those templates and PM changes have been implemented. (See note)

Score (Color)	**Rating**	**Effectiveness of Template Development and Implementation**
10 (Green)	Industry Best	All PMs are evaluated against a formal PM template basis document. A formal maintenance strategy is defined from this process that is easily retrievable and utilized by site Engineers on a regular basis. Newly created templates are implemented in a timely fashion and the initial assignment dates are appropriate based on work history.
8 (Green)	Industry Strength	All templates exist and all have been implemented. Newly created templates are implemented in a timely fashion and the initial assignment dates are appropriate based on work history.
6 (White)	High	All templates exist and most have been implemented.
4 (Yellow)	Medium	Most templates exist and some have been implemented.
2 (Red)	Low	Few templates exist and the licensee is unable to implement them.

Note: The terminology "PM template" used in the context of this metric includes each site's basis for establishing PM activities and frequencies, and may include guidance provided by EPRI.

Integration of Industry Data into PM Templates

Basis – It is beneficial to use subject matter experts to incorporate industry data into PM templates to substantiate a living program. Industry data may include INPO operating experience (OE), EPIX data, EPRI guidance, PMCG recommendations, component failure history, etc. (See note)

Score (Color)	**Rating**	**Effectiveness of Integrating Industry Data into PM Templates**
10 (Green)	Industry Best	The most current industry data is incorporated into all PM templates on a regular basis, and a process exists to periodically review and update PM templates.
8 (Green)	Industry Strength	Recent industry data is incorporated into all PM templates
6 (White)	High	Recent industry data is incorporated into most PM templates
4 (Yellow)	Medium	Some data is incorporated into some PM templates
2 (Red)	Low	Industry data has not been incorporated into PM templates

Note: The terminology "PM template" used in the context of this metric includes each site's basis for establishing PM activities and frequencies, and may include guidance provided by EPRI.

5.4 Scoring the Self-Assessment Performance Metrics

5.4.1 Numerical Scoring

Key Technical Point
Appropriate site personnel should review and adjust the performance metrics and performance levels provided in this report to match site-specific processes.

One method of objectively assessing the major program attributes is to assign a numerical value to each selected performance metric. A score of 10 implies that no cost-effective improvements are identified. A score of 8 or 9 might still represent a "Best Practice". A score of 5 to 7 is considered effective, with significant opportunity for improvement. A score below 5 is not effective, with improvement necessary. Table 5-2 illustrates a scale for numerical scoring and the significance of each numerical score.

Table 5-2
Numerical Scoring of Performance Metrics

Score	Rating	Indication of Score
10	Industry Best	No cost-effective improvements are identified.
8	Industry Strength	Few cost-effective improvements are identified, and the process should be considered as a strength in the nuclear power industry.
6	High	Process is effective but there is significant opportunity for improvements.
4	Medium	Process is marginally effective and there is significant opportunity for improvements.
2	Low	Process is ineffective and there is significant opportunity for improvements.

There is no expectation that a given licensee needs to have the capabilities to measure all seventeen of the metrics presented in this report. Instead, each site should decide the benefits of measuring each metric provided, and make the necessary modifications to their plant/site/fleet information management systems to accommodate desired measurements. Additionally, the numerical scores associated with each metric represent values derived through consensus among key utility participants. Because of this and because there is still some degree of subjectivity associated with many of the performance metrics, each site retains the flexibility to adjust these scores as necessary to optimize the effectiveness of the self-assessment process at their unit/site/fleet.

Numerical scoring is effective if the results of the self-assessment are to be portrayed in a spider or scatter chart. Figure 5-1 represents the seventeen assessment areas as radial lines as on a spider chart. Each radial line is graduated with a scale from zero to ten. Eventually, the plant will be scored in each area from zero to ten. The score is intended to estimate the percentile ranking of the plant in that area, with a score of 10 representing the 100th percentile. (Whole numbers from one to ten are used so as not to overstate the resolution of the estimate).

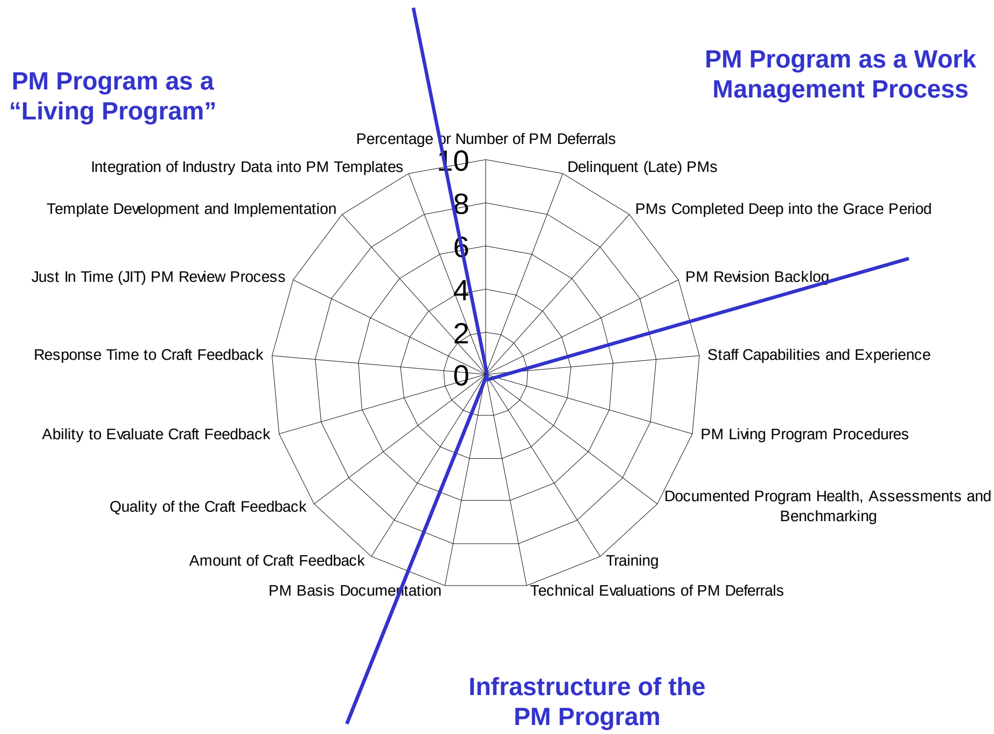

Figure 5-1
Example of Numerical Scoring Using a Spider/Scatter Chart

5.4.2 Color Coding

Another method of assessing major program attributes is to assign a color to the numerical value resulting from the self-assessment of each selected performance metric. Table 5-3 illustrates the color scheme used to code the numerical scores for the purposes of this report. Licensees have the flexibility to assign other scoring techniques and scales to best meet the specific needs of their plant site or fleet.

Table 5-3
Color-Coding the Numerical Scores of Performance Metrics

Score (Color)	**Rating**	**Indication of Score**
10 (Green)	Industry Best	No cost-effective improvements are identified.
8 (Green)	Industry Strength	Few cost-effective improvements are identified, and the process should be considered as a strength in the nuclear power industry.
6 (White)	High	Process is effective but there is significant opportunity for improvements.
4 (Yellow)	Medium	Process is marginally effective and there is significant opportunity for improvements.
2 (Red)	Low	Process is ineffective and there is significant opportunity for improvements.

Color-coding is effective if the results of the self-assessment are to be portrayed on a dashboard or matrix display, and may be combined with a spider chart for added clarification.

5.5 INPO PM Program Self-Assessment Guidance

The user of this report should be aware that INPO has developed guidance for using two performance indicators associated with the effectiveness of the PM program. These two performance indicators are PM deferrals and delinquent PMs. The user is encouraged to consider this guidance when establishing scoring criteria for their site/fleet-specific self-assessment program.

INPO 05-005[10] "Guide for Performance Improvement at Nuclear Power Stations" should be considered as another source for guidance, and should be integrated into each site's self-assessment program related to the PM process. Figure 2-2 of this report fully complements the INPO guidance as it stresses the importance of leadership/oversight, knowledge/skills, and culture for facilitating improvements associated with the PM process.

[10] Access to INPO reports and materials is restricted to organizations authorized by INPO. The information is confidential and for the sole use of the authorized organization.

Section 6: Supporting EPRI Implementation Guidance

The purpose of this section is to provide the user a listing of EPRI references that can assist in the implementation of the four key elements of the living PM process.

6.1 Availability and Use of Cited References

6.1.1 References to EPRI Reports

The user of this report should be aware of the following key points regarding the references cited in this section:

- The compilation of references provided in this report represents a reasonable grouping of primary references that would be useful to engineering and maintenance personnel. It should not be interpreted as a complete listing, as there are many additional EPRI and industry references that could be informative to plant personnel that are not included in this report.
- Similarly, the references provided represent those EPRI documents that were available at the time of publication. Since that time additional references may have been published that are not included, and some of the older references may no longer be available.
- The availability of some EPRI material referenced in this report may be limited only to members of the program or sector within EPRI that owns the material.

The references are grouped into the following four sections, which coincide with the four key elements of the living PM program process. Within each grouping, the references are listed alphabetically. Included with each reference is a brief description stating the purpose and general scope of each document.

6.1.2 References to INPO Products

INPO products are not accessible to the general public, and reference to these documents in this report does not in any way change this policy. As such, INPO references are footnoted as follows "Access to INPO reports and materials is restricted to organizations authorized by INPO. The information is confidential and for the sole use of the authorized organization."

The INPO web-site should be consulted for the latest OE, and other pertinent information related to specific equipment, system and program issues. The web-site provides ready access to many types of technical information including (but not limited to) the following:

- Equipment Failure Experience (EFE)
- Just-in-time (JIT) Operating Experience
- Operations & Maintenance Reminders (O&MR)
- Significant Event Notifications (SEN)
- INPO Event Reports (IER)
- Significant Operating Experience Reports (SOER)
- Topical Reports

6.2 PM Program Basis

The following references are provided to assist the use of this report with detailed implementation guidance regarding the PM Program Basis. Recommended sources of detailed guidance include the following EPRI technical reports:

A History of the Maintenance Rule 10CFR50.65: Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants. EPRI, Palo Alto, CA: December 2007. 1015517.

> The U.S. Nuclear Regulatory Commission (NRC) regulation 10CFR50.65, known as the Maintenance Rule, was developed as a negotiated regulation among the NRC, Nuclear Management and Resources Council (NUMARC) (now Nuclear Energy Institute [NEI]), and the utility industry. When people try to understand and use the regulation and the various guidance documents associated with it, it is helpful to know where the actual wording came from and why it is the way it is. Many of the people originally involved with the development of the Rule have retired, and many more of them are nearing retirement. This report captures the collective memory of this segment of the industry for posterity.

Critical Component Identification Process—Licensee Examples: Scoping and Identification of Critical Components in Support of INPO AP-913. EPRI, Palo Alto, CA: December 2003. 1007935.

When implementing INPO AP-913, Equipment Reliability Process Description, one of the key "entry points" is accurate "Scoping and Identification of Critical Components"; this activity facilitates appropriate targeting of plant resources to those components that truly affect safety, reliability, and production. While AP-913 discusses a limited number of categories for components (Critical, Non-Critical, and Run-to-Failure), some utilities have implemented programs that result in further subdivision and have developed implementation strategies based on these categorizations — a "graded approach."

This report is the initial output from a project to assist utilities that are implementing (or considering implementing) AP-913 by developing tools to assist in maximizing the benefits of scoping and criticality identification efforts. The report documents the graded scoping and identification programs being implemented by five U.S. utilities and presents the rationale behind each approach.

Equipment Useful Life. EPRI, Palo Alto, CA: December 2005. 1012052.

In 2004, several EPRI Nuclear members expressed interest in obtaining improved information to support decision making related to the "Useful Life" of plant equipment. This project responds to those interests. The ultimate objective is to identify the time in the service life of a component when consideration should be given to changing the component maintenance strategy. For example, equipment service life and failure mechanisms may dictate a change from time-based Preventive Maintenance to another strategy, such as replacement or major refurbishment.

Guide for Determining Preventive Maintenance Task Intervals. EPRI, Palo Alto, CA: December 1993. TR-103147.

This report represents the first step in a long-term effort to improve industry knowledge of the effects of PM tasks and intervals on equipment performance. The data presented here reflect existing practice, while the methods of using the data are an attempt to learn from industry experience ways to improve PM intervals at individual plants. Much work remains in correlating the data with equipment condition and performance and in improving the quality of maintenance reporting before the industry can truly optimize PM tasks and intervals. Nevertheless, the current approach will serve in the interim to help reduce maintenance costs.

Guidelines for Application of the EPRI Preventive Maintenance Basis. EPRI, Palo Alto, CA: February 2000. TR-112500.

This work represents an important step in the full use of the PM Basis data developed by EPRI in 1997 and 1998. There is a continuing need, however, for a more integrated product that provides all the content and functionality of these products but offers additional value. This need includes the following:

- Efficient and integrated access to all of the PM Basis information from a single database
- Feedback from users to improve and supplement the existing PM Basis information
- Periodic updates of the PM Basis information including more component types, more basis information for existing component types, and additional guidelines and analysis tools

Ongoing EPRI-sponsored activities are designed to accomplish each of the above objectives. These activities are part of the Preventive Maintenance Information Repository (PMIR) project.

Also, there is a mistaken impression among some potential users of the PM Basis reports that the primary value of the PM Basis information is for the development and update of RCM studies. In fact, the need for the technical PM basis information is generally valid, regardless of the method selected for task and interval selection. Furthermore, this information is essential for the continuing optimization and evolution of the PM program throughout the life of the plant. This report clearly shows the potential usefulness of the PM Basis information in the day-to-day maintenance of power plant equipment.

Guidelines for Balancing Reliability and Availability. EPRI, Palo Alto, CA: December 2002. 1002936.

This report explains the connections between the reliability and availability of commercial nuclear power plant components and the Preventive Maintenance (PM) they have been subject to. The scope includes a simple outline of the main characteristics of failure rates, probabilities of failure-on-demand, reliability, and availability of equipment in general, and relates these characteristics to elements of existing testing and PM programs. It also covers the processes of optimizing Preventive Maintenance programs, of achieving balance between reliability and availability, and of monitoring reliability and availability at nuclear power plants. In particular, it relates these topics to the decisions required of personnel who manage and implement PM programs. The report is therefore geared toward maintenance professionals who are seeking to understand and apply concepts involving reliability, availability, equipment monitoring, and PM.

Improving Maintenance Effectiveness. EPRI, Palo Alto, CA: May 1998. TR-107042.

Effective maintenance programs can ensure reliable performance of plant systems, structures, and components (SCCs). Special performance requirements and increased competition in the utility industry demand a well thought-out maintenance strategy that is supported by a balanced mix of maintenance activities and techniques to achieve reasonable equipment reliability and availability.

Nuclear Maintenance Applications Center: Impact of Maintenance Workload on Equipment Reliability Describing and Quantifying Low-Impact Work. EPRI, Palo Alto, CA: December 2010. 1022243.

The long-term goal of this project is strategic: to improve and sustain the ability of utilities to focus resources on high value equipment reliability-related tasks by reducing tasks of low value. While mainstream industry initiatives associated with equipment reliability (under INPO AP-913) and work management (under INPO AP-928) continue, this project will begin to accumulate the information necessary to respond to relentless economic pressure expected after the current initiatives become broadly successful.

Recommendations include: develop screening criteria and simple methods to identify low value work; improve the ability to quantify low value work to enable valid cost/benefit-related decision-making; improve the process of collecting craft and technician feedback used to extend preventive maintenance and surveillance intervals; and develop change-management protocols for the different kinds of reducible work. The three-step model of "see it—quantify it—change it" is proposed as a general framework within which low value work can be managed.

Obsolescence Management, A Proactive Approach. EPRI, Palo Alto, CA: December 2007. 1015391.

Future products and research resulting from the Obsolescence Initiative will require the specialized expertise and experience of system engineering, maintenance, operations, design engineering, procurement engineering, and supply chain personnel. Identification of existing plant processes and decision points that should include obsolescence information will help to effectively integrate obsolescence information and considerations into plant processes.

In addition, industry-wide obsolesce information can be collected and analyzed with tools and methodologies described in this update. These data can be used to identify obsolete equipment that is common to multiple EPRI members. EPRI members can collaboratively develop replacement solutions for high-priority obsolete equipment. In certain

cases, industry-wide information related to anticipated demand for replacement can be used to recruit suppliers with the appropriate technical expertise to participate in the development of solutions.

Obsolescence Management. EPRI, Palo Alto, CA: November 2008. 1016692.

This report describes the results of research conducted as part of EPRI Plant Support Engineering's Obsolescence Initiative. The objective of the initiative is to develop methodologies that can be used to minimize the impact that obsolescence has on plant production and cost. This report builds upon the concepts discussed in EPRI product 1015391, Plant Support Engineering: Obsolescence Management – A Proactive Approach, the technical update published by Plant Support Engineering in November 2007.

This report can be used to assist in the development and implementation of a proactive obsolescence program, or to assess and enhance the effectiveness of an existing obsolescence program. In addition, it can be used to demonstrate that an effective obsolescence program requires active participation of several key plant organizations.

PM Basis Version (Preventive Maintenance Database) 2.1. EPRI, Palo Alto, CA: November 2009. 1018758.

The Preventive Maintenance Basis Database (PMBD) is a software tool developed by EPRI Nuclear Maintenance Application Center (NMAC) so that technically applicable and cost-effective PM tasks can easily be accessed by member utility engineers.

The objective of the PMBD application is to make utility experience of technically applicable and cost-effective PM tasks easily accessible to utility engineers. This objective requires that recommendations on PM tasks include an outline of the technical basis in a way that utility engineers can adapt to plant conditions, and requires integrated guidelines for the user to be able to use the database efficiently for common tasks. The Application Guideline incorporates utility experience and state-of-the art developments, especially for the evaluation of PM task intervals and deferrals. The PMBD application was developed to provide assistance to utility engineers who are charged with reducing and controlling Preventive Maintenance costs, and improving equipment performance. For this to succeed, utilities require information on the most appropriate tasks and task intervals for the important equipment types, while accounting for the influences of functional importance, duty cycle and service conditions. The PMBD application is a Microsoft Windows™ client-server database application that utilizes the Microsoft .NET Framework technologies. It provides the utility user with a summary of industry experience, informing him or her on which tasks and task intervals represent a sound, cost-effective PM program for over 130 major component types.

It also outlines the relationships between a component's degradation mechanisms and the factors which influence them, the time scale of progression to failure, and the opportunities to discover and prevent degraded conditions, so that utilities can adapt the programs to plant conditions.

Preventive Maintenance Basis Database (PMBD) 1.0 Component Export Plug-in. EPRI, Palo Alto, CA: November 2008. 1018396.

The PMBD Component Export Plugin, Version 1.0, is a plugin that can be added to Preventive Maintenance Basis Database (PMBD) software Version 2.0 or higher (Product ID 1014971) that will allow component data to be exported as XML.

Preventive Maintenance Basis Database 2.0 User's Guide. EPRI, Palo Alto, CA: December 2008. 1018110.

The Electric Power Research Institute (EPRI) has developed a software application to help its members create a maintenance strategy that is based on failure modes and their frequencies. This database is able to analyze the impact of changing the maintenance strategy by changing the interval at which a maintenance task is performed or even eliminating the task itself. In addition to providing the failure rates changes that are associated with the task frequency changes, this database provides other information such as an As-Found Condition Checklist, Most Probable Degradation Checklist, and other information to allow the maintenance professional to develop a comprehensive strategy. This software, although its use is sufficiently intuitive for a casual user, is complex enough that a user´s manual or desktop guide in needed to receive the maximum benefit from the software.

Preventive Maintenance Program Implementation Self-Assessment Guidelines for Nuclear Power Plants. EPRI, Palo Alto, CA: December 2007. 1014798.

Preventive Maintenance (PM) programs throughout nuclear plants in the United States have evolved from strict compliance with the supplier's general recommendations (which are likely to be much too conservative) to more flexible tasks that are intended to accommodate plant-specific service conditions. During the 1990s, the industry, with support from the Electric Power Research Institute (EPRI), embarked on Preventive Maintenance Optimization (PMO) programs. Most utilities either have implemented or are in the process of implementing these PMO programs.

The next logical step in the licensee's PM program development is to perform self-assessments of the implementation of these programs. EPRI has been requested to develop an industry standard to perform these PM program implementation self-assessments.

- The successful implementation of a PM program should result in the following:
- Identifying the optimum level of PM tasks necessary to achieve a balance between the equipment performance and the effective use of resources
- Providing a well-documented engineering basis for selecting PM strategies that can be the same as, different from, or in addition to the vendor's recommendations
- Addressing the component failure modes that could impact the plant's safety and availability
- Identifying the appropriate scope of the critical equipment for which PM activities are needed
- Identifying components that are not important to the plant's safety or availability but that can be removed from the PM program to make the maintenance resources available for other more important tasks

This report provides nuclear power plant personnel with a self-assessment generic process and methodology, including the self-assessment preparation and planning guidance. Detailed guidance on conducting a comprehensive self-assessment of their PM program implementation using the performance metrics is also provided, including criteria for scoring and benchmarking each metric. The report provides a graded approach to the PM program implementation self-assessment by offering a number of tools for collecting and reviewing the plant's information that helps the self-assessment team focus on the most appropriate major program attributes to examine.

6.3 PM Task Planning and Scheduling

The following references are provided to assist the use of this report with detailed implementation guidance regarding the PM Task Planning and Scheduling. Recommended sources of detailed guidance include the following EPRI technical reports:

Effective Refueling Outage Preparation and Execution Guidance. EPRI, Palo Alto, CA: May 2007. 1014480.

This report provides detailed guidance to assist the outage manager and outage team during the preparation and execution phases of an outage. Included is guidance that addresses how the outage activities support long-range and strategic plans developed by the site or fleet of units.

Detailed guidance regarding how the licensee should transition into the outage from on-line maintenance activities and operating plant status is provided, as well as guidance regarding the effective execution of planned outage activities and contingencies that may arise during the conduct of the outage. This report also provides the licensee with guidance on how to transition out of the outage mode and return the plant safely and effectively to its operating mode. Guidance on how to conduct post-outage assessments and measure outage performance is also included.

Guidance for Developing and Implementing an On-Line Maintenance Strategy. EPRI, Palo Alto, CA: September 2004. 1009708.

This report provides members with a strategy and plan that will allow them to perform selected maintenance activities while the unit remains on-line rather than performing those tasks during a refueling outage. Topics addressed include guidance on performing risk assessments (operational risk rather than nuclear risk) of planned work activities, risk management, a general description of the work management process in use by members, strategies to help mitigate the risk of performing the activity on-line, and steps to be taken during the implementation of the activities.

This guide provides overall strategy and implementation guidance for planning and effectively conducting on-line maintenance activities. The key aspects of planning and implementing the strategy are:

- Close interface and coordination of many of the same organizations involved in each licensee's existing work control process
- Inclusion of an assessment of risk
- Interim opportunities to review and challenge the feasibility of performing the work on-line

Guidelines for Addressing Contingency Spare Parts at Nuclear Power Plants. EPRI, Palo Alto, CA: 1013472

This report provides an overview of the process for identifying parts needs and supplemental guidance on how licensees can enter and group parts requirements into their respective materials information systems. The report also offers guidance on how contingency parts demand-versus-availability analysis should be conducted as well as process measures that licensees may consider when they implement the guidance.

The information contained in this report represents a significant collection of human performance information, including techniques and good practices, related to the identification and supply of spare or replacement parts in support of common work activities at a nuclear power plant. This compiled information provides a single point of reference for plant work planning and supply chain personnel. Through the use of this report in close conjunction with the industry guidance provided by the Institute of Nuclear Power Operations (INPO), EPRI members should be able to significantly improve and consistently implement the processes associated with identifying contingency spare parts and making them available when they are needed. This will subsequently help members to achieve increased reliability and availability of the components on which work activities are performed.

How to Conduct Material Condition Inspections. EPRI, Palo Alto, CA: September 1994. TR-104514.

This Tech Note focuses primarily on the mechanics of performing power plant or industrial facility material condition inspections. The information provided can be used as a tool to teach the non-licensed operator, field/system engineer, manager, supervisor or craftsman how to enter the power block and look for material condition problems and to readily identify those areas that can be improved. Key elements and how they can be applied during an inspection will be reviewed. Frequent, quality material condition inspections will help ensure that small problems are identified and that they will not expand into larger problems resulting in industrial safety hazards or costly plant shutdowns.

Maintenance Work Package Planning Guidance. EPRI, Palo Alto, CA: December 2005. 1011903.

The work management process is one of the core business processes outlined within the Nuclear Energy Institute (NEI) Standard Nuclear Performance Model for operation and maintenance of nuclear power plants. The preparation of work packages is a key element of this overall process. The purpose of this report is to provide guidance to power plant personnel regarding work package quality as a supplement to AP-928, Work Management Process Description, Appendix F, "Graded Approach to Planning." This report provides a consistent approach for administrative control, achieving an appropriate level of detail and ensuring an acceptable level of use, work package format, and application.

This report provides an overview of regulatory and industry requirements addressing work package content, level of detail, and quality, as well as guidance regarding skills and performance attributes essential for work planners and those personnel implementing the work packages. The focus of the report is guidance for developing work packages, which relates different types of work activities and other parameters to various general categories of work packages. It also provides guidance for establishing an appropriate structure, format, and content for work instructions—the primary element of a quality work package. The report also provides the licensee with several means for measuring the quality of work packages.

Nuclear Maintenance Applications Center: Considerations for Developing a Critical Parts Program at a Nuclear Power Plant, EPRI, Palo Alto, CA: 2002007. 1011861.

In 2003, EPRI published the report Critical Component Identification Process—Licensee Examples: Scoping and Identification of Critical Components in Support of INPO AP-913 (1007935). That report was the initial output from a project to assist utilities that were implementing Institute of Nuclear Power Operations (INPO) AP-913, Equipment Reliability Process Description. Two of the key aspects of INPO AP-913 are the accurate scoping and identification of critical components, which subsequently make it easier for plants to focus their resources on those components that truly affect safety, reliability, and production.

Critical Component Identification Process provides tools to assist in maximizing the benefits of scoping and criticality identification efforts, and it documents the graded scoping and criticality identification programs being implemented by five U.S. utilities. It also presented the rationale behind each approach. Although INPO AP-913 discusses three categories for components (critical, non-critical, and run-to-failure [RTF]), the EPRI report Critical Component Identification Process demonstrates how some utilities have successfully implemented programs that have resulted in further subdivision and how utilities have developed implementation strategies based on these categorizations.

This report gives an overview of the process for identifying, categorizing, and making available parts within critical equipment. This report also provides guidance regarding how best to meet planned and unplanned needs for items (components or parts) to support maintenance activities, optimize inventory, and subsequently enhance equipment reliability.

6.4 Performing Preventive Maintenance

The following references are provided to assist the use of this report with detailed implementation guidance regarding the performance of Preventive Maintenance. Recommended sources of detailed guidance include the following EPRI technical reports:

Assembling Bolted Connections Using Spiral-Wound Gaskets: Sealing Technology and Plant Leakage Reduction Series. EPRI, Palo Alto, CA: July 1999. TR-111472.

> EPRI views this series of reports pertaining to plant leakage reduction as an important and needed contribution to the state of the art with respect to plant maintenance practices and O&M cost reduction. Because spiral-wound gasketed joints represent virtually all of the critical piping system joints found in nuclear power primary system applications, EPRI further believes this document within the series to be of significant potential value to members concerned with improving plant safety, operability, and availability, while reducing associated O&M costs.

Assembling Threaded Connections: Sealing Technology & Plant Leakage Reduction Series. EPRI, Palo Alto, CA: December 2000. 1000972.

> Upon completion of the training, the following should occur:
>
> - Engineers should be prepared to update plant maintenance procedures to reflect the latest knowledge and to assess the root cause of leaking threaded joints.
> - Work planners should be able to prepare better work packages.
> - Mechanics should have a better understanding of the key factors that lead to high integrity joints.
> - QC personnel should have the knowledge to determine which of the assembly practices warrant the most attention
> - Plant management should have a better overall perspective of the issues associated with leakage from threaded joints.

Bolt Preload Stress for ANSI Raised-Face Flanges Using Spiral-Wound Gaskets: Sealing Technology and Plant Leak Reduction Series. EPRI, Palo Alto, CA: May 2000. 1000066.

> EPRI believes that information contained in this report clearly summarizes, perhaps for the first time, the body of knowledge necessary to enable interested parties to develop effective bolt torque specifications for tensioning conventional piping flanges that employ spiral-wound gaskets. Industry experience with continuing flanged joint leakage has demonstrated that even strict adherence to vendor-supplied recommendations, combined with proper work practices and quality assurance oversight, has not been sufficient to overcome leakage occurrences in many situations without resorting to additional remedial maintenance actions. This information, resulting from a blend of controlled product testing results and computerized finite element analysis modeling, should enable end-users to accurately develop effective bolt torque specifications for a wide range of ANSI raised-face

flanges. When employed in conjunction with prior EPRI work published in TR-111472, Assembling Bolted Connections Using Spiral-Wound Gaskets, end-users should be able to develop effective procedures, training programs, and engineering and maintenance work practices that will significantly improve their ability to reliably seal flanged piping connections for the duration of intended operations.

Bolted Joint Fundamentals. EPRI, Palo Alto, CA: December 2007. 1015336.

Over the years, EPRI has published various reports that provide guidance on bolting usage. As a result of advancements over time in understanding the problems with bolted assembly makeup as well as human performance, these reports presented sometimes-contradictory recommendations. This report reconciles and consolidates the earlier documents and is a newer version of TR-104213 - Bolted Joint Maintenance & Applications Guide.

Elastomer Handbook for Nuclear Power Plants. EPRI, Palo Alto, CA: August 2007. 1014800.

The report provides information on elastomer considerations for determining the appropriate characteristics for specific applications. The intent is not to solve all elastomer application questions but to describe key considerations, problems that could occur in applications, and ways to correct or eliminate possible failure mechanisms. References to further detailed information are provided. Characteristics of elastomer materials and comparisons of capabilities are provided, as are considerations for specific applications.

This report has been developed to aid plant personnel in the selection of appropriate rubber materials for use in nuclear plant applications. The materials and their properties are described as well as the dominant applications of elastomers. Failure modes and their causes are described to help users to determine causes of in-plant failures and to preclude further failures and misapplications. Information on physical properties, chemical compatibility, and aging characteristics are provided. This document is not meant to circumvent the need for material and applications specialists, but rather to support the dialog between plant staff members and such specialists.

Establishing an Effective Fluid Leak Management Program: Sealing Technology & Plant Leakage Reduction Series. EPRI Palo Alto, CA: December 2000. TR-114761.

Using the material contained in this report, those involved in creating and managing fluid leak management programs should be able to:

- Evaluate the effectiveness of their current fluid leak management program
- Establish practical goals for an improved program
- Select a fluid leak management program coordinator with the requisite skills
- Establish engineered leakage acceptance criteria, based on the magnitude of the leak and the criticality of the application, that avoid costly efforts for small leaks in systems of lesser importance
- Establish and implement a cost-effective fluid leak management program
- Track the performance of the program and make improvements as warranted

Establishing an Effective Plant Fluid Sealing Technology Program. EPRI, Palo Alto. CA: August 2009. 1018959.

Using the material contained herein, those involved in creating and managing leakage management programs should be able to:

- Justify the benefits of developing and implementing a plant fluid sealing technology program.
- Evaluate the effectiveness of their current leakage management program.
- Establish practical goals for an improved program.
- Select a leakage management program coordinator with the requisite skills.
- Track the performance of the program and make improvements as warranted.

Foreign Material Exclusion Guidelines. EPRI, Palo Alto, CA: July 2008. 1016315.

This report provides a comprehensive overview of technical considerations required to develop, implement, and manage an FME program at a commercial nuclear power plant. In addition to providing uniform guidance in order to define personnel responsibilities and key nomenclature, this report presents a process-driven approach to the planning, preparation, and performance of plant operations, maintenance activities, outages, and other key plant activities (for

example, modifications and supply chain material control) from an FME perspective. This report also provides a way to evaluate prospective work tasks and activities against standardized criteria in order to identify the appropriate level of FME controls. Appendices give examples of FME equipment and documents that can be used in the development of specific plant information.

Foreign Material Exclusion: Striving for Industry Excellence (DVD). EPRI, Palo Alto, CA: July 2008. 1014962.

Foreign material (FM) that enters plant systems can cause equipment degradation or inoperability, fuel cladding damage, and high radiation and contamination levels that can spread throughout a plant. In 2006, nuclear utility executives endorsed a policy of "zero fuel failures by 2010" for all U.S. facilities. This challenge to the industry calls for the total eradication of fuel failure events regardless of cause. One fuel failure mechanism that affects all reactor types is debris-induced failures. This mechanism results from FM being left behind following a work activity in plant systems that come in contact with the reactor. To raise the awareness level of this and all FM issues in the plant, EPRI's Fuel Reliability Program teamed with industry experts to create an awareness video designed to communicate this serious topic to all workers. Utility executives and FME Coordinators appear in the production. Examples and consequences of poor foreign material exclusion practices are presented, as well as techniques and good practices for preventing FM from entering plant systems. This 20-minute video can be incorporated into plant training materials and will be useful to all plant workers, including management, plant staff, contractors and supplemental workers.

Guideline on Nuclear Safety-Related Coatings, Revision 2 (Formerly TR-109937 and 1003102), Final Report. EPRI, Palo Alto, CA: December 2009. 1019157.

This report provides detailed guidance on the following aspects of a plant nuclear safety-related coatings program:

- Key concepts and definitions
- Qualification and selection of coating systems
- Procurement and materials management
- Surface preparation and coating application
- Inspection of surface preparation and application
- Condition assessment
- Management of non-conforming coatings
- Personnel training and qualification

This report is a revision to the original guideline to ensure that the information pertaining to safety-related coatings and the standards that are used for the design basis are communicated. Plant personnel use this guideline as a tool to assist them in ensuring that the coatings used in the plant do not create any issues relating to the safety and reliable operation of the plant.

Nuclear Maintenance Applications Center: Preservation of Failed Parts to Facilitate Failure Analysis of Nuclear Power Plant Components. EPRI, Palo Alto, CA: March 2009. 1016907.

The information contained in this report represents a significant collection of human performance information, including techniques and good practices, related to project teams in their support of investigating failed equipment at a nuclear power plant. Assembly of this information provides a single point of reference for plant engineering and management personnel, both now and in the future. Through the use of this guideline, in close conjunction with industry guidance, EPRI members should be able to significantly improve and consistently implement the processes associated with investigating failed equipment, determine the likelihood that failure analysis will be warranted, and subsequently preserve evidence to facilitate further examination. These abilities will help members achieve increased reliability and availability of plant components and the systems in which they are installed by selectively analyzing certain failed components and precluding similar failures in the future.

Nuclear Maintenance Applications Center: Self-Assessment Guideline for Evaluating Operations and Maintenance Interactions for Improved Performance in Equipment Reliability. EPRI, Palo Alto, CA: April 2010. 1019548.

This project produced a self-assessment tool for nuclear plant personnel to evaluate the effectiveness of the interactions between the maintenance and operations departments in support of improved performance and ER. The tool does not assess every aspect of the daily functions of either department but focuses on areas that rely on one another to execute work, such as the plant's PM program. To perform an effective assessment, attributes in several major areas are identified along with the related attributes.

This self-assessment tool should be used by maintenance and operations managers in their efforts to improve departmental performance and overall ER. The TAG believes that incremental positive changes in the performance in each element of the MOI assessment will lead to improvement in overall equipment and plant reliability.

On-Line Leak Sealing NP-6523-D Performance Characterization of Bolt Torquing Techniques. EPRI, Palo Alto, CA: March 2002. 1003150.

While controlled torquing is the de facto method of choice for assembly of bolted joints in nuclear plant applications, this preference often stems as much from prevailing wisdom as from objective comparison of the options. Furthermore, many individual details concerning joint assembly remain subjects of debate. As part of its ongoing research on flanged joint leakage prevention, EPRI has reviewed existing guidance on joint assembly practices and conducted a series of controlled tests to generate comparative data. This report presents analytical test results on the four general approaches to bolt torquing, as well as comparative analysis of a number of specific practices and techniques.

Post Maintenance Testing Guide, Revision 1. EPRI, Palo Alto, CA: December 2004. 1009709.

EPRI's NMAC developed this guide to meet the concern of member utilities about post-maintenance testing and to fill a void in comprehensive documentation on post-maintenance testing. It is expected that by using this guide, member utilities will enhance their programs by using consistent test selection and implementation of post-maintenance testing. Post-maintenance testing covers a vast territory; this guide is intended as a first step in addressing industry concerns on this important topic.

For each component covered in the guide, a matrix provides various combinations of tests for each type of work activity performed. In addition, the guide offers a set of test definitions to assist in the efficient and consistent execution of post-maintenance testing. While avoiding repetitive testing, the guide covers every inspection, check, or verification that occurs during or after the maintenance activity. The selected tests must always be commensurate with the component and the type of work performed. Accordingly, to use the guide at an operating facility, adjustments and conversions to site-specific documents will be required.

Sealing Technology and Plant Leakage Reduction Series: TR-111413, TR-111472, TR-114761, 1000066, 1003150, 1000922, 1000923, and 1000972. EPRI, Palo Alto, CA: July 2002. 1007072.

Using the material contained herein, those involved in creating and managing leakage management programs should be able to:

- Evaluate the effectiveness of their current leakage management program.
- Establish practical goals for an improved program.

- Select a leakage management program coordinator with the requisite skills.
- Establish engineered leakage acceptance criteria based on the magnitude of the leak and the criticality of the application that avoid costly efforts for small leaks in systems of lesser importance.
- Establish and implement a cost-effective leakage management program.
- Track the performance of the program and make improvements as warranted.

6.5 Feedback on PM Implementation

The following references are provided to assist the use of this report with detailed implementation guidance regarding the use of feedback on PM implementation. Recommended sources of detailed guidance include the following EPRI technical reports:

Aging Assessment Field Guide. EPRI, Palo Alto, CA: December 2003. 1007933.

> This guide provides practical information that describes the aging degradation mechanisms likely to affect plant systems, structures, and components (SSCs). It also describes the indicators of these mechanisms and how to mitigate their effects, and it identifies the aging degradation mechanisms likely to be found in a variety of plant systems.
>
> As nuclear plants continue to age, nuclear plant staff need practical tools to identify and address aging degradation. This field guide provides plant engineers with a practical guide to assist in the identification and mitigation of the negative impact of aging degradation.

AP-913 Industry Capabilities Gap Analysis Results. EPRI, Palo Alto, CA: December 2002. 1003478.

> As equipment reliability (ER) becomes a focus at many U.S. nuclear facilities, the Institute of Nuclear Power Operations' (INPO's) report, AP-913 "Equipment Reliability Process Description," is the blueprint that many plants are adopting to implement as their ER process. AP-913 breaks the ER process into six areas, each with a host of subordinate elements. These process areas span most departments and disciplines requiring in some cases a fundamental change in plant communications and culture.
>
> An ER Process area or subordinate element that does not have technical information or tools to support its implementation, or a process area or subordinate element for which industry performance is

less than desired is called a "gap." This report chronicles an industry-wide gap analysis performed to address plant equipment reliability information resources, plant performance, and potential process improvements. For the purpose of this report, there are three types of gaps identified:

- Information Gap
- Process Improvement Opportunity

The report draws on the industry-wide gap analysis, as well as several other information sources to identify the process gaps. These other data sources include:

- ER Benchmarking Project
- Industry AP-913 Support Information Database
- ER Process Case Studies
- ER Benchmarking Project Workshop and ER Forum

After the gaps are identified, their causes are determined, and recommendations are made to correct these gaps.

As-Found Module. EPRI, Palo Alto, CA: March 2006. 1011918.

The intent of this report is to describe the process which will integrate the EPRI Preventive Maintenance (PM) BASIS application with As Found field data. By collecting site field data, the degradation mechanisms that lead to a component failure can be monitored at the industry level. This process will benefit the industry by connecting live failure information with performance monitoring and equipment reliability. This tool will give the end-user a solution to monitor their equipment that can provide and capture indicators that demonstrate the probability of component failure.

Due to reduced manpower and loss of personnel with specific skills at nuclear power plants throughout the US and the world, Operations and Maintenance departments need to increase their utilization of electronic performance support systems (EPSS), or the Wired Worker concept. The key to implementation of EPSS at nuclear plants lies in the development of a user interface that will enable a worker to perform his tasks more efficiently. Many nuclear plants use commercially available product to perform Operator, Chemistry, Radiation Protection, and Maintenance rounds, and several are using it to perform System Engineering walk-downs. These industry available products are a state-of-the-art tool that employs an intuitive user interface, one designed and embraced by plant personnel. This functional specification further develops the As Found interface to the EPRI PM Basis Database and improves the ability of a technician performing rounds to capture in detail the equipment condition. This provides an excellent tool for smarter and timelier decision making for plant maintenance personnel.

Equipment Condition Assessment, Volume 2: Technology Evaluation and Integration. EPRI, Palo Alto, CA: December 2004. 1009601.

This report describes the emerging technology of equipment condition monitoring (ECM), also referred to as equipment condition assessment (ECA). This report is the second in a series on this subject and covers current technology capabilities, gaps, and areas for future research. Volume 1 in the series covered on-line monitoring (OLM) applications. ECM technology has the capability to provide early warning before failure, which allows maintenance staff to proactively schedule maintenance during more ideal conditions than when reacting to a failure. The foundation of this technology is OLM, which has been the subject of many EPRI studies for the past decade. The extensions from the precursor technology of OLM to the more advanced ECM technology were evaluated in a pilot study. Interpretation is based on combining identified failures or anomalies, which are the end result of an OLM system. While commercial tools available today are uniformly robust and capable of providing anomaly detection, this report identifies gaps in the capabilities and identifies areas for future research.

Equipment Condition Assessment: Application of On-Line Monitoring Technology. EPRI, Palo Alto, CA: December 2004. 1003695.

This report describes the emerging technology of equipment condition monitoring (ECM), also referred to as equipment condition assessment (ECA). ECM technology has the capability to provide early warning before failure, which allows maintenance staff to proactively schedule maintenance during more ideal conditions than when reacting to a failure. The foundation of this technology is on-line monitoring (OLM), which has been a subject of EPRI studies for the past decade. This report describes the extensions from the precursor technology of OLM to the more advanced ECM technology. These extensions require the development of interpretive tools based on component failure mode analyses. One such approach to developing an interpretive tool is explored in this report; it is based on a simulated failure analysis. Interpretation is based on combining identified failures or anomalies, which are the end result of an OLM system. An understanding of the mechanisms by which anomalies are identified is needed before a method to interpret OLM system anomalies can be developed. Illustrations of the most commonly occurring anomalies, as gained through EPRI experience during the OLM projects, are presented. Insight into the costs and benefits of ECM technology is also provided.

Equipment Condition Monitoring Templates: Addendum to the Preventive Maintenance Basis, TR-106857 (Volumes 1-38). EPRI, Palo Alto, CA: September 2000. 1000621.

> This project summarized equipment condition monitoring information for 22 of the 38 PM Basis components and compiled it in one report. Until now, information on condition monitoring was contained throughout the 38 component volumes and often within a description of larger Preventive Maintenance tasks. This report identifies additional tasks that can be performed and provides more detailed information to aid in the understanding and application of the tasks. Also, additional data has been provided for incorporation into the PM Basis Database.
>
> This addendum report is a reference for utilities seeking to validate their current predictive maintenance/condition monitoring program. It will also assist those hoping to perform intrusive maintenance tasks less frequently and those utilities seeking to improve PM tasks as appropriate corrective action under the Maintenance Rule 10 CFR 50.65. It is not intended for the addendum to be used independently of the PM Basis Documents/Database.

Equipment Reliability Case Studies: INPO AP-913 Equipment Reliability Process Implementation Summaries. EPRI, Palo Alto, CA: December 2002. 1003479.

> This report chronicles the implementation process of the Institute of Nuclear Power Operations' (INPO's) AP-913 to address equipment reliability (ER) at three utilities. The contributing utilities are Exelon Nuclear, PPL Susquehanna, and Dominion Nuclear - Surry. The information in this report was obtained primarily through interviews with plant personnel, with additional information being provided by the contributing utilities in hard copy form. The report begins by documenting the motivation behind implementing an ER process and the steps leading to the selection of AP-913 as the basis for an ER process. The report also lists the similarities found in the implementation steps and the common process areas that will benefit from a longer term approach. The goal of this report is to support utilities considering the adoption of AP-913 by citing three different examples of organizations with significant experience in efforts to improve equipment reliability.

Guideline for As-Found Reporting: A Process for a Living PM Program. EPRI, Palo Alto, CA: November 2003. 1002935.

> In nuclear power plants and in many other industries, only a fraction of the useful information potentially available from Preventive Maintenance (PM) activities is actually recorded. This information is often in the form of brief, non-specific text entries provided by craft

personnel in PM work orders. The capture and review of relevant component condition information during the performance of a specific PM task is a crucial step in the ongoing refinement of the overall PM program. It is this information and the associated determination of component degradation that can directly influence future PM task activities and intervals. Such information may be a key input to a living PM program. Its use may reasonably be expected to result in improved reliability with reduced maintenance costs.

This report describes the tools developed for the capture of equipment condition information and an evaluation process that can be used during the review of such information to improve the PM program.

Industry AP-913 Capabilities Database Version 1.0 on CD-ROM for Win98/NT/2000/XP. EPRI, Palo Alto, CA: July 2003. 1008252.

The Industry AP-913 Capabilities Database provides users with a searchable index of EPRI and industry documents relating to the implementation of the AP-913 Equipment Reliability Process promulgated by the Institute of Nuclear Power Operations (INPO).

The database contains a comprehensive list of industry documents that relate to the AP-913 Equipment Reliability Process . The products are mapped to the six major areas of AP-913 (Process Instructions) and to the activity elements within each of the major areas. Individual products that have applicability to multiple areas and elements have been mapped to each of the areas and elements where applicable. The degree of applicability of the EPRI products is designated by "tiers":

- Tier 1: Products generically applicable to an AP-913 area and element
- Tier 2: Products applicable to an AP-913 area and element on a product specific basis
- Tier 3: Products applicable to a specialized part of an AP-913 area and element

Infrared Thermography Guide, Rev. 3. EPRI, Palo Alto, CA: May 2002. 1006534.

This guide, which provides a compendium of information rather than definitive standards, describes IR theory, summarizes existing and potential IR applications, and offers technical information necessary for developing an effective in-house IR program. Key topics that are included in this guide are:

- The science of thermography
- Selection of infrared instruments
- Inspection techniques

- IR applications
- Basic elements of an in-house program
- Training and certification

This revision provides updated information on commercial infrared sensing and imaging instruments, IR applications, and training and certification criteria.

Infrared thermography is a valuable tool in a predictive maintenance program, as has been demonstrated by those applying the principles described in the Infrared Thermography Guide. Periodic updates of the guide keep the utility thermographer aware of recent developments in IR equipment technology, criteria for training and certification, and proven IR applications that add value to the utility IR program. The guide also serves as benchmark reference for those who contract their IR inspection services.

Maintenance Engineering Fundamentals for Nuclear Utility Personnel - Student Handbook. EPRI, Palo Alto, CA: December 2008. 1016313.

This EPRI report is the student handbook for participants in a training course on maintenance engineering fundamentals for nuclear utility personnel. The training course was developed in conjunction with EPRI report 1015307, Nuclear Maintenance Applications Center: Maintenance Engineer Fundamentals Handbook. Among the materials in the student handbook are an overview of the entire course; lists of pertinent definitions, acronyms, and resource materials; summaries of learning objectives and key points for each module of the course; and reduced copies of the presentation slides used by the course instructor. An appendix of the handbook also presents the instructor's lesson plan.

Nuclear Maintenance Applications Center: Maintenance Engineer Fundamentals Handbook. EPRI, Palo Alto, CA: December 2007. 1015307.

The scope of this report includes a general discussion on why maintenance is necessary and some common concepts concerning equipment failure and the major failure mechanisms in the nuclear industry today. The various maintenance strategies—that is, corrective, preventive, predictive, reliability-centered, fleetwide monitoring, on-line, outage management, and so on—are presented. Regulatory programs, such as the Maintenance Rule, environmental qualification, risk management, human performance, and operability determination, are discussed.

There are many influences on the implementation of maintenance strategies; these include life cycle management, useful life, foreign material exclusion, control of heavy loads, and equipment replacement. One of the new technology tools—wireless technology—is included.

Problem-solving techniques are important to the plant engineer's success in performing effective maintenance. Troubleshooting, corrective action, condition reporting, and root cause analysis contribute to solving equipment problems.

Several processes affect the maintenance programs in the plants. The processes include work management, maintenance metrics, working with supplemental personnel, post-maintenance testing, configuration management, and maintenance effectiveness.

There are various technical resources available for the plant engineer today. This report contains a listing of EPRI Nuclear Maintenance Applications Center reports, other EPRI resources, Institute of Nuclear Power Operations (INPO) documents, U.S. Nuclear Regulatory Commission documents, piping code information, metals information, civil engineering concepts, and information about elastomers and insulation. Useful databases include the INPO Equipment Performance and Information Exchange database and the EPRI Preventive Maintenance Basis Database.

Because of the large number of topics covered in this report, the topics cannot be explained in their entirety. The overviews of these topics should provide an adequate knowledge level for the plant engineer to be successful in his or her position. References for more in-depth coverage of these topics are provided.

On-Line Monitoring Cost-Benefit Guide. EPRI, Palo Alto, CA: November 2003. 1006777.

This report provides detailed information regarding the cost-benefit of on-line monitoring to nuclear plant instrument systems. Although much has been written regarding the technical application of on-line monitoring for signal validation and equipment condition monitoring, very little has been published regarding the relative costs of on-line monitoring compared to the expected benefits.

On-Line Monitoring for Equipment Condition Assessment. EPRI, Palo Alto, CA: December 2008. 1016724.

This project demonstrates an approach to obtaining an integrated source of data for power plant equipment that merges traditional process measurements with new data streams made available through the processing and conversion of high-frequency vibration data. The integrated source of data can feed empirical monitoring software systems to improve their diagnostic capabilities. In addition, this project demonstrates the deployment of a wireless vibration monitoring system that is of reasonable cost and is robust in an industrial environment. Methodologies to extract specific spectral features from vibration spectra and to transmit this information to a plant historian are demonstrated and suggested as a partial way of supporting and improving typical periodic vibration collection and analysis for rotating machinery health monitoring.

PdM Technology, Identification, Development, and Implementation – 2004. EPRI, Palo Alto, CA: November 2004. 1003684.

This report summarizes the observations of EPRI personnel regarding the utilization of various predictive maintenance technologies at nuclear power plants, both in the United States and abroad. Possible barriers to more extensive use are noted.

Performance Metrics for Condition-Based Maintenance Technology Application Programs. EPRI, Palo Alto, CA: December 2003. 1003682.

This report has been prepared as a reference document to assist EPRI-member utilities in improving their condition-based maintenance technology processes. To assist members with identifying program strengths and improvement opportunities, the report presents the key elements that are included in comprehensive lubrication, infrared thermography, and vibration technology monitoring program evaluations. The spider chart approach of the EPRI Monitoring and Diagnostics (M&D) Center is used to graphically depict each Key Element of a best practice Technology Application Program. EPRI believes that technology application monitoring program improvements can be identified and made by using the program performance metrics contained in this report and specific EPRI-prepared Lube Oil, Infrared Thermography, and Vibration Technology Application Program guidelines.

Plant Support Engineering: Guideline for System Monitoring by System Engineers. EPRI, Palo Alto, CA: March 2010. 1020645.

This report is an update of TR-107668, which was issued in 1997 and was the first nuclear industry guidance on system monitoring by system engineers. The Maintenance Rule was the main regulating requirement for evaluating equipment reliability at that time, but since then, the equipment reliability process has enhanced and expanded the scope of equipment that should be covered by performance monitoring. Therefore, while the process developed in 1997 for how a system monitoring performance plan should be done has withstood the test of time, the guide required updating for the inclusion of equipment reliability criteria for the scope of equipment and functions to be monitored. The revised guidance should prove useful to the U.S. nuclear industry in enhancing their system monitoring process. In addition, this revised guide will provide better guidance than what previously existed for international nuclear members or new plant engineers who may not yet have developed their system monitoring plans.

This report has been created as a tool to be used by system engineers for the preparing, or updating of their system monitoring plans based changes within the industry since TR-107668 was developed in 1997. It expands the guidance to include the concept of equipment reliability as it pertains to the scope of systems, structures, and components that should be monitored. This report also includes management responsibilities for sponsorship, approval, and ongoing oversight of the system monitoring effort. Because system health and performance are one of the major focuses of system engineers, their support of the equipment reliability process, and management's stake in the success of effective system monitoring, these organizations were targeted to support the development of the revision to ensure that they will derive the expected benefit of the final product.

Predictive Maintenance Primer: Revision to NP-7205. EPRI, Palo Alto, CA: November 2003. 1007350.

The "Predictive Maintenance Primer" revision provides nuclear plant personnel with current information regarding the predictive maintenance technologies and their applications. This guide will assist a plant in improving its predictive maintenance program.

Predictive Maintenance Self-Assessment Guidelines for Nuclear Power Plants. EPRI, Palo Alto, CA: November 2000. 1001032.

The document describes both a traditional Self-Assessment Team Approach and a Stakeholders Workshop Approach. Both approaches use data review and discussion to acquire information and results for a quantitative score in 14 key areas. These areas are: PM Task Technical Basis; Technology Application; Process Flow Definition; Program Leadership and Coordination; Organization, Roles, and Responsibilities; Information Management and Communication; Equipment Condition Assessment and Decision Making Training; and Qualifications; PdM Work Prioritization and Scheduling; Work Closeout and Maintenance Feedback; Goals and Performance Metrics; Calculation of Cost-Benefits and Return on Investment; Customer Satisfaction; and Continuous Improvement.

A prioritized list of potential process improvements results from the PdM assessment. Key impediments to success are also identified.

The report provides a complete guideline for assessing the PdM process at a nuclear power plant. Section 1 provides all the background, definitions, and perspective necessary for the reader to understand the scope of PdM as used in this document. It also discusses the objectives of a PdM assessment and the potential benefits. Section 2 summarizes the two alternative assessment approaches that are detailed in the report. Section 3 provides detailed guidelines for the pre-assessment steps: planning, scheduling, and technical preparation. Section 4 provides detailed guidelines for performing the assessment using the Self-Assessment Team Approach. Section 5 provides detailed guidelines for performing the Stakeholders Workshop Assessment. Also included in this report are specific evaluation criteria, sample forms for use, credentials for participants, and other products directly useful in the assessment.

System, Component and Program Health Reporting: Utility Best Practices. EPRI, Palo Alto, CA: December 2004. 1009745.

Development and use of accurate health reports, whether for systems, components, or programs, is a fundamental activity in understanding and managing the overall status of plant equipment and processes. As utilities continue to focus on equipment reliability issues and implementation of INPO AP-913, the development of these plans is becoming an area requiring close attention and improvement.

A utility workshop was held to discuss the key attributes of health reporting; a task group determined the most important issues in report development and captured current state-of-the-industry techniques.

This report, which presents the results of the task group's consideration on the industry's current state, should support utilities in developing their own effective monitoring and reporting programs.

Vibration Monitoring and Analysis Program Development: Interim Guideline. EPRI, Palo Alto, CA: December 2004. 1009586.

Utility Perspective: EPRI and its members have known that the preparation of reliable maintenance process improvement guidelines provide a significant advantage in the competitive market that the power industry has been facing in recent years. The EPRI-member utilities have implemented many of the maintenance processes, condition monitoring tools, and predictive maintenance (PdM) programs that have been developed by EPRI, and as a result, they have realized substantial benefits. However, the goals leading to improved vibration monitoring and analysis programs have not been met in all cases. This vibration monitoring and analysis guideline will not only contribute substantially to the identification of the areas that need improvement to achieve those best practices goals, but also the tools included can be used as part of continuous improvement efforts that are needed to maintain future competitive positions.

6.6 References for Key Supporting Elements

The purpose of this section is to provide references related to the four key supporting elements of the PM process. These references may also address topics inherent to some of the process elements. Enveloping the PM Process are four key supporting elements that facilitate its ability to change and live:

- A plant culture that encourages change and strives for excellence
- Leadership and oversight from site management because of the cross-disciplinary and cross-departmental nature of the process
- A desire to continuously improve the PM process and subsequently the reliability of plant equipment
- Excellent worker knowledge and skills

6.6.1 INPO Documents

INPO products are not accessible to the general public, and reference to these documents in this report does not in any way change this policy. As such, INPO references are footnoted as follows "Access to INPO reports and materials is restricted to organizations authorized by INPO. The information is confidential and for the sole use of the authorized organization."

Achieving Excellence in Performance Improvement, Leader and Individual Behaviors That Exemplify Problem Prevention, Detection, and Correction as a Shared Value and a Core Business Practice. INPO, Atlanta, GA: September 2009. Guideline 09-011.[11] (Available only to INPO members.)

Achieving High Equipment Reliability – A Leadership Perspective. INPO, Atlanta, GA: January 2001. Guideline 01-004.[11] (Available only to INPO members.)

Equipment Reliability Process Description. INPO, Atlanta, GA: March 2011. AP-913, Revision 3.[11] (Available only to INPO members.)

Guidelines for the Conduct of Maintenance at Nuclear Power Stations. INPO, Atlanta, GA: June 2005. Guideline 2005-004.[11] (Available only to INPO members.)

Guidelines for the Conduct of Outages at Nuclear Power Plants, INPO, Atlanta, GA: 2006. Guideline 06-008.[11] (Available only to INPO members.)

Maintenance/Engineering: Controlling Troubleshooting Activities. INPO, Atlanta, GA: March 2000. NX-1025.[11] (Available only to INPO members.)

[11] Access to INPO reports and materials is restricted to organizations authorized by INPO. The information is confidential and for the sole use of the authorized organization.

Nuclear Utility Obsolescence Group (NUOG) Obsolescence Program Guideline, Revision 1. INPO, Atlanta, GA: 2003. NX-1037.[12] (Available only to INPO members.)

NX-1023 12/99 Maintenance: Predictive Maintenance Program Implementation. INPO, Atlanta, GA: December 1999. NX-1023.[12] (Available only to INPO members.)

NX-1024 1/00 Maintenance: Predictive Maintenance Periodic Reports. INPO, Atlanta, GA: January 2000. NX-1024.[12] (Available only to INPO members.)

Outage and Work Management: Outage High Impact Teams. INPO, Atlanta, GA: May 2003. NX-1046.[12] (Available only to INPO members.)

Outage and Work Management: Work Package Reviews and Walkdowns. INPO, Atlanta, GA: July 2002. NX-1042.[12] (Available only to INPO members.)

Outage Process Description. INPO, Atlanta, GA: November 1998. INPO AP-925.[12] (Available only to INPO members.)

Post-trip Reviews, Rev. 1(OP-211). INPO, Atlanta, GA: July 1991. Guideline 88-024.[12] (Available only to INPO members.)

Predictive Maintenance Activities to Improve Equipment Performance (MA-321). INPO, Atlanta, GA: December 1998. Guideline 98-006.[12] (Available only to INPO members.)

Preventive Maintenance Program Enhancement (MA-319). INPO, Atlanta GA: December 1992. Guideline 92-014.[12] (Available only to INPO members.)

Principles for Maintaining an Effective Technical Conscience (Preliminary). INPO, Atlanta, GA: July 2010. Guideline 10-005.[12] (Available only to INPO members.)

Reducing the Occurrence of Plant Events Through Improved Human Performance. INPO, Atlanta, GA: October 1992. SOER 92-1.[12] (Available only to INPO members.)

Root Cause Analysis (OE-907). INPO, Atlanta, GA: January 1990. Guideline 90-004.[12] (Available only to INPO members.)

Work Management Process Description, Appendix H. INPO, Atlanta, GA: June, 2010. INPO AP-928, Revision 3.[12] (Available only to INPO members.)

Work Management: Forced Outage Preparation and Implementation. INPO, Atlanta, GA: September 1999. NX-1016.[12] (Available only to INPO members.)

[12] Access to INPO reports and materials is restricted to organizations authorized by INPO. The information is confidential and for the sole use of the authorized organization.

6.6.2 PMCG Documents

Preventive Maintenance (PM) Deferral Guidelines, Rev 4. PMCG: April 2006.

No PM Required, PM Basis Development Guide (No Cost Effective PM to Increase Reliability), Rev 4. PMCG: June 2005.

Criteria for PM Frequency on I&C Calibrations, Rev 4. PMCG: January 2008.

6.7 Bibliography

U.S. Nuclear Regulatory Commission. Quality Assurance Program Requirements (Operational). USNRC Regulatory Guide 1.33, Revision 2, Washington, D.C., February 1978.

Preventive Maintenance (PM) Program Guideline: Composite Flowchart. EPRI, Palo Alto, CA: July 2011. 1023209.

Appendix A: Listing of Key Points

Key O&M Cost Point
Emphasizes information that will result in overall reduced costs and/or increase in revenue through additional or restored energy production.

A.1 Key O&M Cost Points

Referenced Section	Page Number	Key Point
2.3		Each site should have a person or team that drives and coordinates the implementation of the PM process.
3.1.2.1		The PM task scope should be based to eliminate most common failure mechanisms/modes, and should also consider the criticality of the component.
3.2.2.1		By examining PM tasks with compatible frequencies, work can be efficiently bundled to optimize costs, minimize equipment out-of-service time, and efficiently use maintenance resources.
3.2.2.1		Once PM scope and schedule are identified, staffing reviews can commence to ensure the most effective use of available resources.
3.4.2.4		Recommendations for initiating changes to PM tasks and frequencies should be encouraged and come from as many organizations involved with the reliability of the equipment as possible.

Key Technical Point
Targets information that will lead to improved equipment reliability.

A.2 Key Technical Points

Referenced Section	Page Number	Key Point
2.1		PM implementation should be a dynamic process that continually improves and adjusts to accommodate the age of the equipment, design modifications of plant structures/systems/components, and the results and lessons learned from performing maintenance over the life of the equipment.
3.1.2.3		A key factor affecting the living PM program is accurate documentation of the actual equipment currently installed in the plant.
3.1.2.4		Each site should have a procedure for approving the PM technical basis that resulted in clearly defining PM tasks and respective interval frequencies.
3.3.2.4		Standardized PMT procedures and instructions should be used whenever possible.
3.4.2.1		The capture and review of relevant component condition information during the performance of a specific Preventive Maintenance (PM) task is a crucial step in the ongoing refinement of the overall PM program.
3.4.2.2		In addition to as-found conditions, operating experience is another key feedback input to facilitate change to the PM task scopes and frequencies, and in a generic sense, keep the process dynamic and living.
4.2.1		Industry experience suggests that if condition codes are going to be used they should be low in number (no more than 5 with 3 being good) with very clearly defined definitions.
4.3		Performance monitoring results should supplement the documentation of as-found conditions and operating experience.
5.4		Appropriate site personnel should review and adjust the performance metrics and performance levels provided in this report to match site-specific processes.

Key Human Performance Point
Denotes information that requires personnel action or consideration in order to prevent personal injury, equipment damage, and/or improve the efficiency and effectiveness of the task.

A.3 Key Human Performance Points

Referenced Section	Page Number	Key Point
2.3		Although the roles and responsibilities of the PM Coordinator(s) will vary from site to site, the two functions that tend to be common to any nuclear utility are: – Leading the PM change process – Conducting PM process assessments
3.2.2.2		The work planner should generate separate tasks for support activities to ensure PM task completion.
3.2.2.2		Preventive Maintenance work instructions are written for maintenance activities that do not change the design of the plant, and are not subject to 10CFR50.59. As such, a technical review is appropriate, in lieu of the review process described in the regulation.
3.3.2.2		The use of skill-of-the-craft in the performance of a job is not considered to be a change of work scope, providing it is confined to the job covered by the work package and that all other work done is in agreement with approved procedures.
3.3.2.2		Using human performance tools by maintenance personnel should be in compliance with their individual site procedures, many of which are based upon INPO guidelines.
4		A key aspect of ensuring the success of any "model" is to make certain that the owners of the PM Technical Basis are in line with management's clearly defined expectations regarding changes to PM scope and frequency.

Key Supervisory Observation Point
Identifies tasks or series of tasks that can or should be observed by Maintenance First Line Supervisors to improve the performance of the Maintenance Staff and improve the reliability of the component.

A.4 Key Supervisory Observation Points

Referenced Section	Page Number	Key Point
3.2.2.2		The planner should be careful when using a Bill of Material parts list that the most current part number is used for needed parts.
3.3.2.3		Work practices exercised during PM activities should exemplify high standards of quality and workmanship.
3.3.2.4		When a PMT needs to be prepared, the planner should select the appropriate test scope from a PMT matrix.

Appendix B: Examples of PM Coordinator Functions and Job Descriptions

The purpose of this appendix is to provide an illustrative example of the typical functions and job description for a site PM Coordinator. The job functions and description described below are provided for illustrative purposes only and will most likely vary somewhat from those site-specific duties assigned on a case-by-case basis.

B.1 General Accountabilities

Provide oversight for Preventive Maintenance (PM) Program process implementation and provide guidance through the transition to current PM technical basis management. Lead the site in evolving the PM Program towards the industry standard Equipment Reliability Process model (INPO AP-913[13]).

B.2 Specific Accountabilities

B.2.1 Oversight

- Act on behalf of Department Manager in the role of ensuring conformance to PM Technical Requirements.
- Act on behalf of Department Manager in the role of ensuring conformance to Critical Equipment Identification and Categorization procedures.
- Monitors PM Program metrics and performance indicators and reports monthly on the health of the site/fleet PM Program.
- Is accountable for identifying weaknesses, but is not accountable for compliance with governance (line management accountability).
- Meet with site PM contacts (Equipment Reliability Section) to ensure consistent application of PM Program.

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- Coach and mentor engineering personnel on current PM Process computer software.
- Work with other station groups involved in PM execution to provide direction for the resolution of implementation issues (e.g., software navigation, PM process steps, metrics, processing feedback).

B.2.2 Governance

- Initiate revision of PM-related computer software supporting the PM Process.
- Incorporate industry best practices consistent with INPO AP-913[14].

B.2.3 Industry Involvement and Interface

- Evaluate Equipment Reliability and PM Program related operating experience.
- Periodically attend industry work shops to monitor trends and maintain program alignment, and perform benchmarking against best practices.

B.2.4 Equipment Criticality Categorization

- Provide guidance for the consistent application of criticality codes to all equipment in each site's materials management information system in support of establishing the scope of PM Program, and performance monitoring.
- Approve changes to criticality code assignments.

B.2.5 Continuous Equipment Reliability Improvement

- Provide guidance for the consistent application of PM templates and maintenance strategies for the development of PM.
- Approve PM templates and maintenance strategies.
- Periodically monitor the feedback process to ensure the continuous optimization of PM (The Living Program).
- Periodically monitor deferral request and change request backlogs to ensure timely processing.
- Work with Predictive Maintenance (PdM) Teams to integrate PM and PdM activities and administration.
- Take the lead in implementing PM efficiency initiatives, e.g., PM bundling, pegging, trends.

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B.2.6 PM Implementation

- Ensure appropriate work groups establish appropriate metrics for monitoring the scheduling and execution of PM.
- Provide guidance to ensure metrics are consistent between sites and industry standards.
- Periodically monitor PM execution rates to ensure targets are being met.
- Periodically monitor maintenance feedback to ensure quality and consistency.

B.2.7 Corrective Action Program Interface

- Review failures of equipment categorized as critical by each site.

B.3 Selection Criteria

- Must be able to demonstrate that the individual values the role and is committed to it.
- Must be judged capable of working at the level as prescribed by site/fleet procedures.

B.4 Skills and Knowledge

- Demonstrated capability to work as a leader to set direction and engage staff.
- Requires a sound knowledge of the integrated design, operation and maintenance of a nuclear generating facility.
- Ability to break down complex problems into manageable parts, to develop alternate solutions and make recommendations.
- Ability to communicate effectively with individuals at all levels of the organization and to convey complex matters in simple terms.
- Requires a demonstrated good working knowledge of best business practices in the subject area (Equipment Reliability and Preventive Maintenance).
- Requires knowledge and experience in the areas of operation and maintenance of a nuclear generating facility.
- Must possess good oral and written communication skills.

Appendix C: Examples of PM Process Measurement Performance Indicators

The purpose of this appendix is to provide actual examples of PM process measurement performance indicators. These examples are consistent with the recommended performance indicators described in Section 5 of this report.

C.1 Example #1

The following example, which was recorded July – September 2008, resulted in a composite score of 7.4, or WHITE.

PM Program Health Index				
Score (Color)	Major Program Attributes	Related Performance Metrics	Score (Color)	
8.0 (Green)	The PM Program as a work management process	1.1 Number of PM deferrals	10	(Green)
		1.2 Delinquent (late) PMs	6	(White)
		1.3 PMs completed deep into the grace period	9	(Green)
		1.4 PM revision backlog	7	(White)
7.2 (White)	The infrastructure of the PM Program	2.1 Staff capabilities and experience	7	(White)
		2.2 PM living program procedures	6	(White)
		2.3 Documented program health, assessments, and benchmarking	7	(White)
		2.4 Training	6	(White)
		2.5 Technical evaluations of PM deferrals	9	(Green)
		2.6 PM Basis Documentation	8	(Green)
7.0 (White)	The PM Program as a "living program"	3.1 Amount of craft feedback	9	(Green)
		3.2 Quality of the craft feedback	7	(White)
		3.3 Ability to evaluate craft feedback	7	(White)
		3.4 Feedback response time to craft feedback	6	(White)
		3.5 Just in time (JIT) PM review process	8	(Green)
		3.6 Template Development and Implementation	6	(White)
		3.7 Integration of industry data into PM templates	6	(White)

C.2 Example #2

The following example, which was recorded January 2011, resulted in a composite score of 8.0, or GREEN.

OVERALL PARAMETERS:

Health Score	8.00 (G)

GRADED PARAMETERS:

Ability to Evaluate Craft Feedback	Amount of Craft Feedback	Bench Strength	Delinquent (Late) PMs	Documented Program Health, Assessments, and Benchmarking
1.00 (G)	100.00 (G)	1.00 (W)	0.00 (G)	1.00 (G)
Industry Participation	Integration of Industry Data into PM Templates	Just in Time (JIT) PM Review Process	Number of Critical PM Deferrals	Percentage of PMs Completed Deep into the Grace Period
0.00 (G)	1.00 (G)	1.00 (G)	0.00 (G)	12.00 (W)
PM Basis Documentation	PM Living Program Procedures	PM Revision Backlog	Quality of Craft Feedback	Quality of Engineering PM Feedback
1.00 (G)	1.00 (G)	56.00 (W)	67.00 (Y)	100.00 (G)
Response Time to Craft Feedback	Staff Capabilities and Experience	Technical Evaluations of PM Deferrals	Template Development and Implementation	Training
31.70 (Y)	1.00 (G)	1.00 (G)	2.00 (W)	1.00 (G)

Appendix D: User Training Material

The purpose of this appendix is to provide a brief summary of related training courses and training material that may be of benefit to the site PM Coordinator.

Preventive Maintenance Implementation Training

- Nuclear Maintenance Applications Center: Maintenance Engineer Fundamentals Handbook. EPRI, Palo Alto, CA: December 2007. 1015307.

Maintenance Rule Training

- Education of Risk Professionals Module 1. EPRI, Palo Alto, CA: December 2009. 1019203.
- EPRI Education of Risk Professionals Program. EPRI, Palo Alto, CA: October 2009. 1019540.
- EPRI Probabilistic Risk Assessments (PRA) Computer Based Training (CBT) v1.0. EPRI, Palo Alto, CA: January 2010. 1019204.

Predictive Maintenance Training

- Predictive Maintenance Technologies – (Life Cycle Institute) www.education@LCE.com

Life-Cycle Management and Long-Term Operations Training

- Identification and Detection of Aging Issues. EPRI, Palo Alto, CA: August 2003. 1007932.

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