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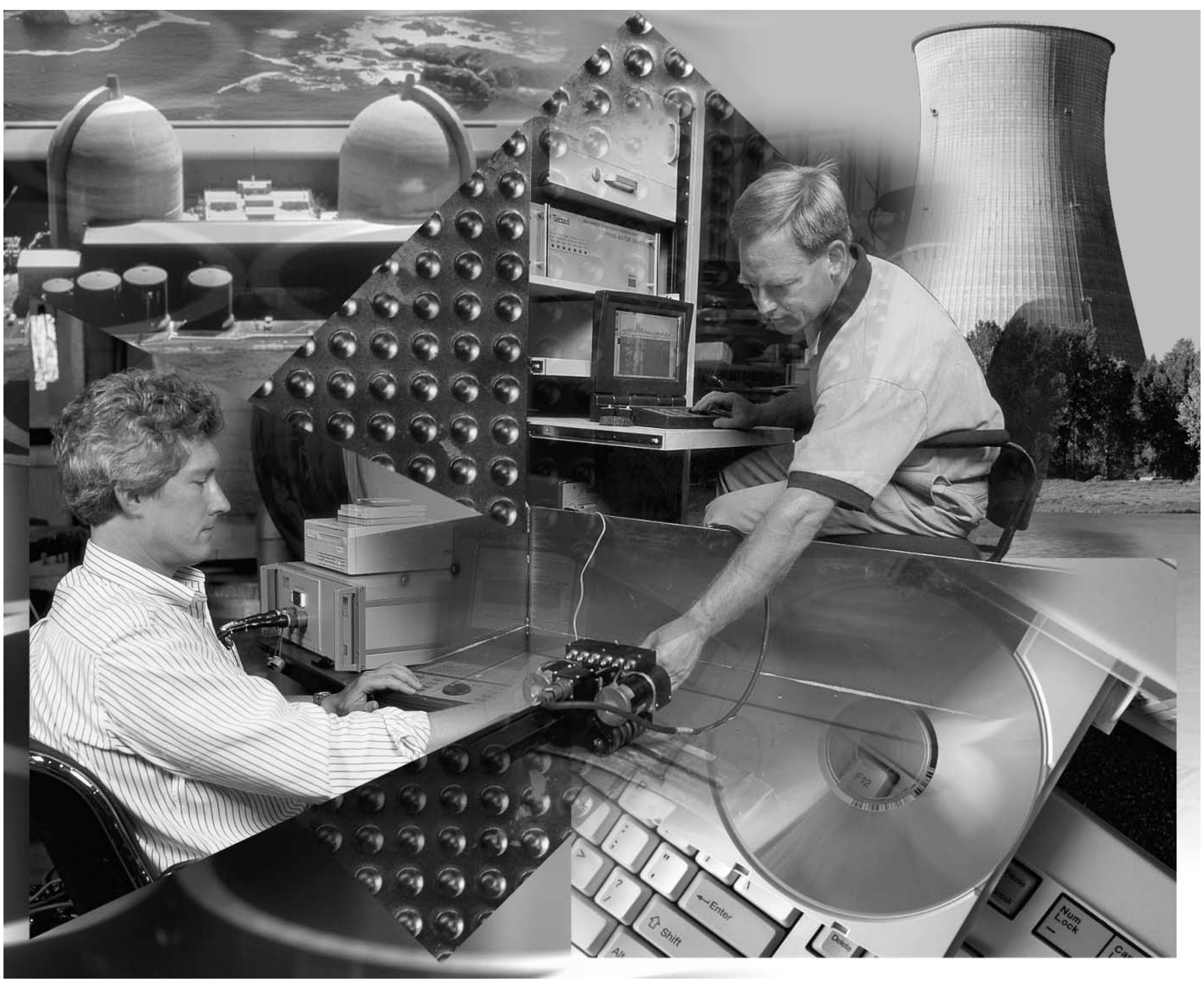
Predictive Maintenance Self-Assessment Guidelines for Nuclear Power Plants

Technical Report



T.E.A.M.
Technology for Equipment Assessment and Maintenance

Predictive Maintenance Self-Assessment Guidelines for Nuclear Power Plants

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Final Report, December 2000

EPRI Project Manager
M. Bridges

EPRI • 3412 Hillview Avenue, Palo Alto, California 94304 • PO Box 10412, Palo Alto, California 94303 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

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This report was prepared by

Altran Corporation
451 D Street
Boston, MA 02210

Principal Investigators
P. Cafarella
J. Gaertner

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REPORT SUMMARY

There is a need at nuclear power plants for optimization and continuous improvement in the predictive maintenance (PdM) process. This need is based upon increased reliance on PdM to contribute to low unplanned capability loss factors, prevent significant equipment failures, reduce resources for maintenance, manage assets in support of license renewal and aging control, incorporate new technologies and advanced information management, and manage the risk associated with maintenance activities. This document provides a demonstrated assessment method to achieve an optimized PdM process.

Background

EPRI has been an industry leader in research, development, and applications of PdM technology. Through the EPRI Maintenance and Diagnostic Center (M&DC), EPRI has participated in over 100 successful PdM program assessments in many industries. The M&DC organized and managed a PdM advisory group since 1989 consisting of industry PdM professionals. This group, along with M&DC expertise, identified PdM assessment areas and developed objective evaluation criteria. In 1998, the EPRI Nuclear Power Division began a PdM Initiative to transfer and enhance the EPRI non-nuclear guidelines for the nuclear industry. The cornerstone of this effort was a collaborative effort of Omaha Public Power District, PECO Nuclear, and UNICOM to develop and demonstrate PdM assessment techniques to identify and implement “Best PdM Practices” at their respective plants. This assessment guideline is a result of that successful experience.

Objective

- To provide practical guidelines to nuclear power plant personnel in assessing and subsequently improving their PdM process. Furthermore, the evaluation criteria and results format build on the PdM Advisory Group efforts and standardize the approach for the Nuclear Industry so that plant personnel can share information and benchmark their processes.

Approach

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
- Continuous Improvement

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

Results

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.

EPRI Perspective

Based on techniques used during successful Tailored Collaboration efforts with PECO Nuclear, Omaha Public Power District, and UNICOM, these guidelines should have significant value to each EPRI member nuclear plant. PdM, as well as condition-based maintenance, is a rapidly evolving area that has great potential benefit for nuclear plants in a competitive power environment. This benefit can be enhanced by the use of a common, comprehensive assessment methodology to facilitate benchmarking and communications among plant personnel. This document supports the efforts by the Institute of Nuclear Power Operations (INPO) to optimize PdM in order to reduce unplanned capacity losses and to achieve an effective equipment reliability process in the industry.

Keywords

Maintenance
Monitoring and diagnostics
Predictive maintenance
Preventive maintenance

ABSTRACT

This document details a predictive maintenance (PdM) assessment method based on its successful application at many sites, most recently at the nuclear units of PECO Nuclear, Omaha Public Power District, and UNICOM. PdM is a process of integrating knowledge of plant equipment condition with other maintenance, operations, and engineering experience to make timely maintenance decisions for the equipment. The PdM process includes not only collecting the condition and performance information, but also evaluating the functional capability or condition of the equipment, supporting plant decisions for appropriate corrective or preventive actions, and continuously improving all activities and interfaces necessary to achieve the process.

The document describes both a traditional Self-Assessment Team Approach and a Stakeholders Workshop Approach. The team approach uses data review and interviews to acquire information and results in 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
- Continuous Improvement

The Team Approach identifies strengths and weaknesses in each area using interviews and information reviews and offers potential process improvements. The Workshop Approach uses presentations and group exercises to understand the PdM process and results in a quantitative

score for the same 14 key areas. The group develops a prioritized list of potential process improvements and identifies key impediments to success.

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1 INTRODUCTION

1.1 Background

Predictive maintenance (PdM) is a process of integrating knowledge of plant equipment condition with other maintenance, operations, and engineering experience to make timely maintenance decisions for the equipment. Condition monitoring data collection is non-intrusive preventive maintenance (PM) performed at intervals governed by industry PM basis templates or by the observed condition of equipment and the expected progression of the degradation mechanism. Its purpose is to monitor, trend, and diagnose indicators of equipment functional capability or condition. Results of PdM activities indicate current and future schedules for recommended corrective or preventive maintenance. They also provide for continuous improvement of all PdM activities and interfaces.

The above discussion of PdM is supported by a definition developed by the EPRI PdM Advisory Group:

> *Predictive maintenance is a process that requires technologies and people skills, that integrates all available equipment condition indicators (diagnostic and performance data, operator logged data), maintenance histories, and design knowledge to make timely decisions about maintenance requirements of important equipment.*

An extensive list of equipment condition monitoring technologies, commonly referred to as "predictive maintenance" technologies, is in the EPRI document *Improving Maintenance Effectiveness Guidelines* (TR-107042) and is included in Table 1-1.

Table 1-1
Survey of PdM Technologies in Use at Nuclear Plants

• Temperature monitoring – Infrared thermography – Contact temperature monitoring – Area temperature monitoring • Lubricant analysis – Spectroscopy – Ferrography – Particle CT – Transformer oil dissolved gas analysis • Motor condition monitoring – MCA – Motor circuit evaluation – Hi-pot – Surge test – Winding resistance – Insulation resistance • Other electrical condition monitoring – Partial discharge – Indenter for cables – ELCID, ECAD for cables – Oxidative induction time for cables • Vibration monitoring – Generator end-turn vibration monitoring – Rotating equipment bearing monitor – Alignment check using vibration	• Acoustic • Ultrasonic • Radiography • Eddy CT probes • Remote visual inspection – Fiber optic sensors – Borescope – CCTV – Robots – Other technologies • MOV motor power monitoring – Cycle counters for switchgear – Operating deflection analysis – Ultrasound for valve/steam trap leak • Beta analysis diesel generators

1.2 Need for Guidelines Document

There is a need for PdM self-assessment at nuclear power plants to benchmark and ensure continuous improvement of the PdM process. Furthermore, there is a need for a guidance document that ensures that the self-assessment will be complete, effective, and efficient. This document is intended to satisfy both of these needs.

The need for PdM self-assessment is based upon increased reliance on PdM to contribute to:

- Low unplanned capacity loss factors
- The prevention of significant equipment failures
- The reduction of resources for maintenance
- Asset management in support of license renewal and aging control

- The incorporation of new technologies and advanced information management
- The management of the risk associated with maintenance activities

As a result, utility management and industry organizations, including the Institute of Nuclear Power Operations (INPO), Nuclear Energy Institute (NEI), and the Nuclear Regulatory Commission (NRC), are placing increased emphasis on PdM and its role in the safe and reliable operation of plants. Recent INPO publications underscore the significance of not only implementing PdM programs but also using them effectively. INPO Good Practice MA-321, *Predictive Maintenance Activities to Improve Equipment Performance*, provides guidance on all aspects of effective PdM. INPO document AP-913, *Equipment Reliability Process Description*, details the role of PdM in an effective equipment reliability process at nuclear plants. In the latter document, PdM plays a direct role in performance monitoring:

- As preferred tasks to intrusive preventive maintenance tasks
- As a contributor to a long-range maintenance plan accounting for aging
- As a key input to effective planning and scheduling

INPO provides assistance to utilities in both PdM and equipment reliability areas. Their assistance efforts use the principles in these documents.

The NRC has confirmed the importance of performance and condition monitoring in effective maintenance through 10CFR50.65, the Maintenance Rule. The Nuclear Energy Institute (NEI) provides the guidance for implementation of the Maintenance Rule in NUMARC 93-01, *Guidelines for Monitoring the Effectiveness of Maintenance.*

Nuclear insurers reinforce the importance of PdM through credits available to nuclear plants that substantially reduce insurance premiums based on the presence of specific PdM program elements applied to critical components and systems at the plant.

The need for this PdM assessment guide is based upon the complexity of the PdM process to address the expectations described above. As the PdM definition above illustrates, the PdM process involves many technologies, many individual activities, and the interaction of many groups within the plant. Furthermore, new monitoring technologies and new information management capabilities for PdM are evolving rapidly. Therefore, it is particularly challenging to optimize the process. This document describes a success path to assess the current status of a PdM program, compare the results of the assessment to proven standards, and determine improvements necessary to achieve world class performance in the area of PdM.

1.3 EPRI Credentials for Developing PdM Assessment Guidelines

EPRI has been an industry leader in research, development, and application of PdM technology for many years. Much of this work has been performed through the EPRI Maintenance and Diagnostic Center (M&DC), which as a result of these EPRI projects, has developed and maintained a staff of PdM technology and program experts. Since 1989, the M&DC has organized and managed a PdM advisory group consisting of industry PdM professionals. This advisory group, along with M&DC expertise, identified PdM assessment areas and developed objective evaluation criteria. Through the M&DC, EPRI has participated in over 100 successful PdM program assessments encompassing the nuclear industry as well as other industries. EPRI has published numerous guidelines and resource documents on PdM technologies. Report TR-109241, *Predictive Maintenance Assessment Guidelines,* was produced in November 1997 to document guidance based on assessment experience to date—primarily non-nuclear. In May 1996, EPRI produced TR-105855, *Condition-Based Maintenance at Duke Power: Lessons Learned.*

In 1998, the EPRI Nuclear Power Division began a PdM initiative to transfer and enhance the EPRI non-nuclear guidelines for the nuclear industry. The cornerstone of this effort was a collaborative effort of Omaha Public Power District, PECO Nuclear, and UNICOM to develop and demonstrate PdM assessments and to identify and implement “Best PdM Practices” at their respective plants. Assessments were performed at three nuclear plants and a system-wide PdM Stakeholders Assessment Workshop was conducted for PECO Nuclear and AmerGen plants. This PdM assessment guideline is the result of lessons learned from this successful collaboration.

1.4 Expected Benefits of a PdM Self-Assessment

An assessment will examine the existing PdM process and its interfaces with other plant programs and processes to determine whether the elements necessary to achieve success are in place. The effectiveness of the program will be determined by comparison to observed industry best practices that have yielded demonstrated excellence. Recommendations for improvements will be identified to ensure that the program under review is on the path to “Best in Class” performance.

Benefits to be expected from use of this guideline are based on EPRI experience in all industries. The benefits include:

- Awareness of PdM staff and plant management of PdM activities and the value of the activities to plant personnel
- Comparison of the process and its effectiveness with plant-specific objectives
- Comparison of the process and its effectiveness with industry norms and best practices
- Trending of PdM process effectiveness over time
- Recommendations for improved effectiveness and efficiency
- Insights to management on ways to enhance PdM value

2
SELF-ASSESSMENT APPROACH AND SUMMARY

2.1 Scope of the PdM Self-Assessment

The core technologies of oil and grease analysis, vibration monitoring, and thermography are used to varying degrees at most nuclear power sites. This assessment program provides guidelines for determining the effectiveness with which these technologies are being employed and identifies opportunities, where they exist, for improvement. Additional PdM technologies that are used within the PdM program, that are used by other groups within the plant, or that are not used but are expected to be cost-effective, are included unless specifically excluded from the assessment.

Interaction between the PdM group and other stakeholders is evaluated to determine where interfaces exist and how information is being exchanged. The effectiveness of the information exchange and corresponding utilization of data is evaluated, and areas for enhancement are identified.

For nuclear plant applications, the assessment is structured around 14 areas of focus. These 14 areas have been found to completely and effectively address the entire scope of the PdM process. Furthermore, they are consistent with the areas identified by the EPRI PdM Advisory Group. These 14 areas are listed in Table 2-1 and described below.

Table 2-1
Fourteen PdM Assessment Areas

1. PM Task Technical Basis
2. Technology Application
3. Process Flow Definition
4. Program Leadership and Coordination
5. Organization, Roles, and Responsibilities
6. Information Management and Communication
7. Equipment Condition Assessment and Decision Making
8. Training and Qualifications
9. PdM Work Prioritization and Scheduling
10. Work Closeout and Maintenance Feedback
11. Goals and Performance Metrics
12. Calculation of Cost-Benefits and Return on Investment
13. Customer Satisfaction
14. Continuous Improvement

1. PM Task Technical Basis

   Condition monitoring data collection tasks should be considered as a vital part of an integrated PM program for plant equipment. As such, they should have scope and intervals determined to be appropriate considering the functional criticality, service environment, and duty cycle of the equipment. The determination of applicability and frequency of equipment condition-indicating technologies should be in accordance with industry PM task technical basis standards. The process should be documented.

2. Technology Application

   Standard technologies should be in widespread use and competently applied. Hardware should be state of the art and in good condition. Procedures and guidelines should exist. Mechanisms should be in place to identify and evaluate new technologies for application to the PdM program.

3. Process Flow Definition

   The PdM process including its interface with all engineering groups, maintenance, operations, and work planning and control should be well defined and well understood by those performing the work. In addition, the processes should be documented and supported by procedures and guidelines.

4. Program Leadership and Coordination

   Individuals should be identifiable as PdM technology owners and as PdM coordinators responsible for knowing equipment condition and performance. These individuals should be visibly applying and promoting the PdM process. Management support for the PdM process should be visible.

5. Organization, Roles, and Responsibilities

   Roles and accountabilities in the execution of the PdM process should be well defined and clear of any ambiguity. Individuals should be aware of and should support these roles. Evidence should exist that responsibilities are being carried out as defined. There should be real accountability for these responsibilities.

6. Information Management and Communication

   Condition monitoring information should be efficiently entered into databases. Condition information should be accessible in a timely and integrated manner with effective user interfaces. Information relating to the suitability of the equipment for continued operation should be effectively communicated to equipment owners and operating personnel. Also, varying levels of awareness of PdM program activities, goals, roles and responsibilities, and results should be effectively communicated to the appropriate plant and support personnel.

7. Equipment Condition Assessment and Decision Making

   Condition monitoring data should be trended and analyzed. Trained analysts should use analysis software where appropriate. There should be a process in place to generate and distribute equipment condition reports including a technology-integrated status of anomalies for equipment owners to review.

   It should be clear who is making decisions to act, based on indications of equipment condition. Such decisions should be made in a timely manner among personnel taking and analyzing data, owners of equipment, and personnel responsible for assigning, planning, and performing maintenance tasks. There should be a strong working relationship and trust among these personnel.

8. Training and Qualifications

   PdM technologists should be experienced, well qualified, and properly trained to perform PdM process tasks. Other persons who use the technology and its results should have adequate understanding of PdM technologies and the meaning of the results that may be reported to them. Management should support certification of personnel in PdM technologies. Critical activities should require formal certification.

9. PdM Work Prioritization and Scheduling

   Condition monitoring data collection tasks and collection routes should be well defined, planned, and performed on schedule. The plant must be diligent to acquire data from equipment that is often inaccessible. Equally important, PM or corrective tasks indicated by the PdM monitoring should be positively identified, prioritized, and scheduled to prevent failures or disruptions.

10. Work Closeout and Maintenance Feedback

    Closeout of PM tasks, corrective maintenance (CM) tasks, or other corrective actions that result from the PdM process are a necessary element of the PdM process. Timely and thorough closeout not only ensures that the immediate action is correct but also provides information for the continuous improvement element of the PdM process described later. Closeout activities should include documenting as-found conditions and feedback of information to program, technology, and equipment owners.

11. Goals and Performance Metrics

    Goals and performance metrics should be in place, well developed, and designed to link PdM activities and the PdM group to the optimizing of plant maintenance and operations. Stakeholders should be aware of metrics and their relationship to PdM objectives. Metrics should be used for optimization.

12. Calculation of Cost-Benefits and Return on Investment

    The results of the PdM program should be tracked. Case histories, cost-benefits, and contributions to plant performance should be documented, publicized, and used to justify current use and growth of PdM. Management should understand and support the value of these activities. Budget for PdM activities should be clearly identified and should reflect the actual and potential return on investment of the process.

13. Customer Satisfaction

    The entire PdM process should support the cost-effective and reliable operation of the plant. Persons with specific responsibilities for achieving these operational and cost objectives—management, operations, system and equipment owners—should use and value the PdM process. These end users should be viewed as customers.

14. Continuous Improvement

    The PdM process should have feedback and assessment elements to ensure that it continuously or periodically changes in response to plant experience, industry experience, and new technology. Changes in the process to reduce tasks or substitute for PM tasks, improve thermal performance, increase equipment reliability and availability, or prevent costly failures should be identified.

2.2 Objectives That Can Be Addressed by the Self-Assessment

Having realistic objectives and designing the self-assessment to achieve these objectives is the single most important element contributing to success.

This section discusses, “What are the realistic self-assessment objectives that can be addressed by this self-assessment?” It does not discuss, “What are the PdM process objectives against which the process is to be assessed?” This latter question is addressed in detail in Sections 3, 4, and 5 of this guideline.

The objective of a self-assessment program is not only to establish the current constitution and effectiveness of the PdM process but also to promote continuous improvement. The best list of candidate self-assessment objectives is provided by the list of expected benefits from Section 1:

- Awareness of PdM activities and their value to plant personnel
- Comparison of program and its effectiveness with plant-specific objectives
- Comparison of program and its effectiveness with industry norms and best practices
- Trending of PdM process effectiveness over time and verifying improvement recommendations are implemented
- Recommendations for improved effectiveness and efficiency
- Insights to management on ways to enhance PdM value

This guideline is designed to support either a one-time focused PdM assessment or a program of periodic focused self-assessments. One-time focused self-assessment activities may be triggered by:

- Declining trends in performance data or problems tracked in the corrective action program.
- Plant events triggered by equipment failures.
- Either indication of process inefficiencies manifested by work control issues or equipment problems.
- Input from ongoing self-assessment activities or from internal or external oversight groups.
- Benchmarking activities revealing potential performance improvement opportunities that warrant a focused review.
- Impending inspections or assist visits. In general, the PdM program is not used to satisfy regulatory driven requirements. However, increased emphasis on integrated maintenance activities and the equipment reliability process may indicate a need to assess the effectiveness of the PdM program.
- Significant change initiatives for which an early progress check is needed. Significant changes to the PdM program will necessitate examination of the change impact. Early examination allows adjustments to be made where necessary.
- Recent resolution of industry issues. Increased emphasis may be placed on the PdM program because of issues involving equipment problems.

Periodic self-assessments of the PdM process may be a normal part of the plant continuous improvement effort; that is, not triggered by any event or particular concern.

It should be noted that the self-assessment process is a process for evaluating the effectiveness of an existing and stable program. While it can and does detect areas where process improvement is warranted, the assessment in and of itself does not predict future performance that may result from changes recently implemented or proposed to be implemented. For example, the self-assessment is not designed to predict the impact of proposed staff reductions, reorganizations, technology enhancements, or information system improvements.

2.3 Assessment Team Approach: A Traditional Self-Assessment

The Assessment Team Approach is the most common form of PdM assessment and is most applicable whenever missing elements or incomplete processes are believed to be present in the program. This scenario is usually the case unless the plant has undergone a PdM optimization effort and is successfully involved in a continuous improvement process.

The Assessment Team Approach employs a team of subject matter and plant process experts to perform an evaluation of the PdM program and its interfaces with other plant programs and processes. The team can come entirely from the plant under assessment if the total capabilities of the team can span all areas to be assessed and if they have the depth of experience to differentiate between a poor practice, an acceptable practice, and a good practice. Otherwise, one or more outside experts, peers, or facilitators can be selected along with plant personnel who understand the plant programs and performance.

A mutually agreeable time is chosen and an assessment visit of nominally one week is scheduled at the subject plant. Prior to the visit, program practices and procedures are reviewed to determine the plant’s current PdM program and practices. An assessment plan is formulated and individual stakeholders at the plant are identified. Team members are trained in the assessment process. The team determines what to examine, who to interview, and how to collect the needed information. A detailed interview and meeting schedule is developed. Interviews are conducted and documented. The team evaluates the data and information using a well-defined assessment process that is summarized below and detailed in the remainder of this report.

The assessment process includes developing a quantitative score that estimates the plant’s percentile rating in each of the 14 assessment areas defined in Section 2.1. The team also delineates specific strengths, weaknesses, and other noteworthy observations in each of the 14 areas in support of the quantitative score assigned. The team assesses the plant’s PdM program and processes relative to one or more specific best practice in each assessment area. Finally, the assessment report provides a list of recommended actions, prioritized according to the team’s belief that implementation of the actions will cost-effectively contribute to excellence in the PdM program. Results of the assessment are documented in a report and are presented to plant management.

Plant personnel review the draft report and provide their response. The response is limited to corrections of factual errors and to clarifications or additional information that might change the team observations and recommendations. The team leader weighs their observations and the plant's response and issues a final report.

2.4 Stakeholders Workshop Approach: Awareness and Consensus Building

The Stakeholders Workshop Approach is a less common form of PdM assessment and is most applicable whenever it is believed that all essential elements and processes of the PdM process are in place. However, the elements and processes are not working optimally because of organizational, cultural, management, communications, or similar issues.

The Stakeholders Workshop Approach produces many of the same products as the Assessment Team Approach; however, the method of data gathering and analyzing the information is dramatically different.

Instead of selecting an assessment team, a workshop facilitator is selected. This individual must be familiar with plant programs and must be competent to conduct the workshop according to the guidelines in this document. A plant staff member using an outside meeting facilitator may be the most cost-effective choice to conduct the workshop assessment.

The facilitator establishes clear workshop objectives, defines the workshop agenda, and identifies potential participants. A mutually agreeable time is chosen for an assessment workshop of one to two days.

The participants interpret data and information prepared by the facilitator, evaluate the program elements, and present their observations using a well-defined assessment process that is summarized below and detailed later in this report.

During the first sessions of the workshop, the facilitator is responsible for presenting the necessary background and reference material for the subsequent assessment. These presentations establish a common knowledge base for participants.

The facilitator then conducts a series of exercises including all participants. If time permits, the group customizes a generic PdM process model to represent the specific plant process. Participants are asked to enumerate their pre-workshop PdM enhancement goals and to identify any specific new PdM technologies that should be investigated. Then, through a voting process, a quantitative score is produced that estimates the plant's percentile rating in each of the 14 assessment areas of Section 2.1. The team assesses the plant's PdM program and processes relative to one or more specific best practices in each assessment area. The group then provides a list of recommended enhancements, prioritized according to the team's belief that implementation of the recommendation will cost-effectively contribute to excellence in the PdM program. Finally, the group identifies concerns that might be impediments to successful implementation of the recommended enhancements.

Results of the stakeholders workshop are presented in a final report. The facilitator is responsible for communicating management results back to participants.

3 GUIDELINES FOR PRE-ASSESSMENT: PLANNING, SCHEDULING, AND TECHNICAL PREPARATION

This section applies to the Team Assessment Approach. Together with Section 4, which contains detailed guidance for the actual on-site assessment, this section provides a step-by-step process for a successful PdM team assessment. Many of the items are also applicable to the Stakeholders Workshop Approach and, when applicable, these sections are referenced from within Section 5 that includes detailed guidance for the Stakeholders Approach.

3.1 Establishing Clear Objectives

As pointed out in Section 2.2, there are two distinctly different types of objectives that must be identified at this stage of the self-assessment development. These are:

- **Objectives of the self-assessment.** These objectives are discussed in Section 2.2 and candidate objectives are also listed. These objectives should have already been established at the time the commitment was made to perform the self-assessment according to this guideline.
- **Objectives of the PdM process that are to be evaluated by the self-assessment.** The remainder of this section discusses the establishment of these PdM process objectives.

Establishing objectives will be performed by the plant staff person with responsibility for the performance and success of the assessment. If such an assignment has not yet been made, then the champion for the review assumes this responsibility, most likely the PdM coordinator, engineering manager, or maintenance manager to whom the PdM program reports.

The importance of clearly and completely identifying PdM process objectives and assessment objectives cannot be overemphasized. Table 3-1 identifies items in five functional areas that may be reasons to initiate a self-assessment of the PdM program. Plants may find that additional or other factors may lead to initiation of the process.

Table 3-1
Potential Objectives for PdM Team Assessment

Cost
- Reduce preventive maintenance costs
- Reduce overall maintenance costs
- Improve unit heat rate
- Reduce scope addition to scheduled outages
- Eliminate unplanned outages due to equipment failure
- Optimize spare parts inventory
- Maximize return on PdM technologies

Reliability
- Prevent critical equipment failures
- Improve equipment performance
- Reduce number of unplanned load reductions
- Reduce number of unit trips
- Reduce vulnerability due to protection system testing
- Detect and prevent aging-related failures

Availability
- Reduce unavailability of equipment due to preventive maintenance
- Reduce unavailability of equipment due to failure
- Improve safety system performance indicators
- Maximize unit availability
- Shorten outage duration

Safety
- Prevent safety system challenges through failure prediction
- Reduce potential unplanned radiation exposure
- Better manage core damage and large release risk

Infrastructure
- Support reengineering or reorganizational changes
- Accommodate staff turnover and loss of experience personnel
- Achieve consistency among sister plants or within a company
- Increase lead time for workweek and outage planning
- Identify new PdM technology for use at the plant
- Improve use of PdM for system and component health monitoring

After determining the PdM objectives and assessment objectives to be addressed by the assessment, these objectives are communicated to the sponsoring management and stakeholders in the PdM program and process for their comment and support. The final set of PdM objectives and assessment objectives should be communicated in writing to management and stakeholders. This concurrence step is important at this point in the assessment process, for all subsequent steps will be directed toward assessing the program with respect to these stated objectives.

3.2 Assembling the Self-Assessment Team

The self-assessment team should be composed of utility stakeholders and independent professionals including peers or industry experts. Stakeholders should be chosen based on participation in the existing PdM process, those who derive or desire benefit from the process, and those who ultimately manage and/or fund the process. Independent experts and facilitators should be chosen based on their knowledge of the subject matter and industry expertise.

An ideal size for the PdM assessment team is four to six persons. This size enables the use of two interview and review teams of two or three persons each. Experience has shown that one interview and review team has several disadvantages:

- The process drags on and loses enthusiasm and efficiency.
- It is difficult to capture all the necessary experience and expertise with only two reviewers.
- The team can develop biases and false conclusions that can be challenged in debrief meetings with another set of reviewers.

Experience has also shown that larger interview teams can be inefficient and intimidating to interviewees. If larger interview teams are used, the interviews should be structured so that one reviewer directs the interview. The other reviewers should have clearly defined areas or specific questions determined in advance. Spontaneous questions or comments in the interviews should be channeled through the lead reviewer. Also, someone other than the lead interviewer should keep notes.

Larger interview and review teams or more teams might be desirable under some circumstances. These circumstances include:

- Other sites or units send team representatives so they can use the assessment as a benchmark for their programs.
- Other sites or units send representatives so they can perform a similar, consistent assessment.
- Other sites or units send team representatives because a stated objective of the assessment is to achieve corporate consistency among plants.

Plant and corporate stakeholders must include the predictive maintenance coordinator or a key staff member familiar with all PdM technologies at the plant. Another excellent team member is the preventive maintenance engineer or coordinator. A key system engineer or component engineer who uses and supports PdM technology is a good assessor. The Maintenance Rule coordinator is often a good candidate. Operations staff, maintenance supervisors, work control and outage management personnel, and corporate stakeholders including General Office engineering staff should be considered. When selecting people it is important to get the best mix of experience and technical knowledge, including the areas listed in Table 3-2.

Table 3-2
Checklist of Experience and Expertise for Assessment Team

- PdM technologies and procedures
- Plant work planning and scheduling
- PM program
- Corrective action program
- Maintenance Rule program
- ISI and IST programs
- Performance monitoring programs
- Operator rounds
- Operations work control
- Plant maintenance information systems
- Major plant systems and components
- Maintenance supervisor and craft duties
- I&C test and maintenance duties
- Failure analysis and reporting

Outside members can include industry experts in predictive maintenance and maintenance process improvement. These individuals should bring knowledge of other successful PdM programs at other plants. They should not be unduly biased toward a unique approach to PdM. Outside participants often make excellent assessment facilitators because:

- They have participated in similar assessment in the past.
- They are trained and experienced at facilitation.
- They are viewed as independent and unbiased by management and the interviewees.
- Up to two outside assessors is ideal—one assessor on each review and interview team accompanied by at least one plant staff person on each team.

3.3 Scheduling Self-Assessment Activities

Experience has shown that the team assessment should be done within one contiguous week on-site. Ideally, the on-site assessment is preceded by 1) a training session of the assessment team and 2) a period of documentation review by each participant individually. Below are two representative schedules.

Schedule A, Table 3-3, is a preferred schedule if logistics and budget allow the assessment team to meet in advance of the assessment week. It is also preferred if the objectives of the review are so aggressive that an entire week on-site is considered necessary for data gathering and assessment.

Schedule B, Table 3-4, enables the entire involvement of the assessment team, except for the team leader, to be focused within a single week.

Table 3-3
Detailed Assessment Schedule A (Two Weeks)

Monday, Assessment Week Minus One

- Training of the assessment team (one half day)

Remainder of Assessment Week Minus One

- Review of plant and PdM program documentation
  (as needed by each individual, up to two full days)

Monday, Assessment Week

- Entrance meeting with plant management
- Mobilization meeting of assessment team
- Interview sessions
- Midday
- Interview sessions
- Team reviews activities of day
- Team modifies remainder of week, if necessary

Tuesday

- Mobilization meeting of assessment team
- Interview sessions
- Midday
- Interview sessions
- Team reviews activities of day
- Team modifies remainder of week, if necessary

Wednesday

- Mobilization meeting of assessment team
- Final document gathering, if needed
- Follow-up interviews, as necessary
- Midday
- Team compiles strengths, weaknesses, and observations by area
- Team modifies remainder of week, if necessary

Thursday

- Team evaluates plant relative to industry best practices
- Team scores plant in each of 14 areas
- Midday
- Team develops recommended cost-beneficial actions
- Team prioritizes recommended actions

Friday

- Results assembled for presentation to management
- Final presentation to management produced
- Midday
- Exit meeting and presentation with plant management
- Discussion of recommendations with management
- Discussion of action items with management
- Final assessment report completed
- Follow-up activities scheduled as needed

Table 3-4
Detailed Assessment Schedule B (One Week)

Monday, Assessment Week
- Training of the assessment team
- Midday
- Review of plant and PdM program documentation

Tuesday
- Entrance meeting with plant management
- Mobilization meeting of assessment team
- Interview sessions
- Midday
- Interview sessions

Wednesday
- Review and mobilization meeting of assessment team
- Interview sessions
- Midday
- Follow-up interviews, as necessary
- Team modifies remainder of week, if necessary

Thursday
- Team compiles strengths, weaknesses, and observations by area
- Team evaluates plant relative to industry best practices
- Midday
- Team scores plant in each of 14 areas
- Team develops recommended cost-beneficial actions

Friday
- Team prioritizes recommended actions
- Results assembled for presentation to management
- Draft presentation of results presented within the team
- Final presentation to management produced
- Midday
- Exit meeting and presentation with plant management
- Discussion of recommendations with management
- Discussion of action items with management
- Final assessment report completed
- Follow-up activities scheduled as needed

Interviews should be conducted with representative individuals holding a stake in the PdM process. Individuals selected will vary with the plant and existing program structure. Table 3-5 is provided as a guideline for selecting potential interviewees.

Table 3-5
Potential Interviewees for PdM Assessment

- Site Vice-President/Plant Manager
- Site Engineering Manager
- Operations Manager
- Maintenance Manager
- Work Control Manager
- PM Coordinator
- Manager of IST
- PdM Program Coordinator
    - – Infrared (IR) Thermography Lead
    - – Vibration Lead
    - – Oil Analysis Lead
    - – Electric Motor Lead
- System Engineers
- Component Engineers
- Performance Monitoring Engineers
- Maintenance Supervisors
- Maintenance Personnel

Interviews should be scheduled during the first two days of the assessment visit to ensure sufficient time is available to consider all input and to seek clarification or follow-up information, if necessary. Interviews should be conducted with as many of the personnel listed in Table 3-5 as can reasonably be accommodated by the assessment team. Sometimes small groups of workers or system engineers can be interviewed at once, but only if it will enhance, not stifle, their participation. Interviews should be assigned on the basis of subject area and assessment team member expertise. In the interest of efficiency, team members with similar backgrounds should interview plant personnel. However, interviews by individuals from cross-functional areas with different perspectives can be beneficial and should not be discounted.

3.4 Training of the Self-Assessment Team

Whichever schedule or variation thereof is used from Section 3.3, training of the assessment team is an important step. Until now, the team is a group of individuals selected for their individual expertise. The first objective of the training is to integrate the group into a team. Achieving this coherency requires that each person understand the objectives of the assessment that was carefully developed and communicated to management according to Section 3.1. These objectives define their mission.

It is important to provide background and perspective about PdM in the utility industry and the nuclear industry, pointing out the increased emphasis that is placed on condition monitoring by management, operations, maintenance, and regulators.

It is then necessary to provide an overview of the scope of the PdM assessment, illustrating that the formal PdM program at the plant represents only a portion of the equipment monitoring that will be investigated. Furthermore, the PdM data collection, evaluation, and reporting are only several of the elements that will be assessed. The other areas involve interface with the plant work process, organization and plant culture, communications, and information management. Team training is best accomplished by providing an overview of the 14 areas that will form the backbone of the assessment.

Next, a detailed review of the assessment steps is provided to the assessment team. It is important to review each of the following steps:

- Pre-assessment examination of plant information for reference and review
- Performing plant interviews
- Compilation of strengths, weaknesses, and observations by area
- Evaluation of plant relative to industry best practices
- Scoring of plant in each of the 14 areas and development of radar chart
- Evaluation of radar chart results
- Development of cost-beneficial recommended actions
- Prioritization of recommended actions
- Assembly of results for presentation to management
- Documentation of the final assessment report

3.5 Reviewing Industry Best Practices

Preparation for the assessment exercise on-site requires that each team member become familiar with the constituent elements of each of the 14 assessment areas. In addition, each team member should become familiar with what constitutes best practice in each area. The following discussion of each of the 14 areas is provided as background material for this process of familiarization.

Figure 3-1 represents the 14 assessment areas as radial lines on a radar screen. 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.) 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. Sections 4 and 5 of this report will discuss the process for scoring and evaluating the results of the scored radar chart.

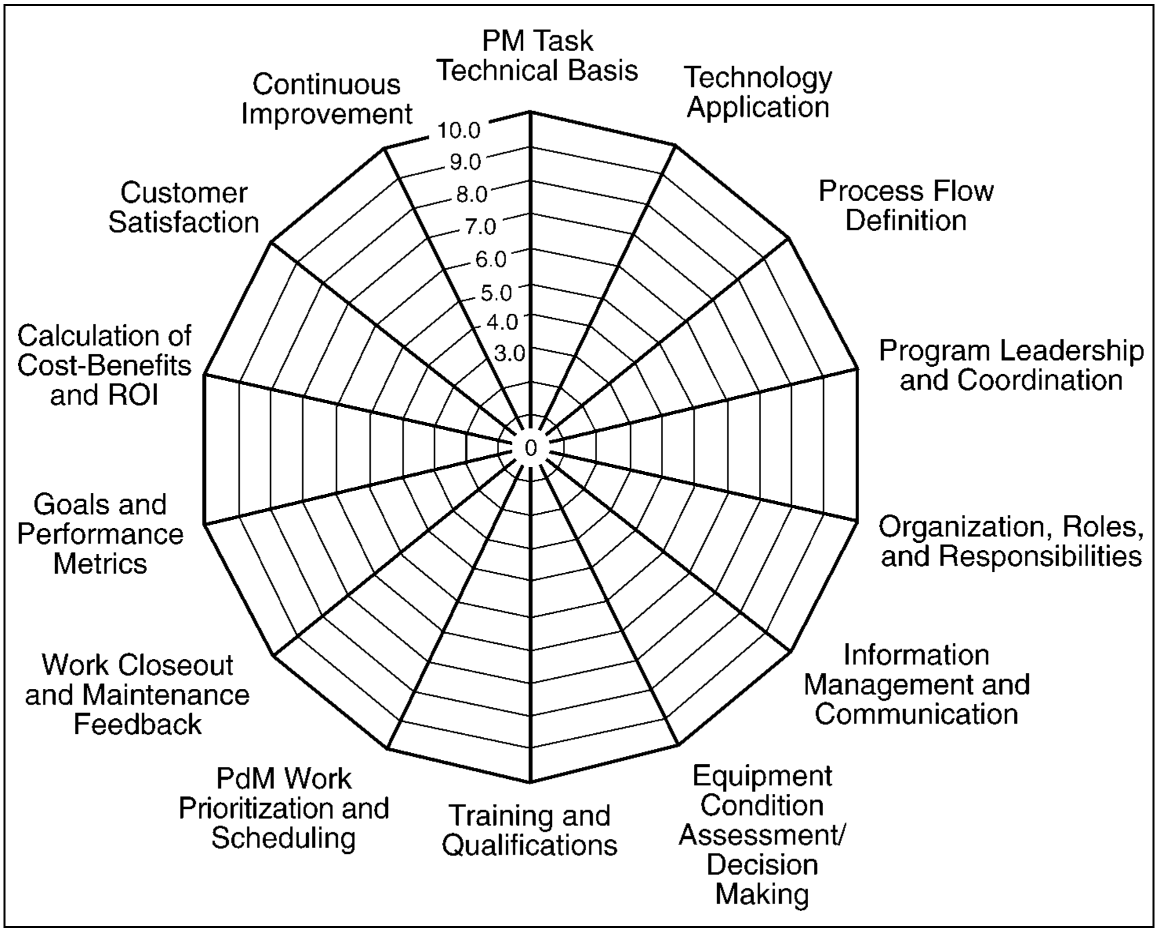

Figure 3-1
Blank Radar Chart

Area 1: PM Task Technical Basis

Discussion:
Condition monitoring data collection tasks should be considered as a vital part of an integrated PM program for plant equipment. Such tasks are generally preferable to repetitive PM or surveillance tasks. This situation is true when the condition monitoring task is applicable and can cost-effectively prevent failures or predict the timing of necessary refurbishment. Also, when the

surveillance requires operation or intrusive activity on equipment. As such, they should have scope and intervals determined to be appropriate considering the functional criticality, service environment, and duty cycle of the equipment. The determination of applicability and frequency of equipment condition-indicating technologies should be in accordance with industry PM technical basis guidelines. Certainly, the PdM tasks should not be done in addition to other tasks that protect against the same degradation mechanisms. PdM tasks should be optimized and justified together with other PM and monitoring for the same equipment. The process should be documented.

Best Practice:
Formal processes and documentation are in place to verify that the appropriate PdM tasks are being performed on the right equipment, at the right intervals, without being redundant to other tasks. These processes employ industry PM basis information from sources such as EPRI TR-106857, *Preventive Maintenance Basis*, and as-found information from plant maintenance activities. Appropriateness of PM tasks is evaluated as part of the analysis of maintenance preventable failures.

Interview Questions:

1. Are personnel comfortable extending intrusive PM task intervals based upon condition monitoring activities?
2. Do deferrals receive the correct approval?
3. Are the scope and frequency of PdM tasks documented in the PM technical basis?
4. Does the basis consider criticality, duty cycle, and operating environment?
5. Is a continuous or periodic process in place for updating the maintenance basis with learning from condition monitoring?
6. Is a process in place to use condition data to extend intervals of intrusive PM tasks?
7. Are PdM task frequencies based upon providing early detection of equipment degradation?
8. Is PdM considered an effective corrective action for Maintenance Rule failures or (a) (1) goal setting for the Maintenance Rule?
9. Is there a documented technical basis that describes the failure modes and degradation mechanisms addressed by the PM tasks?

Area 2: Technology Application

Discussion:
The PdM technologies are at the heart of the PdM process. Standard technologies should be in widespread use and competently applied. Hardware should be state of the art and in good condition. Procedures and guidelines should exist. Mechanisms should be in place to identify and evaluate new technologies for application to the PdM program.

Best Practice:
Oil and Grease Analysis

- Condition data from oil analysis can be used to monitor not only the quality of the lubricating oil but to make judgments regarding the condition of equipment. New oil reference samples are used for comparison and alert/alarm level determination and adjustment.
- Lubricating oil is changed only when analysis shows degradation of lubricant properties or accumulated wear particles (normal wear).
- Oil analysis sample taps are utilized to increase program consistency, repeatability of samples, and lower labor costs.
- Sample locations are selected based on system design.
- Analysis results from labs are transmitted to the customer in 24–48 hours. The results are electronically mailed to the site with trending data through the use of common software supplied by the laboratory.
- The analysis testing package is tailored to the type of equipment being monitored, including items such as large particle analysis, where applicable.
- Oil filtering equipment is used, where applicable, to further increase oil change intervals.
- The manufacturer nominally ± 10% determines viscosity limits.
- Baseline comparison levels are determined by new oil sample analysis.
- Large particle wear analysis is used to monitor equipment condition.
- Alarm and alert levels are established using ISO and ANSI standards as a basis.

Vibration Monitoring

- Vibration data are trended for subtle anomalies and integrated with other condition-based information.
- Periodic reports are prepared for all equipment monitored by the program.
- Initially, all reports are routed to a PdM coordinator. Problem condition reports are routed to the equipment owner (system/component engineer) and to the PdM coordinator.
- The PdM vibration technology owner is responsible for coordinating data, assigning problem severity, initiating action, coordinating post maintenance follow-up testing, documentation distribution, and case closure.
- Coordination of vibration monitoring data and lube oil analysis data is important. One technology serves as an important backup to the other. With careful coordination, significant increases in value will result.
- Alarm and alert levels are established using ISO and ANSI standards as a basis.
- Equipment history is used to tighten alarm and alert levels to achieve optimum equipment performance and life.
- Vibration data are integrated with other condition data to assess equipment condition.

- Vibration baseline values are established in post-maintenance tests.
- Post-maintenance baseline values are taken for major components.

Infrared Thermography

- Pre-survey meetings are held with equipment owners and operations to ensure information exchange about subtle equipment anomalies.
- Post-survey meetings are held with equipment owners and operations to ensure that information about each survey is conveyed in a timely manner.
- A database program is used to maintain route lists of equipment to be inspected, maintain baseline images, and generate reports.
- Inspection reports are prepared after each survey and conveyed to the appropriate groups.
- Follow-up actions are taken with maintenance to gather information regarding the as-found condition of equipment that was identified in the report as exhibiting thermal anomalies.

Electric Motor Predictive Maintenance (EMPM)

- Periodic electrical tests are performed on all critical motors, in addition to routine vibration, lube oil, thermography surveys, and insulation resistance testing.
- EMPM data are gathered and integrated. Data should include off-line meggers and high pot testing. Parameters recommended for trending include motor starts/stops (if available), amps, winding temperatures (if available), and run time hours. Periodic diagnostics applied during equipment operation include:
  - Motor current
  - Vibration
  - Thermography
  - Oil analysis
- Motor maintenance traceability is maintained both in-house and at vendor facilities.
- EMPM reports are prepared on a periodic basis.

Ultrasonic and Acoustic Leak Detection

- Ultrasonic and acoustic leak detection technology owners should perform surveys on critical plant valving, compressed air and gas systems, and other applicable equipment.
- Survey routes are established and performed with input from the plant PdM coordinator, engineering, and maintenance personnel.
- Acoustic leak detection data are integrated with infrared thermography and other PdM data.
- Reports are prepared after each survey and distributed to the appropriate work groups.

Interview Questions:

1. Are equipment owners knowledgeable of PdM technology applications, and do they have reference materials for baseline-prescribed tasks?

2. Is condition data history stored and trended on important equipment?

3. Are baseline data available for comparison?

4. Is analysis of new data timely and comprehensive—including complementary technologies?

5. Does a controlled maintenance basis maintain updates, changes, and applications of condition monitoring tasks?

6. Are alert and alarm conditions established for important equipment—are ISO or ANSI standards referenced or utilized?

7. Are alert levels tightened based upon data history?

8. Are equipment data collection points marked/specified for consistency, repeatability, and ease of collection?

9. Is data collection equipment tested/calibrated on a periodic basis?

10. Are data from operator rounds included as condition data and part of the process?

Area 3: Process Flow Definition

Discussion:
The PdM process includes not only the PdM group, but also its interfaces with engineering, maintenance, operations, and work planning and control groups. These interfaces are equally important to the effectiveness of PdM as the technologies themselves. The process should be well defined and well understood by those performing the work. In addition, the processes should be documented and supported by procedures and guidelines.

Best Practice:
Procedures, guidelines, and flow charts depicting key activities, information flows, and roles of plant personnel in the PdM process are available. Further, the process is well-understood and internalized by program participants. Charts serve as shorthand for how the plant PdM process operates.

Interview Questions:

1. Is a program/process manual that describes goals, roles, responsibilities, and process flow available and understood by those participating in the process?

2. Are guidelines or procedures for technology applications utilized? Are topics such as equipment operating instructions, data storage and reporting processes, alarm and alert levels detailed?

3. Is a process flow chart available that summarizes the process or shows the flow of information and decision making? Does the flow depict actual conditions and do participants understand it?

4. Are program scope limitations and boundaries defined?

Area 4: Program Leadership and Coordination

Discussion:
PdM is generally not regulatory driven. Therefore, it must be management driven. Both enhanced implementations of PdM technologies and enhanced utilization of the results by other plant organizations will not occur if the plant staff does not perceive that PdM has a high importance to plant management. Also, reliance on PdM for decision making is perceived as higher risk. This perception of high risk, without an incentive to assume that risk, results in a staff unmotivated to advance the use of PdM.

Best Practice:
The maintenance strategy is well-understood and can be articulated by management. Symbolic acts are planned and orchestrated by management in order to model and legitimize desired behaviors and to accelerate new programs in their development. There is a PdM supervisor or coordinator who promotes the use and integration of PdM.

Interview Questions:

1. Is station management knowledgeable and supportive of the role of the PdM process?
2. Does an entity—PdM coordinator, work group, department, or supervisor—have ownership of the PdM process to ensure continued growth and development?
3. Is there a process and/or person responsible for coordinating action on early indications of equipment trouble?
4. Are adequate resources (training and equipment) provided to personnel both for technology applications and plant processes to work?

Area 5: Organization, Roles, and Responsibilities

Discussion:
PdM programs reside in various organizations at different plants. They can be part of system engineering, support engineering, maintenance, or maintenance engineering. Different technologies can be within different groups, even when these technologies must be integrated for complete condition assessment of a single piece of equipment. There can be a PdM coordinator over several technologies or the technology experts can have no formal coordination. Data collection can be performed by various operations personnel, by a small group of dedicated technicians, or by the technology engineers. Finally, the equipment owners can be responsible for analysis of PdM data and action determination or the primary responsibility for analysis can lie with the PdM technology owner. Each of these and other decisions about organization and responsibility can influence the effectiveness of PdM. Roles and accountabilities in the execution of the PdM process should be well-defined and clear of any ambiguity. Individuals should be aware of and should support these roles. Evidence should exist that responsibilities are being carried out as defined. There should be real accountability for these responsibilities.

Best Practice:
The quality and consistency of PdM data collection are assured by the training and assignment of conscientious technicians. Responsibilities of the PdM technology engineers do not preclude having adequate time for quality and timely analyses. The PdM engineers are confident that the PdM analyses are properly considered in corrective action decisions. Plant equipment owners are identified and sponsored by the respective management to own and sponsor maintenance decisions. An optimum level of coordination between PdM and condition monitoring activities is taking place, preferably by a PdM coordinator.

Interview Questions:

1. Is there a document that succinctly defines roles and responsibilities of personnel?
2. Are roles and responsibilities clearly understood?
3. Are roles, behaviors, and general expectations for equipment and technology owners established, monitored, and corrected?
4. Are equipment owners and technology owners clear about the responsibilities they have?
5. Does the PdM function report appropriately in the organization? Is it given attention and access to management support and collaboration with groups having complementary responsibilities?
6. Are individuals held accountable for poor results from lapses in responsibility?

Area 6: Information Management and Communication

Discussion:
The very heart of a PdM program is taking data on equipment condition, turning the data into new and useful information, and taking appropriate action on the new information. Figure 3-2 illustrates the process.

Gathering the data, performing analysis, integrating data from multiple technologies, and specifying action are new activities for many organizations. PM and PdM program coordinators, PdM technologists, system engineers, component engineers, maintenance planners, and Maintenance Rule personnel all need access to records of condition data and history of action taken. Processes must be put in place to make this task manageable for plant personnel. Information relating to the suitability of the equipment for continued operation should be effectively communicated to equipment owners and operating personnel. Also, varying levels of awareness of PdM program activities, goals, roles and responsibilities, and results should be effectively communicated to the appropriate plant and support personnel.

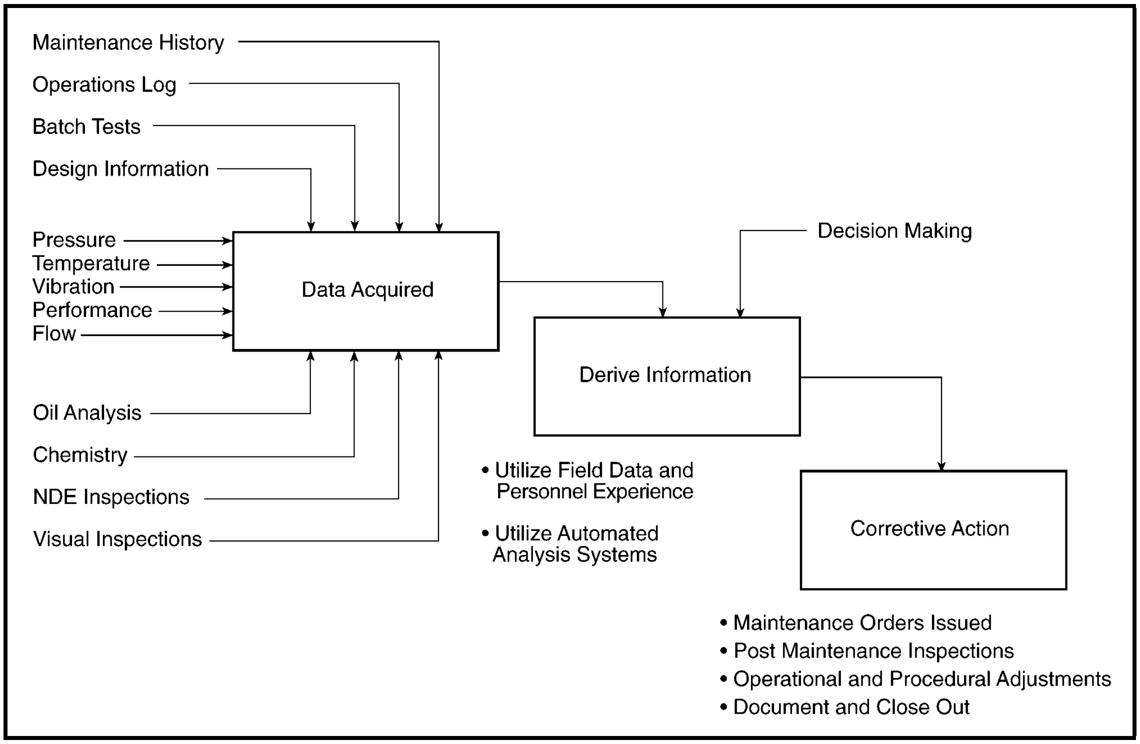

Figure 3-2
Information Flow for PdM Condition Monitoring

Best Practice:
Information integration tools are used to make data collection, monitoring, and analysis available on a broader basis for plant-wide decision making. The software has the capability to be updated by analysts, accept recommended actions, and is accessible to various users to provide an overall assessment of current condition of the critical plant equipment. Systems are capable of accepting common, one-time entry of information on costs, physical descriptions, and identifications that can be permanently stored in the database and easily retrieved for future reference. Actions are recorded and case histories maintained.

Interview Questions:

1. Are all parameters of condition monitoring listed or available for high priority equipment?

2. Is summary information of technology/process/parameter monitoring that reflects status of data evaluation available?

3. Is summary information, reporting equipment on the PdM watch list and actions in progress, available and reported to management?

4. Is action—as a result of equipment anomaly indications—assigned, coordinated, and tracked?

5. Is equipment condition data stored centrally and easily available to all personnel with need?

6. Is data integration from multiple technologies performed?

Area 7: Equipment Condition Assessment and Decision Making

Discussion:
This area assesses the effectiveness of condition monitoring, which includes the collection of PdM data, analysis of that data, integration of data from multiple technologies, and presentation of the data in an appropriate report or format for use by end-users. Condition monitoring data should be trended and analyzed. Trained analysts should use analysis software where appropriate. There should be a process in place to generate and distribute equipment condition reports including a technology-integrated status of anomalies to equipment owners for review.

It should be clear who is making decisions to act based on indications of equipment condition. Such decisions should be made in a timely manner among personnel taking and analyzing data, owners of equipment, and personnel responsible for assigning, planning, and performing maintenance tasks. There should be a strong working relationship and trust among these personnel.

Best Practice:
Best practice plants have controls in place to consistently collect high quality data on schedule, for all relevant equipment, for all PdM technologies. Also, best practice plants create an equipment condition report with all condition indicators for each important piece of equipment. The report clearly identifies degraded conditions or adverse trends. The report is distributed to all work groups. The station corrective action program is used to document deficiencies discovered during PdM activities.

Equipment and technology owners function “as one” in the process of monitoring equipment condition. People in both roles rely heavily on the knowledge of the other and are clear about the responsibilities and accountabilities for each. A PdM Program Coordinator with regular reports, updates, and meeting processes facilitates interaction. All sources of condition data are utilized—not just vibration, oil analysis, and thermography. Decisions to take corrective action based on PdM data and analysis appropriately involve the equipment and technology owners.

Interview Questions:

1. Are PdM data collected on schedule and of a consistently high quality?
2. Is data collection frequency and consistency adequate to establish a baseline condition?
3. Are the data trended to detect undesirable degradation?
4. Are there appropriate alert and alarm levels?
5. Are data reviewed and analyzed in a timely manner?
6. Is condition monitoring data reported in an integrated report for all technologies by component?
7. Are anomalies and indications of degraded condition clearly presented?
8. Are operations personnel notified of degraded performance in a timely manner?

9. Is it clear who makes decisions about equipment from condition data and it is understood in the organization? Is there an "owner" of the equipment? Do they take responsibility?

10. Is all available information on a component available and utilized prior to decision making?

11. Are operations, maintenance, technical, and other involved groups consulted? Do they have input prior to maintenance decisions being made?

12. Are decisions made in a timely manner?

13. Is it clear who the owner(s) of PdM technologies are and whom you go to for action when needed?

14. Is it clear who is responsible for expert analysis of equipment condition data?

15. Are decisions timely?

16. Are decisions trusted?

Area 8: Training and Qualifications

Discussion:
The ultimate value of PdM technology applications relies on the quality of the data collected, the analysis of the data, and the interpretation of the analysis. Although there is a lack of industry-wide requirements for training and certification for each of these activities, an adequate level of training and demonstrated skill is necessary for success. Technologists should be experienced, well qualified, and properly trained to perform PdM process tasks. Other persons who use the technology and its results should have adequate understanding of PdM technologies and the meaning of the results that may be reported to them. Management should support certification of personnel in PdM technologies. Critical activities should require formal certification.

Best Practice:
The plant staff has received PdM program level-of-awareness training. Technology owners are certified to Level II or higher for their areas of responsibility. Equipment owners have had technology overview training on PdM technologies. PdM technicians are Level I certified in areas of technical responsibility.

Interview Questions:

1. Are personnel performing analysis of PdM data trained in the use of predictive technologies—Level I, II, or III certifications?

2. Are PdM personnel knowledgeable of plant equipment and failure mechanisms?

3. Are PdM data collection tasks standardized and simplified so that completion of tasks is not dependent on a limited number of personnel?

4. Are all end users of PdM generally aware of the process?

Area 9: PdM Work Prioritization and Scheduling

Discussion:
PdM data collection and analysis are most often not formally controlled by the maintenance work management system. However, they must be performed at the proper intervals and times to establish adequate baseline values and trends. The plant must be diligent to acquire data from equipment that is often inaccessible. Also, corrective actions resulting from PdM analyses must be scheduled and performed in a timely manner to prevent degraded performance or failure. The effective use of PdM data and analyses is first manifest by the timely and accurate identification of work and generation of a work order whenever a single PdM data point, a trend of a single parameter, or an integrated consideration of several condition parameters on a component justifies a corrective action. This assessment area examines whether this work identification has been successful at the plant. It also examines whether the formal work process assures continued success. It examines whether, independent of the formal process, there are impediments to this process caused by work culture, organizational inefficiencies, poor information systems, work loads, or other factors.

Best Practice:
PdM monitoring tasks are scheduled and performed on schedule. Schedules are not vulnerable to the availability or workload of a single individual. The work management process is effective at planning and scheduling PMs and CMs called for by the PdM program. There is a formal, timely, and effective process for work orders to be written based upon PdM data and analysis. Maintenance interfaces with PdM personnel or otherwise understands the PdM basis for a work order prior to work execution when necessary.

Interview Questions:

1. Are PdM tasks scheduled and executed on a regular and consistent basis?
2. Are PdM tasks scheduled with a due date and grace period?
3. Are PdM tasks outside of grace reprioritized and rescheduled with review and approved by equipment owners?
4. Are efficient data collection routes established to maximize productivity of data collectors?
5. Are post-maintenance testing/operability checks utilizing PdM technology routine and appropriate? Is a process in place to identify requirements for this?

Area 10: Work Closeout and Maintenance Feedback

Discussion:
Closeout of PM tasks, CM tasks, or other corrective actions, which result from the PdM process, is a necessary element of the PdM process. Timely and thorough closeout not only assures that the immediate action is correct, but also is used to improve the scope and frequency of the PdM activities and the threshold for corrective action. This information is also used for critical cost-benefit determinations. Closeout activities should include documenting as-found conditions and feedback of information to program, technology, and equipment owners. This area also considers

whether replaced parts are examined. In addition, it examines interface of the craft personnel with the PdM personnel and information.

Best Practice:
As-found information is recorded in a useful fashion by craft personnel and validated by maintenance supervision. Parts are saved and made available for examination after repairs. Technology owners, equipment owners, and PM program owners all review the as-found information for desirable PdM changes.

Interview Questions:

1. Are causal data from equipment failures fed back into the condition monitoring plan for equipment?

2. Are as-found conditions documented per procedure or work instructions?

3. Are craft/technician comments solicited at close out of work orders? Are comments reviewed and acted upon by equipment owners, PM, PdM, and Maintenance Rule coordinators?

4. Are unexpected indications of equipment degradation acted upon in a timely manner and tracked through resolution?

Area 11: Goals and Performance Metrics

Discussion:
All nuclear plants have extensive goals and metrics to indicate effectiveness of plant programs and processes and to measure progress toward desired improvements. These metrics do not always relate to the effectiveness and progress of the PdM program itself. Therefore, it is useful to have a clearly defined set of performance measures that specifically relate to the PdM process.

Best Practice:
PdM programs are judged with performance indicators that reflect performance and trends in:

- The following four important cost areas:
  – Equipment reliability and unit availability
  – Operations and maintenance costs
  – Capital expenditures
  – Thermal unit performance

- Maintenance task balances among unplanned CM tasks that are totally reactive, planned CM on run-to-failure equipment, repetitive PM tasks, and condition directed tasks that are planned CM or PM tasks initiated as a result of decisions from the PdM process. Planned CM is defined as situations where equipment has been predetermined as run-to-failure or condition monitoring has detected degradation of the equipment and allowed time for proper planning and optimum scheduling of the task.

- Return on investment for PdM activities.

- Effectiveness in implementing the PdM process.

Interview Questions:

1. Are there formal or informal goals and/or performance indicators associated with Predictive Maintenance? If so, what are they?

2. Do the goals and performance indicators relate to the operating performance of the plant? Guide the program? If so, how? Examples:
   - X power reductions from material condition
   - X unplanned equipment failures
   - X equipment condition “action reports”

3. Do the goals/PIs reflect continued development of the PdM process/program?

4. Are there data on how maintenance tasks are changing from reactive to planned?

5. Are there data on equipment reliability/availability?

6. Are overall/cumulative vibration levels tracked and trended?

7. Are the data periodically reviewed with appropriate members of plant staff?

Area 12: Calculation of Cost-Benefits and Return on Investment

Discussion:
Project experience demonstrates that initiating and maintaining a record of PdM program savings, cost avoidance, and calculating an ongoing return on investment is necessary for the following reasons:

- Making the costs and savings of the program public knowledge in the organization keeps plant personnel focused on the PdM activities that contribute value. It drives advancement and improvement of the program. As the program becomes successful in reducing costs and improving material condition, personnel react positively and seek to contribute more.
- When other priorities confront an organization, decisions are often made to reduce, limit, or suspend resources devoted to PdM activities in lieu of higher value activities. The view of PdM being an optional part of maintenance strategy without a clear payback to the plant is minimized over time as the financial benefits become widely known and understood.
- The plant is making an investment in the PdM program and management should expect to see the return to the business.

Also, the budget for PdM activities should be clearly identified and should reflect the actual and potential return on investment of the process.

Best Practice:
Return on investment is calculated, well publicized in the organization, and reviewed formally by plant management approximately annually. PdM costs are easily retrieved from plant information systems.

Interview Questions:

1. Are "avoided costs" tracked and publicized?
2. Are reduced periodicity or elimination of PM tasks captured and cost savings calculated? Is the information publicized?
3. Is the cost of the PdM process captured, annualized, and publicized through a return on investment calculation?
4. Are plant personnel aware of the return on investment (ROI) of the PdM program?
5. Are ROI data credible to plant management?
6. Are ROI data used by plant management to make decisions relating to PdM program funding?

Area 13: Customer Satisfaction

Discussion:
Generally, PdM is a service that supports various end-users including operations, maintenance, and system engineering among others. These end-users can be viewed as customers whose satisfaction is a measure of the effectiveness and future support of PdM services. In assessing customer satisfaction, it is necessary to determine if customer expectations are realistic, if the PdM staff understands them and if these expectations are being met.

Best Practice:
The PdM staff perceives operations, maintenance, and system engineering as customers and they strive to achieve satisfied customers. Both suppliers and customers understand the expectations, strive to achieve quality service, and value the relationship.

Interview Questions:

1. Does the PdM staff recognize operations, maintenance, and system engineers as customers?
2. Can customers state their expectations and are they realistic?
3. Does the PdM staff know the current level of customer satisfaction?
4. Do PdM staff and customers communicate opportunities to improve the PdM services?
5. Are there any serious shortcomings in the way the PdM services are provided to customers?

Area 14: Continuous Improvement

Discussion:
The PdM process is a dynamic area because predictive technology continues to evolve. As it evolves, it becomes more effective at preventing failures and managing the life-cycle cost of equipment. Therefore, continuous improvement is a necessary element of a successful program.

The PdM process should have feedback and assessment elements to ensure that it continually or periodically changes in response to plant experience, industry experience, and new technology. Changes in the process to reduce tasks or substitute for PM tasks, improve thermal performance, increase equipment reliability and availability, or present costly failures should be identified.

Best Practice:
The best PdM processes have several formal programs to assure continuous improvement. These include:

- Self-assessments and performance indicator reviews on a regular basis
- Feedback of plant and industry maintenance and failure experience
- Review of equipment failures to determine if a PdM task could have been used to detect failure
- Investigation of new technologies and new applications of technologies

Interview Questions:

1. Is there a periodic self-assessment process for PdM?
2. What are the mechanisms to feedback failure experience to PdM task improvements?
3. What are the mechanisms to feedback as-found conditions from PM and PdM tasks to consider PdM task improvements?
4. What are the mechanisms to identify recurring problems for root cause consideration?
5. How is new technology or new applications identified and evaluated?
6. Is operating experience from other plants used to evaluate PdM effectiveness?
7. Are cost-benefit and return on investment calculations used to identify PdM changes?
8. Is the use of the corrective action program an integral part of the PdM process?

3.6 Collecting and Reviewing Plant Information for Reference and Review

An appropriate level of document review is expected of the assessment team members prior to the beginning of interviews and in-depth examination of the program. Generally, the team assessment leader will assemble the information in advance of the assessment. Information that is to be reviewed in advance is transmitted in an appropriate medium to the assessors. Most of the information is made available at an accessible location on-site. Table 3-6 provides a checklist of information for review at this step of the assessment.

Table 3-6
Information for Reference and Pre-Assessment Review

Category 1: Design and Programmatic Information

- System descriptions
- PdM task descriptions
- PdM and diagnostic tasks and frequencies by component
- Procedures and guidelines for PdM technologies
- Procedures and guidelines for other testing and inspection programs
- Description of performance indicator programs
- List of operator rounds
- Description of system health monitoring, Maintenance Rule monitoring, thermal performance monitoring, or other monitoring not included above
- PM Basis documentation, run-to-failure equipment
- Procedures for on-line planning, scheduling, work management, and close-out
- Procedures for shutdown planning, scheduling, work management, and close-out
- Descriptions of condition and performance databases

Category 2: Performance and Condition Information

- Recent periodic PdM summary reports
- List of recent significant failures from various plant sources
- List of recent equipment in (a)(1)
- List of recent PdM saves and PdM initiated work orders
- Recent equipment in alert/alarm or on trouble lists due to condition
- Recent performance indicator reports
- ROI analyses of recent PdM saves or costs of misses

Category 3: Organizational Information

- Plant organization chart including all persons to be interviewed and all management to be briefed during the assessment week
- Work process flow diagrams that include any PdM monitoring or analysis functions
- PdM staff personnel listing with brief biographies

4
GUIDELINES FOR SELF-ASSESSMENT WEEK: CONDUCTING ASSESSMENT TEAM ACTIVITIES

Section 3 of this guideline discusses the activities to be conducted in advance of the intensive self-assessment team activities. Team training and review of reference materials is complete, whether performed during a previous week according to Schedule A (Table 3-3) or performed earlier in the assessment week according to Schedule B (Table 3-4). This section describes the activities during the self-assessment team's dedicated week on site. Section 3.2 addresses the recommended activities and agendas for these activities.

4.1 Plant News Release and Management Briefing

Unlike a self-assessment of a well-defined and limited program at the plant such as In-Service Inspection or Maintenance Rule, the self-assessment of the PdM process transcends the boundaries of numerous programs and functions at the plant. Therefore, the success of the intensive self-assessment week will require a high level of awareness and enthusiasm by plant management and interviewees throughout the plant. The tools used for achieving this awareness and enthusiasm are 1) a plant-wide news release and 2) a pre-assessment management briefing.

The news release can be through a company newsletter or Web page that receives wide distribution in advance of the assessment week. The announcement of the assessment should also be on the Web site or plant TV or posted prominently on bulletin boards throughout the plant during the self-assessment week.

An example announcement is offered below:

> "A Predictive Maintenance Self-Assessment Team will be working throughout the plant during the week of August 20. They will be interviewing personnel and collecting information to determine the effectiveness of and use of condition monitoring to prevent equipment failures and to improve reliability. The following plant personnel, corporate personnel, and consultants comprise the self-assessment team:
>
> (list of individuals and affiliations)
>
> Please offer whatever assistance is needed to this important effort. If you wish to comment to the team, please contact the team leader at (phone and e-mail address).
>
> Results and planned actions will be posted on this Web site soon after the work of this team is complete."

The assessment team should plan to attend a management briefing on the first morning of the self-assessment week. A regularly scheduled managers meeting is a good opportunity for this briefing or a short, special meeting can be convened. The briefing should include the objectives, the schedule, impacted plant personnel, an introduction of the self-assessment team, and a summary of the anticipated self-assessment products.

4.2 Primary Interviews

At the beginning of the intensive self-assessment week, the primary interview schedule (both individuals and times) should be set according to the guidance of Section 3 of this guideline.

Prior to the interviews, the team should strategize to get the most from the interviews. Reviewers ideally should form two core interview teams who will stay together throughout the self-assessment week. If the self-assessment team is large, one extra interview team may be justified. Teams should be constructed so that each team has the broadest coverage of the 14 PdM assessment areas as practical. The team should then divide up the interviews to make best use of their respective subject matter expertise and experience. It is sometimes wise to “borrow” an individual from another team for a particular interview, but in general it is best to communicate questions or concerns to be raised in the interviews of other teams without switching over. There will be ample time and opportunity to get everyone’s input during the debriefing and synthesis sessions to follow.

Several excellent references for techniques to effectively elicit information in interviews are available. These references include *Eliciting and Analyzing Expert Judgment – A Practical Guide*, NRC NUREG/CR-5424 and *Experience-based Interview Process for Power Plant Management*, EPRI TR-110089. Furthermore, some plant training programs for self-assessment include interview training. Therefore, this guideline will not attempt to offer comprehensive interview training but will describe several points specific to interviews for this purpose.

A well-prepared reviewer should not rely on a pre-determined, rigid set of interview questions. However, the interview questions in Section 3.5 of this report should be reviewed and can serve to kick-off the interview and to confirm that significant sub-areas were addressed.

First, the interview team should familiarize the interviewee with the PdM self-assessment objectives and the specific scope of information they hope to discuss during the interview. Team members should introduce themselves and summarize their areas of expertise. The team should identify a lead reviewer who will pose questions. The lead reviewer will continue the interaction until he or she is satisfied that the discussion of the question is exhausted. Other team members can then interject or seek clarification of points made, but they must stay on the lead reviewer’s track and must return control to the lead reviewer after their issue is addressed. A reviewer other than the lead should be responsible for keeping notes of the interview. Figure 4-1 is an effective form for recording interview information. The same form can be used for documenting the review of reference material for consistency, or for later synthesis sessions, with the interviewee block changed appropriately.

After the lead reviewer has completed his or her list of questions, other reviewers can pose questions for additional information. Again, the lead reviewer should maintain control of the interview. Finally, the interviewee should be asked to make any additional comments related to the PdM self-assessment scope and objectives. Often, the most useful information comes from these extemporaneous comments.

Interviewee	**Interviewers**
______________________ (name)	______________________ (lead)
______________________ (title)	______________________
______________________ (duties)	______________________
Date/time ________________	
Notes/Observations	**Significant strength (+), weakness (-) or neutral observation (0)?**

Figure 4-1
Example Interview Documentation Form

Immediately following the interview, the notes should be reviewed, clarified, and embellished by the team. Results that indicate a potential strength, weakness, or other significant observation in any of the 14 assessment areas should be identified and recorded, if possible, at this time. Again, there will be additional opportunity for any reviewer to add significant comments later in the assessment week.

4.3 Assessment Team Synthesis and Iteration

At the conclusion of each day the agenda calls for the self-assessment team to convene for debriefing and discussion. Each interview should be verbally summarized for the entire group. Each team member has the opportunity to question, comment, or suggest a potential observation, strength, or weakness. The keeper of the interview documentation should record significant results of the discussion. Throughout these discussions, other significant observations may evolve unrelated to a specific interview. Each reviewer should maintain his or her own list of such synthesis comments for later use on a form similar to Figure 4-1.

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

4.4 Secondary Interviews and Investigations

The secondary interviews and investigations should be focused to specifically address questions and issues that arise in debriefing sessions. Interviewees should be informed of this focussed intent. However, the person being questioned should still be invited to make any extemporaneous comment within the self-assessment scope, just as was done for primary interviews. All observations and potential strengths and weaknesses should be recorded on a separate interview form and reported at a subsequent debriefing session.

4.5 Assessment Team Synthesis and Closure

At the conclusion of the secondary interviews and investigations, the self-assessment team will convene a session for synthesis and closure.

As a first synthesis activity, the self-assessment leader guides the group to generate a list of strengths, weaknesses, and significant neutral observations in each of the 14 assessment areas. Consensus is sought on each proposed observation; otherwise, it is not selected. Strengths are designated with a “+,” weaknesses with a “-,” and neutral observations with a “0.” Table 4-1 is an example of a partial list from a self-assessment.

Table 4-1
Example of Strengths, Weaknesses, and Significant Observations

	Area 1: Calculation of Cost-Benefits and ROI
+	PdM group can recall equipment saves and PM extensions
-	Above not quantified and documented
-	Not shared plant-wide
-	PdM program costs not tabulated
	Area 2: Program Leadership and Coordination
+	Performance Monitoring group leader provides leadership
+	PdM personnel are aggressive in their role
+	Testing activities are performed routinely and dependably
-	Depth of backup personnel is lacking (reliance on a few individuals)
-	Regulatory driven programs are integrated into station process procedures, but not others
0	Communication between PdM group members could be improved
	Area 3: Process Flow Definition
+	Implementing procedures well developed (especially Lube Program)
-	No governing program document exists
-	Relationship of PdM with PCM, Maintenance Rule, System Health, and Sysmon not clearly defined
	Area 4: PM Task Technical Basis
+	PdM tasks are part of updating and refinement of Preventive Maintenance Basis
-	Have not evolved to the point of focusing on PM substitution
-	Deviations from PCM justified, but not documented
	Area 5: Goals and Performance Metrics
+	High level indicators (Capacity factor, Maintenance Rule, UCLF) are used
-	PdM goals not integrated to station and corporate goals
	Area 6: Organization, Roles and Responsibilities
+	Roles and responsibilities are clear (Vibes, Thermography, and Lubes)
+	Players are accountable
-	Work Analysts and Maintenance Workers interface with PdM on work packages
	Area 7: Training and Qualifications
+	Personnel highly experienced with high level of technical expertise
-	No training standard has been defined (NEIL Credits)
0	Refresher training should continue
	Area 8: Work Identification Prioritization, Scheduling, and Close Out
+	PdM activities are scheduled by technology owners
0	Vibes and Thermography are not in the maintenance management system
-	PdM tasks scheduling not visible (management controls, accounting, and history)
+	Action Reports are written by PdM personnel
0	Feedback process from craft to engineers is in its infancy
+	Failed parts saved when requested
+	Finding problems before equipment fails is excellent
-	Some PMT problems identified
	Area 9: Information Management and Communication
+	Quarterly PdM report developed
+	PdM issues are discussed at Plant Health Committee
-	Data not readily available to all potential users
-	Multiple databases contain PdM information
	Area 10: Technology Applications
+	Vibes, Thermography, and Lube Oil good
-	Motor testing technology not well developed
-	Mindset that PdM group is limited to Vibes, Thermography, and Lubes
-	No longwave camera available
-	Some equipment is not maintained and made available

(Areas 11, 12, 13, and 14 intentionally omitted from table)

The next synthesis activity is quantifying the self-assessment Radar Chart. Each area is given a score 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 a value near the 100th percentile. (Whole numbers from one to ten are used so as not to overemphasize the resolution of the estimate.) 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.

Figure 4-2 presents an example PdM Assessment Radar Chart for a hypothetical plant, which underwent a PdM Team Assessment.

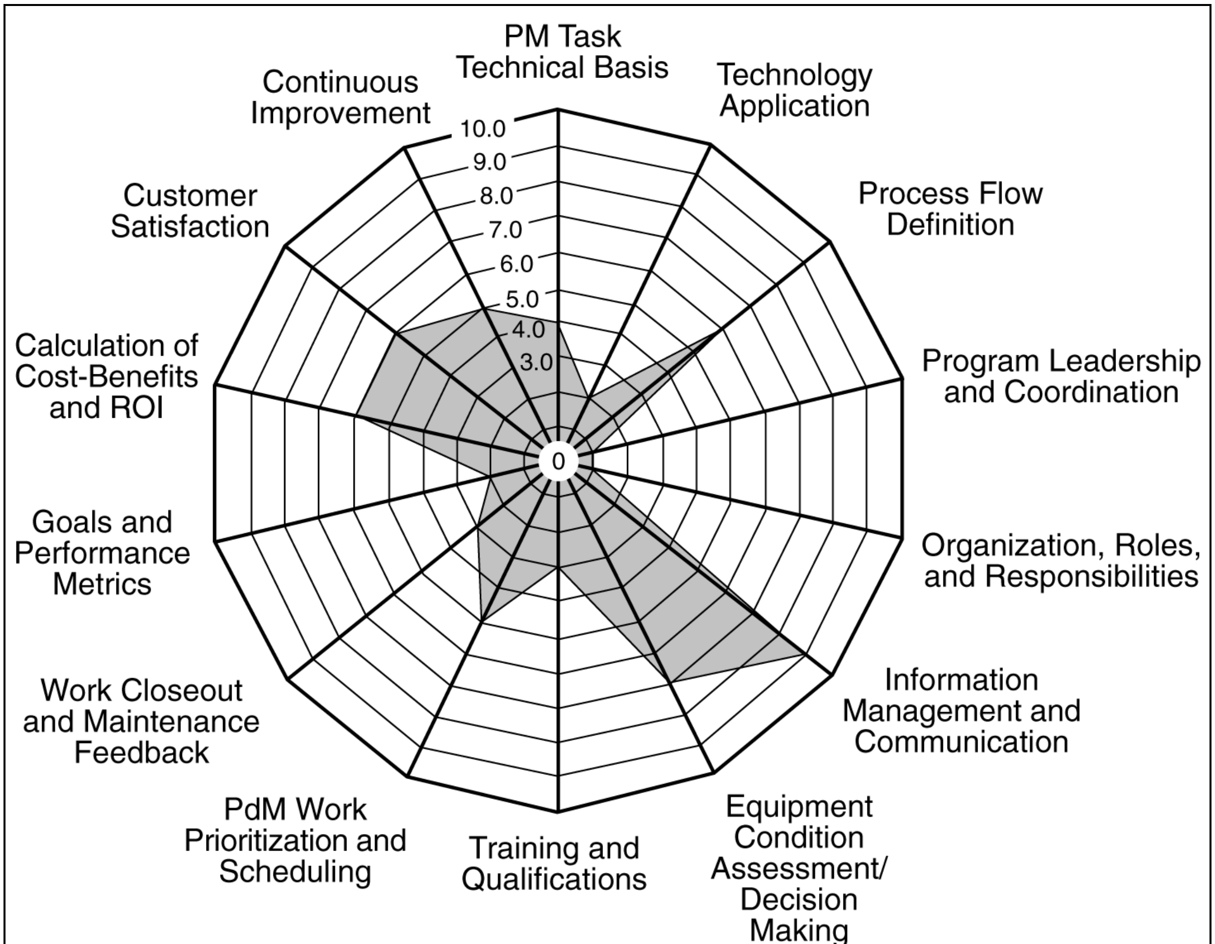

Figure 4-2
PdM Assessment Radar Chart After Quantification

Generally, it is most productive for the group to reach a consensus score on each area by considering the significant observations from the previous activity in each area. Each reviewer should reference the best practices from Section 3.5 and from his or her training during these discussions. Also, the worksheets in Appendix A, Quantification Worksheets for PdM Assessment Radar Charts, are useful.

Finally, the list of significant observations and the quantified radar chart are used to develop a list of potential enhancement actions that will address weaknesses or otherwise be cost-effective for the PdM process at the plant. When the list of new enhancement ideas is complete, the reviewers are asked to prioritize the candidate enhancements according to their perceived cost-benefit and timeliness. Enhancements should be prioritized in the order that the reviewer believes they should be undertaken. An effective means of prioritization is for each reviewer to distribute 10 voting points among the alternatives in any way he or she chooses with the following constraints:

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

The self-assessment team should attempt to identify specific recommended actions for the highest priority PdM enhancements identified. The best way to develop this list is with a brainstorming session of team members.

4.6 Documentating and Reporting of Self-Assessment Results

The self-assessment team report should be a valuable document of information for consideration of future actions. The report can be assembled almost completely from the products of the self-assessment activities developed previously in Section 3 and in this Section 4. The report sections should include:

1. Self-Assessment Team Members
2. Agenda
3. List of Interviewees and Other Contributors
4. Self-Assessment Objectives
5. Strengths, Weaknesses, and Other Significant Observations by Assessment Area
6. Quantification Results of the PdM Radar Chart
7. Identification and Prioritization of PdM Enhancements
8. Recommendations for Actions to Address Highest Priority PdM Enhancements

The self-assessment team should then present the results at a briefing to plant management and appropriate plant staff. The briefing should state the self-assessment objectives and should summarize items 6 through 8 in the documentation outline above. The briefing should ideally be done at the end of the assessment week, even though the final report may still be in process. The final report can incorporate comments and results of minor follow-up activities identified in the management briefing.

5
GUIDELINES FOR STAKEHOLDERS WORKSHOP

As explained in Section 2.4, the Stakeholders Workshop Approach is a method of PdM self-assessment that is most applicable whenever it is believed that all essential elements and procedures of the PdM process already exist; however, the elements and procedures are not working effectively together. The cause of the ineffective process may be organizational, cultural, managerial, the result of poor communications, or similar issues. Generally, this is the case if the plant has undergone a PdM optimization effort and is successfully involved in a continuous improvement process.

Instead of selecting an assessment team, a workshop facilitator is selected. This individual must be familiar with plant programs and must be competent to conduct the workshop according to the guidelines in this document. A plant staff member using an outside meeting facilitator may be the most cost-effective choice.

The facilitator works closely with management sponsors to establish clear workshop objectives, define the workshop agenda, and identify potential participants.

5.1 Establishing Clear Workshop Objectives

As with the team assessment approach, the first step is establishment of clear PdM enhancement objectives. The candidate objectives of Section 3.1 are all applicable here, and they are listed below in an appropriate format for this application.

Table 5-1
Potential Objectives for PdM Stakeholders Workshop Assessment

Infrastructure Improvement
- Support reengineering or reorganizational changes
- Accommodate staff turnover and loss of experience personnel
- Achieve consistency among sister plants or within a company
- Increase lead-time for work week and outage planning
- Identify new PdM technology for use at the plant
- Improve use of PdM for system and component health monitoring
- Increase PdM awareness (required)
- Gain stakeholders consensus for improvement (required)

Cost
- Reduce preventive maintenance costs
- Reduce overall maintenance costs
- Improve thermal performance
- Reduce scope addition to scheduled outages
- Eliminate unplanned outages due to equipment failure
- Optimize spare parts inventory
- Maximize return on PdM technologies

Reliability
- Prevent critical equipment failures
- Improve equipment performance
- Reduce number of unplanned load reductions
- Reduce number of unit trips
- Reduce vulnerability due to protection system testing
- Detect and prevent aging-related failures

Availability
- Reduce unavailability of equipment due to preventive maintenance
- Reduce unavailability of equipment due to failure
- Improve safety system performance indicators
- Maximize unit availability
- Shorten outage duration

Safety
- Prevent safety system challenges through failure prediction
- Reduce potential unplanned radiation exposure
- Better manage core damage and large release risk

For the Stakeholders Workshop Approach, however, at least one of the infrastructural objectives should be primary. Furthermore, objectives must include building awareness of program elements and procedures. Only when there is a common understanding can participants achieve the next required objective: consensus-building for enhanced effectiveness.

The workshop leader will establish these objectives prior to other workshop planning steps. These objectives will influence all subsequent planning steps including the selection of participants and the workshop agenda. Objectives will be presented early in the workshop and participants will have an opportunity to propose others.

5.2 Schedule of Workshop and Identifying Participants

Successful Stakeholders Workshop Assessments have been conducted in one or two days. The choice of one or two days is determined mainly by the availability of key participants. Two days would always be preferable for the purposes of achieving workshop objectives, but other practical constraints may override these objectives. The longer agenda results in more interactive sessions between the workshop facilitators and participants and, consequently, more consensus-building.

Successful workshops have been conducted with as few as 15 and as many as 60 participants. The advantage of the larger group is more extensive training, broader awareness, more extensive input to the workshop results, and more buy-in for the implementation of enhancements. The disadvantage of the larger group has only to do with handling such a large group during the interactive sessions. It is not recommended to break the participants into groups by conducting parallel workshops because the results of interactive sessions could result in inconsistent results or different prioritization, which is difficult to resolve. It would be better to select a cross-section of individuals from the larger group for the workshop and then present the results to the larger group in a training and briefing session.

Who is considered a stakeholder? Who should participate in the Stakeholders Workshop? The list in Table 5-2 includes the most likely participants.

Table 5-2
Potential Participants in PdM Stakeholders Workshop

- PdM supervisors
- PdM coordinators
- First-level managers over PdM engineers
- PdM technology owners, especially vibration, oil analysis, and thermography
- Owner of the PM program
- PM optimization engineers
- Key system engineers who rely on PdM for reliability of their systems
- Key component engineers who rely on PdM for reliability of their components
- Maintenance manager
- Plant performance engineers
- Reliability engineers
- Corporate maintenance personnel
- Operations or test supervisors responsible for collecting PdM and other condition data
- Contractors and consultants who support PM and PdM programs at the plant

Every plant organization differs, so the appropriate persons performing the above functions will result in a different mix of individuals at each plant. Also, managers overseeing any of the functions above but not specifically identified would be contributing participants.

If the workshop is jointly conducted for more than one plant, each plant should be equally represented. It is easy to see how the number of participants can increase dramatically when multiple plants participate in the workshop assessment. As stated above, the workshop approach can accommodate a large number of participants.

5.3 Defining Workshop Agenda

A generic agenda representative for a successful Stakeholders Workshop Assessment is included as Table 5-3. Each of the agenda sessions is discussed in detail in this section.

Table 5-3
Stakeholders Workshop Assessment Agenda

AGENDA
1. Introductions
2. Workshop Objectives
3. PdM Enhancement Goals
4. PdM Process Description
5. PdM Emerging Technology and Innovation
6. Quantitative Assessment Using PdM Radar Chart
7. Identification and Prioritization of PdM Enhancements
8. Impediments to Success of PdM Enhancements

5.4 Workshop Introductions and Objectives

Knowing the identity and responsibilities of each participant is very important in this workshop format because of the interactive nature of most sessions. It is important to distribute an attendance list in the form of a seating chart with useful job descriptions.

The workshop objectives have already been defined and incorporated into the agenda and the content of subsequent sessions. Therefore, this workshop session is a presentation of these objectives by the meeting facilitator. It is important to place these objectives in perspective in as many of the following contexts as apply:

- How do these objectives support higher-level plant objectives or corporate objectives?
- Are these objectives motivated by benchmarking at other plants or by successful efforts of other plants reported in the literature?
- Have measures of recent plant performance indicated the need for enhancements or recommitment to condition-based maintenance?
- Have recent inspections or audits motivated this self-assessment effort?
- Have organizational changes or management changes motivated this reassessment?

This session is also the perfect opportunity to summarize the status of PdM in the nuclear industry and the commitment of the plants under consideration relative to industry leaders and relative to the mean.

5.5 PdM Enhancement Goals

This session is the first interactive exercise of the workshop. The remainder of the workshop will be devoted to creating a prioritized list of specific PdM enhancements that are directed toward the objectives presented in the previous session. It is likely that participants already have ideas in mind for improving the effectiveness of PdM. It is important to acknowledge these ideas at the beginning of the workshop. Participants will be asked to list these ideas as goals linked to the specific stated objective for PdM improvement. An "Other" category should be included also to encourage ideas that have merit but are not directed toward the primary objectives of the workshop. Figure 5-1 is a worksheet that was successfully used at a Stakeholders Workshop Assessment. It should be customized for future use to specifically include the workshop objectives as discrete categories.

Identify what you think targeted goals for PdM Optimization should be for the following categories:

Objective	Targeted Goal
1. Reduce PM costs	____________________ ____________________
2. Prevent forced outages	____________________ ____________________
3. Detect aging-related degradation prior to failure	____________________ ____________________
4. Shorten outage duration	____________________ ____________________
5. Identify new cost-effective PdM technologies	____________________ ____________________
6. Support removal of systems from (a) (1) Maintenance Rule category	____________________ ____________________
7. Other	____________________ ____________________

Figure 5-1
Example Worksheet for PdM Enhancement Goals

After participants complete the individual worksheets, the goals should be discussed for the remaining time in the session. One successful approach is to conduct a round-robin with each individual stating the single goal that he or she believes is most important to accomplish. All of the goals should be collected for later use.

5.6 PdM Process Description

This session consists of an initial presentation by the facilitator followed by an interactive session involving all participants. The purpose of the session is to define the scope and elements of the PdM process at the plants under assessment. This session results in a common perspective for all participants who probably entered the workshop with varying views on the scope and content of PdM.

The first step is defining important maintenance terms including:

- Reliability-centered maintenance (RCM) analysis or other PM Basis method
- Corrective maintenance (CM)
- Preventive maintenance (PM)
- Equipment condition monitoring
- Predictive maintenance (PdM)
- Condition-based maintenance (CBM)
- Proactive maintenance (PAM)

Figure 5-2 presents various combinations of PM, PdM, CM, and PAM that represent the past, present, and potential future states for a hypothetical power plant. This figure should be modified to represent the plants under assessment and used to demonstrate the powerful potential for effective PdM.

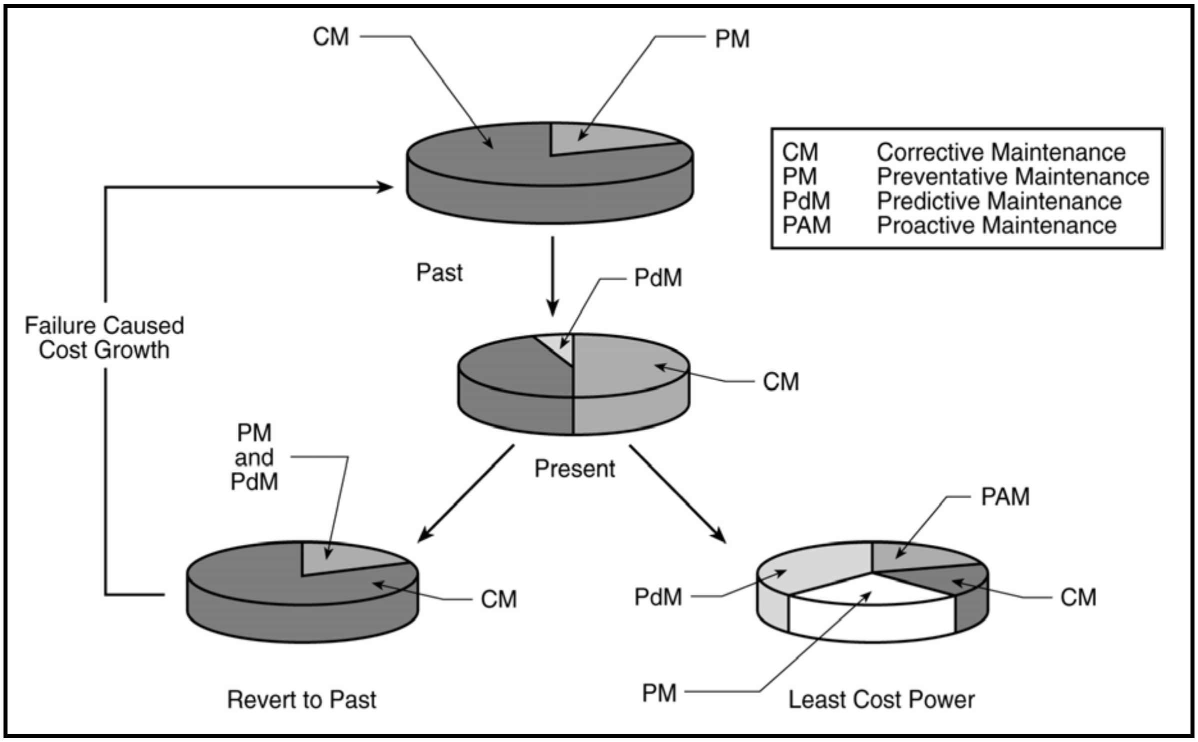

Figure 5-2
Role of PdM in Maintenance Optimization

The facilitator should next present one or more representations of successful maintenance processes at nuclear plants. A simple generic flow diagram that has been used successfully is included as Figure 5-3. A much more detailed and rigorous process diagram is included in the document INPO-913, *Equipment Reliability Process Description.* This document has limited distribution and use, and its diagram cannot be presented in this guideline. However, the document is available for use by INPO members, and the process flow diagram is strongly recommended for use in this workshop session.

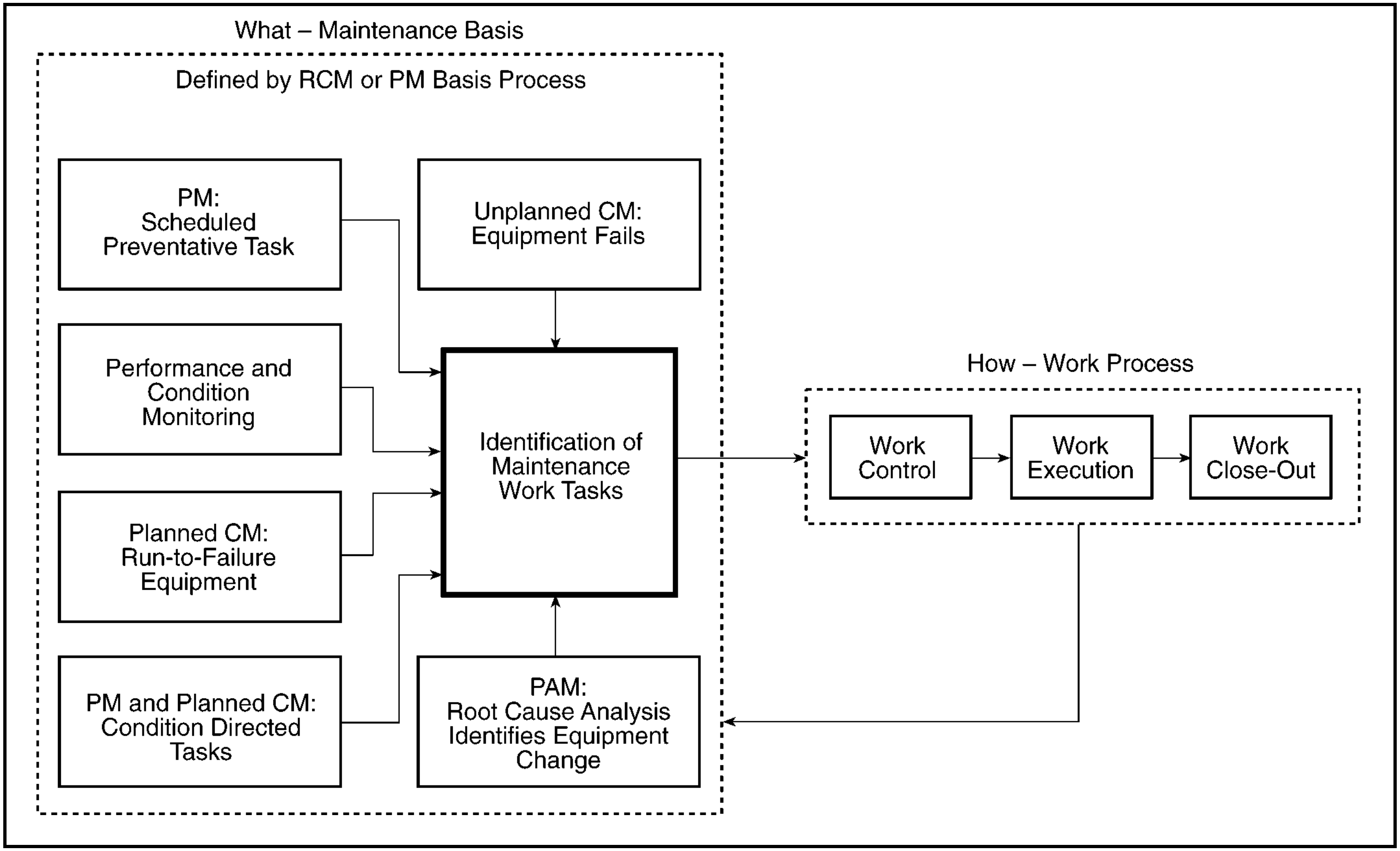

Figure 5-3
Schematic of Maintenance Process Including PdM

Following presentation of the maintenance process, the group should customize the process to the plants under assessment. Specifically, the diagram should include any specific PM Basis program or PM optimization program (such as reliability-centered maintenance) at the plant. PdM technologies in regular use for equipment condition monitoring should be delineated. Performance and condition parameters that are used with PdM to diagnose equipment problems or predict end-of-life should be identified. Corrective action programs including the Maintenance Rule (a)(1) process should also be identified. Finally, the interface of PdM with work planning, work control, work execution, and work closeout should be clearly identified.

The resulting maintenance process diagram will likely provide a valuable resource for the remainder of the workshop and possibly will provide a reference that exists no where else at the plant. At the least, the exercise of developing the process diagram will define the scope and elements of the maintenance process and the PdM process contained therein.

Time constraints may prevent the use of the interactive session on the PdM process. In such a case, the facilitator should present his or her best representation of the maintenance process at the plant. This presentation accomplishes the same objectives and provides the same reference for later use, however, the consensus that results from the interactive session will be less developed.

5.7 PdM Emerging Technology and Innovation

One reason for the strong interest in PdM enhancements at nuclear plants is the availability of new technology that can make PdM applications more timely, cost-effective, and accurate. These innovations include sensing and analysis technologies such as advanced IR thermography, rapid oil analysis, sensitive acoustical monitoring, and on-line dissolved gas analysis for transformers. These innovations also include data collection and information management methods. This session is designed to elicit from the participants their ideas on promising new technologies.

The session should include a survey of technologies that are not in use at the plants under assessment. These technologies have demonstrated use at other facilities, in other industries, or have successful pilot or demonstration applications.

Participants will be asked to list the most promising near-term innovative technologies for consideration at the plants. Figure 5-4 is a worksheet that was successfully used at a Stakeholders Workshop Assessment.

Identify emerging technology applications that you would like to have further investigated for potential application at your facility to enhance the effectiveness of condition monitoring.

Emerging Monitoring Technologies

____

____

Innovative Applications of Existing Technologies

____

____

Advanced Software and Information Systems

____

____

Other

____

____

Figure 5-4
Candidate Innovative PdM Solutions

After participants complete the individual worksheets, the goals should be discussed for the remaining time in the session.

5.8 Quantification of the PdM Assessment Radar Chart

The next session is the quantification of the PdM Assessment Radar Chart including the 14 assessment areas that are presented in Section 2 and discussed in detail in Section 3. The 14 assessment areas are quantified by the self-assessment team in the traditional self-assessment method detailed in Section 4. In the Stakeholders Workshop Approach, the Radar Chart is quantified by each workshop participant. These individual results are combined to yield a composite result for each plant. Furthermore, separate compilations for management, engineering staff, craft personnel, or other categories can be developed. In addition to the above quantitative scores for each element represented by a radius of the chart, the process produces a consensus measure for each value. The measure of consensus indicates whether there was high correlation of answers among participants (the value represents a consensus) or whether there was low correlation of answers among participants (the value represents an average of disparate views). This measure is useful for interpretation of the results.

The facilitator introduces the radar chart to the group and reviews the quantification process. The facilitator will introduce one element at a time. The participant will consider how effective the area is at his or her plant relative to industry best practices. The facilitator will list typical attributes of a best practice plant as well as attributes of a plant with poor effectiveness. Appendix A, Quantification Worksheets for PdM Assessment Radar Charts, presents a list of best practices for effective plants for each assessment area. This table is intended for use by the facilitator during the quantification exercise.

Each participant will assign a score 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 100^{th} percentile (whole numbers from one to ten are used so as not to overemphasize the resolution of the estimate). 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.

Figure 5-5 is a worksheet for quantification of the radar chart. Figure 3-1 presents a blank radar chart before quantification. Figure 4-2 presents a completed PdM Assessment Radar Chart for a plant that underwent a hypothetical PdM Assessment.

Write your scores down (a number between 0 and 10) for each of the Radar Chart categories.

1. PM Task Technical Basis ____________
2. Technology Applications ____________
3. Process Flow Definition ____________
4. Program Leadership and Coordination ____________
5. Organization, Roles, and Responsibilities ____________
6. Information Management and Communications ____________
7. Equipment Condition Assessment and Decision Making ____________
8. Training and Qualifications ____________
9. PdM Work Prioritization and Scheduling ____________
10. Work Closeout and Maintenance Feedback ____________
11. Goals and Performance Metrics ____________
12. Calculation of Cost-Benefits and Return on Investment ____________
13. Customer Satisfaction ____________
14. Continuous Improvement ____________

Name____

Location______________________________________

Function (Mgmt., Ops., Maint., Sta. Sup., Other)

Job Description ________________________________

Figure 5-5
Worksheet for Quantification of PdM Assessment Radar Chart

After each participant estimates his or her score in each area, the results are tallied separately for each plant. Each composite value is a simple average of all the individual values assigned by the participants. If any participant fails to assign a value to any area, that participant's ballot is simply ignored for that area. That participant is effectively assigned the average value of all other voters.

The consensus measure is calculated from the root-mean-squared deviation from the mean value for each composite value. This measure is developed for each composite value by calculating the absolute difference between each participant's assigned value (s_i) and the mean (s_{avg}). Each absolute difference is squared and the squares are summed. This sum is divided by the total number of assigned values (n). The square root of this number is used to get the consensus measure (C) as follows:

$$C = 10 - 2 \times \sqrt{\frac{\sum_{i=1}^{n} (s_i - s_{avg})^2}{n}}$$

Figure 5-6 presents an example of a completed Consensus Measure Radar Chart. Areas with high scores had consistent scores from individual participants. Areas with low scores had large disagreement on scores from individual participants.

The PdM assessment score results for each plant and the consensus measure results should be plotted on the radar chart and presented to the participants for discussion. The PdM Assessment Radar Chart is the starting point for the next two workshop sessions.

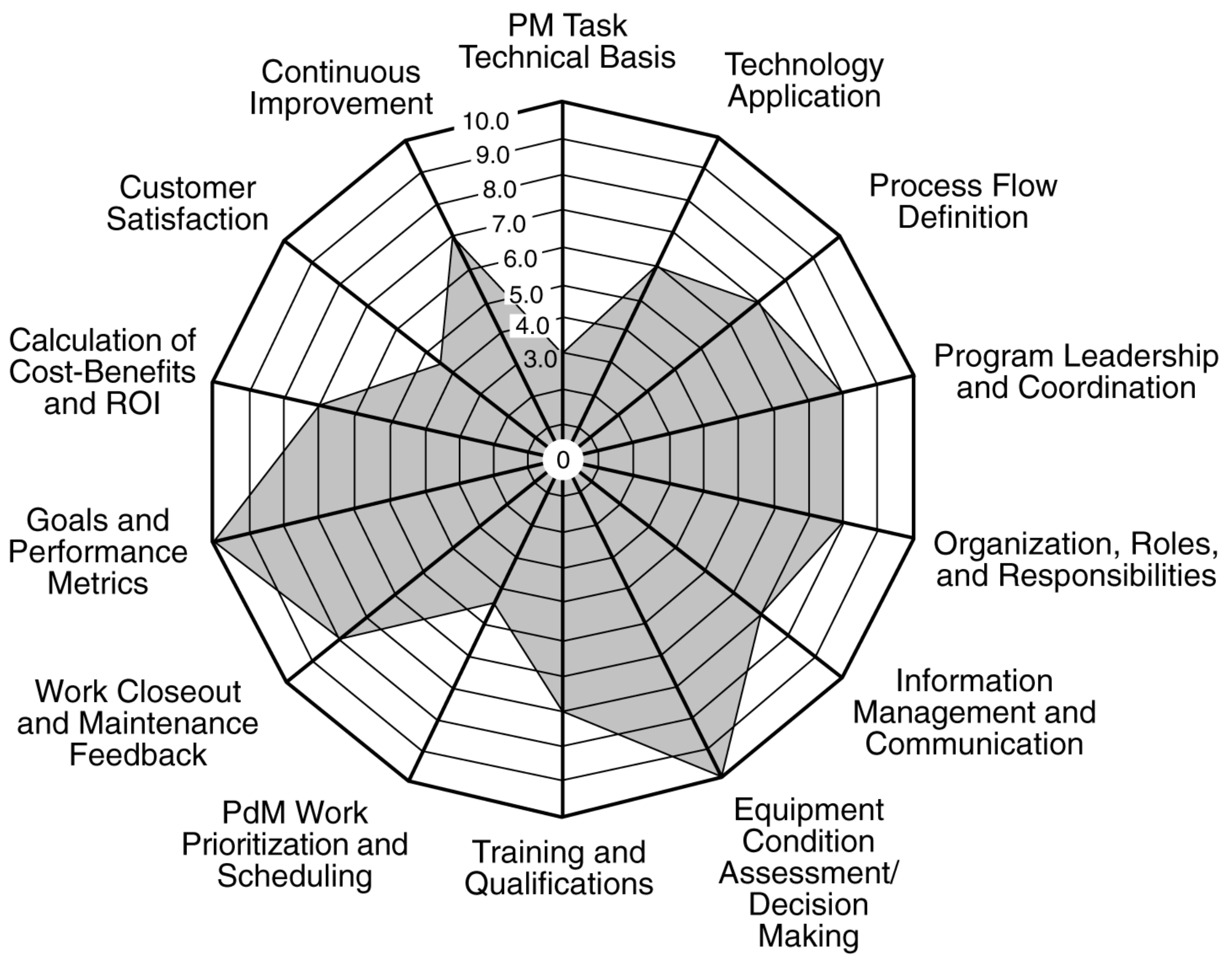

Figure 5-6
Consensus Measure Radar Chart After Quantification

5.9 Identification and Prioritization of PdM Enhancements

The next session of the Stakeholders Workshop Assessment solicits recommendations for PdM enhancements from the participants. Recommendations should be justified in light of the PdM program enhancement objectives and the radar charts developed in previous sessions. Participants should also review their goals and innovative new technology recommendations developed earlier to generate candidate enhancements.

A successful way to generate the list has been to open the floor to a free-format brainstorming session, recording unique recommendations on flip charts or projected electronic lists. The facilitators should probe the originator for justification, and the recommendation should make the list if it appears to have some support by the other participants.

When new enhancement ideas seem to be exhausted, the participants are asked to prioritize the candidate enhancements according to their perceived cost-benefit and timeliness. Enhancements should be prioritized in the order that the participant believes the efforts should be undertaken. An effective means of prioritization is for each participant to distribute 10 voting points among the alternatives in any way he or she chooses with the following constraints:

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

If the group is not too large, it is often useful to have participants mark their votes next to the recommendations as they are posted or projected on the wall. This process enables participants to interact with their peers and to adjust their votes dynamically. The total points for each recommendation are then tallied, and the recommendations are presented in rank order. It is also useful to select a group of highest priority recommendations. Whether the cutoff occurs after 5, 7, or 10 recommendations depends on the distribution of votes. Typically, there is a clear break in the ranking between issues that are well supported and those that receive few votes. Recommendations above this point are conveniently selected as the high priority group.

5.10 Impediments to Success of PdM Enhancements

Previous sessions in the Stakeholders Workshop Assessment have produced valuable awareness, consensus, and tangible assessments and recommendations for PdM enhancements. This session is designed to identify the impediments to successful implementation of the high priority PdM enhancements that resulted from the previous session.

As was suggested for an earlier session, a successful method of soliciting these potential impediments is through a round-robin of all participants, asking each person to offer the single impediment of highest concern. Usually, the principal themes of concern are identified early in the exercise and are merely reinforced as the round-robin continues.

Although similar identified impediments can be combined, all concerns should be listed and no effort should be made to prioritize them.

5.11 Documentation of Workshop Results

The Stakeholders Workshop Assessment report should be a valuable compendium of information for consideration of future actions. The report can be assembled almost completely from the products of the workshop developed in this section of the guidelines. The report sections should include:

1. Workshop Participants
2. Workshop Agenda
3. Workshop Objectives
4. Maintenance Process Description and Role of PdM
5. Candidates for PdM Emerging Technology and Innovation
6. Quantitative Assessment of PdM Radar Chart
7. Identification and Prioritization of PdM Enhancements
8. Impediments to Success of PdM Enhancements

5.12 Commitment to Follow-Up Activities

The final activity of the Stakeholders Workshop Assessment is a commitment by the workshop sponsors to follow up with participants on actions that result from consideration of the workshop's report. This commitment is consistent with the assessment objectives to build awareness and consensus among all stakeholders in the PdM process at the plant.

A
QUANTIFICATION WORKSHEETS FOR PDM ASSESSMENT RADAR CHARTS

1. PM Task Technical Basis

10
High

- A comprehensive matrix of all components in the PdM program exists. All equipment condition indicators related to the PdM program (PdM technologies, process parameters, performance parameters, NDE, Operations logged data points) are identified on the matrix and agreed to by the system/component owner. The scope and intervals for all PdM tasks are documented and there is a technical basis. The technical basis considers the criticality and likelihood of important degradation mechanisms.

- A matrix of plant equipment, electric motor testing data (Motor Current Signature Analysis (MCSA), megger) and the “Big Three” (vibration, IR thermography, lube oil analysis) exists. Routes and frequencies for these technologies have a documented technical basis.

- A plant equipment list exists, identifying the components in the program. Detailed application lists and set routes and frequencies exist for each of the “Big Three” technologies applied.

- A list of equipment included in the program does not exist and set application routes are not followed.

Low
0

2. Technology Application

10
High

- Vibration, lube oil analysis, and IR thermography are applied with a high degree of proficiency. Other applicable condition monitoring technologies such as acoustics/ultrasonics, MCSA, valve diagnostics, and advanced electrical equipment fault detection diagnostics are applied. The technologies are applied to an appropriate plant equipment list. Personnel are skilled to Levels I, II, and III in accordance with industry recognized professional groups. Job performance criteria are well defined. A training/qualifications matrix exists. Qualifications mirror industry recognized professional groups (STLE, ASNT, Vibration Institute, EPRI). Technology application reports are standardized.

- Vibration, lube oil analysis, and IR thermography are applied to a comprehensive plant equipment list with some degree of proficiency. Personnel are skilled to Levels I and II in accordance with industry recognized professional groups (STLE, ASNT, Vibration Institute, EPRI). Job performance criteria are well defined. A Training/Qualifications matrix exists. Qualifications mirror industry recognized professional groups (STLE, ASNT, Vibration Institute, EPRI) Technology application reports are generated.

- Vibration, lube oil analysis, and IR thermography are applied to some plant equipment with some degree of proficiency. Personnel are skilled to Level I in accordance with industry recognized professional groups (STLE, ASNT, Vibration Institute, EPRI)

- Very little application of state-of-the-art condition monitoring technologies. Technology application procedures, guidelines, or personnel qualifications do not exist. Personnel are expected to learn on the job.

Low
0

3. Process Flow Definition

10
High

- A formal detailed PdM process exists. The process is documented, displayed, and practiced. This process identifies each step from data collection, analysis, and integration to information and initiating corrective action. The process is well understood and followed by the groups on a consistent basis. This process is integral to the overall plant maintenance work process.

- A formal detailed PdM process exists. The process is documented, displayed, and practiced. This process identifies each step from data collection, analysis, and integration to information and initiating corrective action. The process is generally followed by the group and beginning to become part of the maintenance work process on a consistent basis.

- A basic PdM process is generally followed by the group only when significant equipment problems are detected.

- A PdM process is not in place nor are any parts of the process documented.

Low
0

4. Program Leadership and Coordination

10
High

- PdM supervisor assigned full time at the plant and positioned appropriately in the organization to easily accomplish communication of equipment condition data to all other plant work groups (Operations, Maintenance, and Technical). Management support of PdM is solid and visible.

- PdM supervisor dedicated but also has other non-reactive maintenance work activities (PM or PAM activities). Management support is present.

- No PdM supervisor position exists. Individual subject experts coordinate various PdM technologies. Management support is not evident.

Low
0

Note: A PdM supervisor or coordinator is responsible for the overall integrated program and has a primary deliverable of equipment condition status reporting (not a technologist).

5. Organization, Roles, and Responsibilities

10
High

- A PdM group exists with a PdM supervisor. Technologists are directly assigned to accomplish PdM technology applications and equipment condition assessment. A PdM program roles and responsibility chart has been developed and approved by management. The chart identifies all roles for each plant work group or specific worker (Operations, Maintenance, Engineering, PdM group personnel, consultants, central support groups). Interface agreements exist as necessary between plant and support organizations (system engineers – PdM group interface agreements).

- A PdM group exists with a PdM supervisor. Technologists are directly assigned to accomplish PdM technology applications and equipment condition assessment. Some data is converted to information and action taken.

- Maintenance or Operations craft in various work groups are assigned to accomplish technology applications. No formal PdM program exists.

Low
0

6. Information Management and Communication

10
High

- All of the identified items below are well communicated to the recipients and no improvement is necessary or feasible.
- Good information systems and databases exist to facilitate this communication.

What	To Whom
PdM plan/Plan adjustments	Mgmt., PdM team, other plant groups
Data/Information/Recommended actions	Responsible working groups
Program metrics/Cost-benefits/Customer satisfaction	Mgmt., PdM team, other plant groups
As-found conditions	Maintenance/Operations working group
Program elements/Experiences	Central support/Sister plants
Roles and responsibilities	All involved
PdM process	PM/PAM process owners

- None of the identified items are communicated at all to the indicated recipients. Information systems and databases do not support the necessary communications.

Low
0

7. *Equipment Condition Assessment and Decision Making*

10
High

- Quality data is consistently collected for all PdM technologies. Baseline values are established for all equipment.
- An integrated component “Health” report based on all equipment indicators is generated and made available to all appropriate personnel. The report clearly identifies exceptions and contains specific recommendations based on input from all work groups (Operations, Maintenance, and Technical).
- Necessary maintenance and operations decisions are made using PdM information to cost-effectively prevent failures. Trained and qualified people are involved in the decisions, their roles are well defined, and they are aware and comfortable with their roles.
- Failures do not occur because a condition indication was missed and a corrective action was not initiated.

- Data collection is not consistent.
- Periodic reports are not generated. Data printouts from technology software are generated when an equipment problem is detected.
- Decisions regarding use of PdM information are not effectively made even when adequate information is available.

Low
0

8. Training and Qualifications

10
High

- A comprehensive PdM training program exists including hands-on and classroom technology application and PdM program training. Job performance criteria are well defined. A training/qualifications matrix exists. Qualifications mirror industry recognized professional groups (STLE, ASNT, Vibration Institute, EPRI). A mentoring program exists with on-the-job training provided by experienced personnel to new PdM recruits. Other plant groups are provided PdM level-of-awareness training as part of their continuing training program.

- Formal PdM technology classroom training is provided to all appropriate PdM team members and on-the-job training is provided by experienced personnel to new PdM recruits. Training is focused on PdM team only.

- PdM technology classroom training is generally provided upon request and on-the-job training is provided by the incumbent to new PdM personnel.

- PdM training program does not exist.

Low
0

9. PdM Work Prioritization and Scheduling

10
High

- Condition monitoring tasks are formally scheduled and worked in the work management system. PM or corrective tasks indicated by PdM monitoring are positively identified and prioritized to prevent failures and disruptions. PdM work is planned, scheduled, and integrated into the mainstream work management process. Closeout of work includes documentation of as-found conditions and feedback of information to program technology and equipment owners.

- Condition monitoring tasks are scheduled and worked by the PdM group. PdM tasks sometimes prevent failures and avoid emergent work situations, but some opportunities are lost. Feedback from work closeout is not thorough or formal.

- Condition monitoring tasks are performed sporadically. PdM activities rarely identify impending failures or avoid emergent work situations. There is little feedback from work closeout.

Low
0

10. Work Closeout and Maintenance Feedback

10
High

- Closeout of work includes documentation of as-found conditions and feedback of information to program technology and equipment owners.
- Replaced parts are saved and sent to technology and equipment owners for evaluation.

- Feedback from work closeout is not thorough or formal.

- There is little feedback from work closeout. Useful recording of as-found information is not consistently done.

Low
0

11. Goals and Performance Metrics

10
High

- Specific goals directly related to the implementation and application of PdM have been established and sponsored by senior management. Targets have been set for:
  – O&M Cost Reduction
  – System/Equipment Reliability/Availability
  – Capital Equipment Cost Reduction
  – Plant Thermal Performance
  – Safety

- Performance indicators directly related to the PdM program goals are tracked and reviewed by management periodically.

- Data Collection goals have been determined only. Some performance indicators are tracked and reviewed periodically.

- PdM activities are ongoing with no goals. Meaningful performance indicators do not exist.

Low
0

12. Calculation of Cost-Benefits and Return on Investment

10
High

- All Costs of implementation and sustaining the PdM program have been captured, used in a return on investment calculation, and are approved and budgeted as a line item in the annual plant budget (Personnel Labor, Condition Monitoring Tools, Training, Consumables, New Technology Applications). Planning and Estimating Guides exist. Return on investment and annual costs are reviewed. All occurrences resulting in equipment maintenance decisions based on the PdM process are tracked. A management approved cost-benefit analysis process is utilized and applied consistently to the appropriate occurrences.

- Mostly, events result in cost-benefit analyses.
- An annual budget for equipment and training exists.

- Costs of the program are not captured; equipment and training expenditures are evaluated on a one-by-one basis.
- Benefits from PdM occurrences are not captured. Evaluation of cost savings are not calculated or tracked.

Low
0

Note: An "Occurrence" is a maintenance (or operations) decision that results from the PdM program (that is, "Take the pump from service immediately to perform maintenance," or "Don't send a 4K v motor for a clean dip and bake.").

13. Customer Satisfaction

10
High

- Customers are clearly identified, for example Maintenance, System Engineers, and Operations. Customers' expectations are clearly identified and understood by the customer and the supplier (PdM team). All expectations are being met. No areas for improvement are achievable or feasible.

- PdM group is functioning well. Some customer expectations have been identified.

- PdM group is functioning well, but customer is unaware has no expectations.

Low
0

14. Continuous Improvement

10
High

- Budgets allow justifiable PdM enhancements.
- All of the identified programs/activities are ongoing and formalized through procedural guidelines:
  – Self-assessment, including assessment of performance indicators
  – Use of industry operational experience (OE)
  – PM program periodic evaluation to incorporate PdM experience
  – Application of emerging diagnostic technologies and/or PdM processes and practices (R&D)
  – PdM program component failure causes addressed

- None of the identified programs or activities exist. Budget constraints prohibit cost-effective changes in PdM.

Low
0

Target:
Nuclear Power

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