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Advanced Nuclear Technology: Equipment Reliability for New Nuclear Plant Projects—Industry Recommendations for Procurement

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EPRI Project Manager
L. Loflin

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ELECTRIC POWER RESEARCH INSTITUTE
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

THE FOLLOWING ORGANIZATION(S), UNDER CONTRACT TO EPRI, PREPARED THIS REPORT:

Electric Power Research Institute (EPRI)

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The following organization prepared this report:

Electric Power Research Institute (EPRI)
Nuclear Maintenance Applications Center (NMAC)
1300 West W.T. Harris Blvd.
Charlotte, NC 28262

Principal Investigators
K. Barry
L. Loflin
M. Pugh

This report describes research sponsored by EPRI.

This report was developed by the EPRI Advanced Nuclear Technology (ANT) Program and the members of the technical advisory group (TAG), who are as follows:

Kenneth Barry	EPRI
Steven Jay Bartman	DTE Energy
Scott M. Bond	AmerenUE
Greg Broadbent	Entergy Services, Inc.
Gary Childers	STP Nuclear Operating Company
Jin Chung	Mitsubishi Nuclear Energy System, Inc.
Bobby Dean	Duke Energy Corp.
Joseph DeMarco	Dominion Resources, Inc.
George Depta	GE Hitachi Nuclear Energy Americas, LLC
Frederick Eisenhuth	PPL Generation, LLC
Bryan David Griner	Southern Nuclear Operating Co.
Michael W. Kelly	AREVA NP, Inc. (USA)
John Maciejewski	Institute of Nuclear Power Operations (INPO)
Bob Mohr	Duke Energy Corp.
Terry A. Printz	Exelon Corporation
Craig Stover	South Carolina Electric & Gas Co.
Richard Louis Szoch	Constellation Energy
Thi Truong	Tennessee Valley Authority (TVA)
Neil Wilmshurst	EPRI

ANT and the TAG were supported in this effort by EPRI-internal reviewers of the EPRI Nuclear Plant Technology Group:

Rob Austin	Instrumentation and Control
Martin Bridges	NMAC
Lee Catalfomo	NMAC
Ray Chambers	Generation
Ken Huffman	Nuclear
Jerry Kernaghan	Plant Support Engineering (PSE)
Andrew Mantey	PSE
Jim McKee	NMAC
Charlie Mengers	PSE
Lee Rogers	NMAC
Marc Tannenbaum	PSE
Tom Turek	NMAC

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ABSTRACT

In many countries, the initial and continued good operating performance of the current build of new nuclear plants is critical to the rebirth of the nuclear option. Good initial and continued performance is vital to the companies making the large investments required for a new nuclear plant. One foundation of good performance is a sound process for establishing and sustaining plant equipment reliability (ER).

This report presents the results of industry efforts to capture and communicate ER lessons learned for the procurement phase of a new plant project. This document is a collection of good practices that provide the best thoughts of the industry; however, the contents of this report are not mandatory for any group. Companies with a new plant project might choose to emphasize or require the use of these recommendations.

Understanding the importance of ER to nuclear plant new construction, the Electric Power Research Institute (EPRI) Advanced Nuclear Technology Program advisors directed that a project be pursued to capture and communicate the ER lessons learned to date. These lessons reside not only in the current fleet of operating nuclear plants, but also in the good practices of the teams of professionals who are currently involved with new plant projects and in the experience of those who designed, built, and operate the current fleet of plants.

The industry professionals who assembled and commented on the contents of this report intend for it to be used by organizations involved with the procurement of systems, structures, and components for new nuclear plants. These include suppliers and subsuppliers of equipment, materials, and services.

It is expected that procurement organizations will consider each of these recommendations and consciously determine the extent to which they will be incorporated into current and future projects.

PRODUCT DESCRIPTION

This report captures and communicates equipment reliability (ER) lessons learned to date as they relate to nuclear plant procurement. It supersedes Electric Power Research Institute (EPRI) report 1018393. Companion reports are dedicated to design, construction, and startup testing.

Results and Findings

This report describes the results of industry efforts to capture and communicate lessons learned about ER for the procurement phase of a new plant project. This document is a collection of good practices that provide the best thoughts of the industry; however, the contents of this report are not mandatory for any group. Companies with a new plant project might choose to emphasize or require the use of these recommendations.

Challenges and Objectives

In many countries, the initial and continued good operating performance of the current build of new nuclear plants is critical to the rebirth of the nuclear option. Good initial and continued performance is vital to the companies making the large investments required for a new nuclear plant. One of the foundations of good performance is a sound process for establishing and sustaining plant ER.

Many decisions and tasks in a new plant project impact ER, which makes the organization of ER-related recommendations difficult. Therefore, in this report, topics are addressed according to the phases of the project in which they are encountered. Some cross-referencing between phases might be necessary to fully understand the topic.

Applications, Value, and Use

The industry professionals who assembled and commented on the contents of this report intend for it to be used by organizations involved with the procurement of systems, structures, and components for new nuclear plants. This includes suppliers and subsuppliers of equipment, materials, and services.

It is expected that procurement organizations will consider each of these recommendations and consciously determine the extent to which they will be incorporated into current and future projects.

EPRI Perspective

Understanding the importance of ER to nuclear plant new construction, EPRI's Advanced Nuclear Technology Program advisors directed that a project be pursued to capture and communicate the ER lessons learned to date. The lessons learned reside not only in the current fleet of operating nuclear plants, but also in the good practices of the teams of professionals involved with new plant projects and in the experience of those who designed, built, and operate the current fleet of plants.

Approach

The report assumes that procurement-related organizations have or will put in place the necessary procedures and instructions to achieve the safety, quality, and performance objectives of the projects. The recommendations and examples provided in this report are intended to bring focus to aspects of ER that can be included, strengthened, or expanded, as needed, within the current procedural structure of an organization. This report does not attempt to provide all of the details necessary to achieve the recommendations or to implement the cited lessons learned.

Keywords

Corrective action
Equipment reliability (ER)
Nuclear plant construction
Nuclear plant procurement
Nuclear plant startup

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OVERVIEW

1.1 Summary

The initial and continued good operating performance of the current build of new nuclear plants is critical to the rebirth of the nuclear option in many countries. Good initial and continued performance is vital to the companies making the large investments required for a new nuclear plant. One of the foundations of good performance is a sound process for establishing and sustaining plant equipment reliability (ER).

The Electric Power Research Institute (EPRI) Advanced Nuclear Technology (ANT) Program advisors, understanding the importance of ER to nuclear plant new construction, directed that a project be pursued to capture and communicate the ER lessons learned to date. The lessons learned reside with the current fleet of operating nuclear plants. They also reside in the good practices of the teams of professionals who are currently involved with new plant projects and in the experience of those who designed, built, and operate the current fleet of plants.

This report presents the results of the industry efforts to capture and communicate ER lessons learned for the procurement phase of a new plant project.

1.2 Intended Use

The industry professionals who assembled and commented on the contents of this report intend for it to be used by organizations involved with the procurement of structures, systems, and components for new nuclear plants. This includes suppliers and subsuppliers of equipment, materials, and services.

The report assumes that procurement-related organizations have in place or will put in place the necessary procedures and instructions to achieve the safety, quality, and performance objectives of the projects. The recommendations and examples in this report are intended to bring focus to aspects of ER that can be included, strengthened, or expanded, as needed, within the current procedural structure of an organization. This report does not attempt to provide all of the details necessary to achieve the recommendations nor to implement the lessons learned that are cited.

It is expected that procurement organizations will consider each of these recommendations and consciously determine the extent to which the recommendation will be imbedded in current and future projects. The use of these recommendations may be graded given the criticality or importance of a component to the plant.

This document is a collection of good practices and provides the best thoughts of the industry; however, the contents of this report are not mandatory for any group. Companies associated with a new plant project may choose to emphasize or require use of these recommendations.

1.3 Report Structure

Many decisions and tasks in a new plant project impact ER. This makes organization of the recommendations related to ER difficult. Therefore, topics are addressed in the phases of the project where they would be encountered. Some cross-referencing between phases may be necessary to fully understand a topic.

Just as this EPRI report is dedicated to procurement, other EPRI reports are dedicated to:

- Design (report 1021415)
- Storage, construction, and testing (report 1021413)

The design phase report contains:

- Component classification
- Component monitoring
- Preventive maintenance
- Long-term operability
- Corrective action

The procurement phase report (the current report) contains:

- ER component procurement
- Component monitoring procurement
- Vendor-related preventive maintenance
- Vendor corrective action

The storage, construction, and testing phase report contains:

- Storage of ER components
- Installation and construction maintenance of ER components
- Testing of ER components

1.4 Feedback on This Report

The project team understands that the users of this report will have comments and questions about the content of this report. Please send these to the contacts listed below. Your feedback is greatly appreciated.

Leonard Loflin	Ken Barry
704.595.2010	704.595.2040
leloflin@epri.com	kbarry@epri.com

2
USE OF COMPONENT CLASSIFICATIONS DURING PROCUREMENT

2.1 Scope

This section covers the use of component classifications in the procurement phase of a new plant project for the overall strengthening of the plant's equipment reliability (ER). This includes the following:

- Vendor pre-qualification, bidding, and selection processes
- Equipment design and fabrication
- Inspections, testing, and final documentation

2.2 Recommendations for the Use of Component Classifications in the Procurement Phase

2.2.1 General

- The increased level of procurement-related effort and attention to components classified as critical or important during the basic design phase should be noticeable.
- Effective communication about ER expectations between the design and procurement groups of the project and the selected vendors providing equipment and services related to ER is crucial.
- All critical and important components are not equal. A graded approach can be used in determining the appropriate level of attention needed by a component during the procurement phase.
- An example of a checklist for procurement-related ER requirements is included as Appendix 2.D of this section.
- The procuring group should treat every vendor of ER-related components as though it is not proficient in providing material and components for a nuclear plant. Each vendor should be assumed to not fully understand the requirements for the application of components in nuclear plants and the documentation requirements until their performance proves otherwise. This is a direct lesson learned from both the existing nuclear fleet and nuclear plants currently under construction.

- In some cases, the procuring organization might have to help the suppliers to achieve compliance. This could include:
  - Training on the concepts of ER in the nuclear industry
  - Communicating on ER requirements of the purchase
  - Training on documentation requirements
  - Editing programs
  - Mentoring manufacturing facility inspectors
  - Suggesting organizations with nuclear application experience with which prospective suppliers could partner or benchmark
- Several industry initiatives for improving the quality of procured items for the current fleet have been undertaken. The recommendations stemming from these initiatives are captured in the following EPRI reports:
  - 1015171, *Plant Support Engineering: Procured Item Quality Initiative Initial Findings*
  - 1016693, *Guidance for Managing the Impact of Procured Item Quality Issues on Generating Asset Economic Performance*
- In association with the Nuclear Energy Institute (NEI), the industry has developed a guideline that contains recommended practices for the procurement process:
  - NEI AP-908, *Materials and Services Process Description and Guideline*

2.2.2 Vendor Pre-Qualification, Bidding, and Selection Processes for ER-Related Components

- The bidding and selection process for components designated as critical and those designated as non-critical but important should be more demanding and exacting than that for other project procurements.
- Requests for proposal (RFPs) differ in structure and content. The following ER-related recommendations that address bid lists, specifications, and proposal evaluations should be incorporated where applicable in RFPs. Where they are incorporated is not as important as ensuring that they are incorporated.
  1. Provisions should be provided in procurement documents for supporting the equipment in the event that the original equipment manufacturer (OEM) decides to discontinue support for the product. This should include a complete set of design and manufacturing information held in escrow.
  2. Procurement deliverables should be requested in a format that can be easily migrated into the planned or existing asset management (information) systems for the plant.
  3. Procurement documents should contain requirements that the vendor notify the procuring group when changes are made to material or margins that could affect component performance or lifetime.

4. Procurement documents should require that any subcontracts planned for the work are identified. Provisions should be included that require the selected vendor to notify the procuring organization of any new subcontracting after award. These requirements should be passed down to each subcontractor.

- Specific attention is needed in establishing the bidders list, preparation of specifications, and evaluation of bids.

1. Bidders lists should be subjected to greater scrutiny for components that are ER-critical or important to the plant.
   - Consider only vendors with a track record of successful production of the components.
   - Contact members of projects who have recently used the potential vendors and question them about the vendor's performance, especially their quality-related performance.
   - Understand the portions of the work that will be performed in the vendor's shops and those that will be subcontracted (question any sub-subcontracting). This might vary depending on the size of the potential order and the amount of work scheduled for the period of production.
   - Limit the bid list to the qualified few.
   - Visit the potential vendors and observe their operations.
2. In addition to all other normal requirements, specifications should contain the following topics important to ER:
   - A declaration that the subject of the specification is a critical or important item for the plant and the primary functions it will have to accomplish.

- The primary functions need to be clearly identified. It is recommended that a requirements traceability matrix (RTM) be used to delineate between primary system-critical ER functions and other less critical functions (for example, on-board caching of data for later trend analysis).
  - A requirement that projected failure events of the piece parts of the item are identified. See Appendix 2.A for an example of a desired failure event listing. For the failure events listed, provide information on the following. (Note: These topics are described further in Section 4, "Preventive Maintenance.")
- Preventive maintenance (PM; both time-based and predictive) or other mitigation tasks (for example, inspections) necessary to prevent or identify each failure:
  - Task content
  - Task interval, including logic for the interval
  - Condition-monitoring variables, detection techniques, and action levels
- Maintenance instructions necessary to implement the PM tasks
- Maintenance instructions necessary to accomplish corrective tasks
- Critical spares necessary to accomplish the preventive and corrective tasks

- If known and available, optional designs that could eliminate the failure or minimize the effects of the failure should be proposed
    - o Factory functional test requirements, including witnessing of tests, acceptance criteria, and submittal of test plans for approval.
    - o Project documentation requirements and required documentation submittal schedule for the item (see Section 2.2.4).

3. RFPs should contain an ER requirements table. Bid evaluations should be structured so that any deviations by a bidder to ER requirements are visible and called to the attention of the owner.
    - o A standard ER requirements evaluation table should be included with the bid evaluation for any critical or important item (see Appendix 2.B for an example table).
    - o Each bidder should be required to complete the table for their bid, displaying their extent of compliance with ER requirements of the specification and the RFP. Such declarations should be confirmed by a bid evaluator with ER experience and knowledge.

2.2.3 Equipment Design and Fabrication of ER-Related Components

- During detail design of a procured component consisting of multiple subcomponents, a single-point vulnerability (SPV) analysis should be accomplished and documented.
    - – Single-point vulnerabilities are those conditions that could defeat the primary functions of the component, for example, failure of a skid-mounted ac oil lubricating pump when no shaft-mounted oil pump exists.
- Where possible and practical, SPVs should be eliminated if the elimination results in a greater level of ER. Remaining SPVs that could defeat the primary functions of the procured component should be identified to the procuring organization for acceptance. Mitigating steps for SPVs (for example, PM and inspections) should be recommended by the vendor.
- Receipt inspection by the manufacturer of raw materials and subassemblies to ensure that manufacturing requirements are being met should be required.
- The vendor should recommend variables, monitoring points, and set points for predictive maintenance trending.
    - – The EPRI report *Program on Technology Innovation: Advanced Nuclear Technology—Component Margins and Monitoring Database* (1016537) should be considered for minimum monitoring requirements for specific components.
- Deviations and proposed deviation resolutions occurring during manufacture (including assembly or field installation) involving critical and important ER functions should be reviewed by the procuring organization.
    - – An approval process for deviations that impact primary functions and other attributes that are associated with the basis for the system, structure, or component (SSC) being classified as critical should be established by the procuring organization with the supplier organization.

2.2.4 Inspections, Testing, and Final Documentation of ER-Related Items

- During the pre-award stage of the procurement, hold points in the design and manufacturing process for technical review and quality purposes should be reviewed for adequacy. Hold points of ER significance should be selected for witnessing by the procuring organization.
- Vendor inspection guidelines highlighting ER-significant topics should be documented in a formal plan (the plan does not need to be specific to ER as long as ER requirements are covered) and should include the required detail for the following areas (see Appendix 2.C for additional vendor surveillance activities):
  - Verify that the contents of the ER requirements table are accomplished.
  - Witness vendor processes, including manufacturing processes.
  - Witness testing and inspection results and records.
  - Review design documents and drawings.
  - Review or audit manufacturer procedures and implementation.
- The vendor's problem identification and resolution (P&IR) processes should be evaluated, and entries related to the manufacture of the subject item(s) during the past several years should be reviewed. Any current human performance issues that might affect manufacturing of the items being procured should be reviewed.
- The functional test should be approved and witnessed by the procuring organization.
- The owner's acceptance reviews of the required vendor design deliverables related to ER should be accomplished by experienced, qualified reviewers.
- The development of receipt inspection (for use at the job site) and source inspection (for the release of equipment to ship) guidelines will aid in ensuring the quality of vendor-supplied items. The assistance of equipment subject matter experts (SMEs) is essential in preparing effective receipt and source inspection templates.
- Deliverables should include, as a minimum, the data and information required to support the equipment throughout its lifetime. For example:
  - OEM and part number information for each component and subcomponent
  - Complete bill of material information for each component
- The documentation package prepared by the vendor should contain the following ER required information:
  - PM recommendations, including tasks, intervals, task content, and supporting technical details (for example, failure events)
  - Life cycle management details for the component
  - Final documentation, including unique component and manufacturing identifiers
  - Final operation and maintenance manuals
  - As-built drawings
  - Digital images of pre-assembled subcomponents, if applicable

- Assembly drawings
- Final inspection results
- Test reports, including test setup descriptions and data sets taken
- Subcomponent manufacturing details and other quality certificates
- Recommended spare parts lists with critical spares identified
- Full parts lists with parts identified by manufacturer and model number (not primary vendor part numbers)
- Maintenance procedures—preventive and corrective
- Storage requirements

2.3 References

EPRI report 1011861, *Nuclear Maintenance Applications Center: Considerations for Developing a Critical Parts Program at a Nuclear Power Plant*

EPRI report 1015171, *Plant Support Engineering: Procured Item Quality Initiative Initial Findings*

EPRI report 1016693, *Guidance for Managing the Impact of Procured Item Quality Issues on Generating Asset Economic Performance*

EPRI report TR-106102, *Procurement Benchmarking and Performance Measures Report, Revision 2*

EPRI report NP-6630, *Guidance for Performance-Based Supplier Audits (NCIG-16)*

EPRI report 1016157, *Information for Use in Conducting Audits of Supplier Commercial Grade Item Dedication Programs*

EPRI report 1016883, *TST 1.0: Technical Specialist for Audits and Surveys Training, Version 1.0*

EPRI report 1016537, *Program on Technology Innovation: Advanced Nuclear Technology—Component Margins and Monitoring Database*

NEI AP 908, *Materials and Services Process Description and Guideline*

Appendix 2.A – Failure Events Listing

Table 2.A-1 provides an example failure events listing for medium-voltage motors.

Table 2.A-1
Example Failure Events Listing for Medium-Voltage Motors (partial list)

Failure Location	Degradation Mechanism	Degradation Influence	Failure Timing	Discovery Methods
Baffles	Loose hardware	Manufacturing defect	Random	Inspection or vibration
Baffles	Loose hardware	Personnel error	Random	Inspection or vibration
Baffles	Loose hardware	Vibration	Random	Inspection or vibration
Bearing insulation	Broken or cracked	Improper handling	Random	Inspection or electrical tests
Bearing insulation	Insulation degradation	Contamination	Expect to be failure-free for 5–10 years	Inspection or electrical tests
Bearing metering orifice	Blocked	Contamination: debris	Random, but bearing failure quickly follows complete blockage	Bearing temperature, oil pressure, oil level
Bearing metering orifice	Blocked	Personnel error	Random, but bearing failure quickly follows complete blockage	Bearing temperature, oil pressure, oil level
Bearing seals	Wear	Environment: debris	Random	Inspection or oil analysis
Bearing seals	Wear	Excessive grease	Expect to be failure-free for months; excessive grease	Inspection or oil analysis
Bearing seals	Wear	Imbalance or misalignment	Random	Inspection or oil analysis
Bearing seals	Wear	Improper installation	Random: months	Inspection or oil analysis
Bearing seals	Wear	Incorrect lubricant	Random	Inspection or oil analysis
Bearing seals	Wear	Material defect	Random	Inspection or oil analysis
Bearing seals	Wear	Normal wear: duty cycle	Expect to be failure-free for many years; bearing life	Inspection or oil analysis
Bearing seals	Wear	Temperature excursions	Random	Inspection or oil analysis
Bearings, antifriction	Wear	Circulating electric currents	Expect to be failure-free for several years; might not progress to failure	Vibration, insulation resistance checks, or acoustic monitoring
Bearings, antifriction	Wear	Degraded lubricant: duty cycle, contamination, temperature; the greater the DT, the shorter the life	Expect grease and oil to be failure-free for 24 months for normal conditions	Oil sampling, oil level and color, bearing temperature, vibration, acoustic monitoring, or increased current
Bearings, antifriction	Wear	Excessive lubricant	Expect to be failure-free for several months	Bearing temperature, acoustic monitoring, or increased current

Table 2.A-1 (continued)
Example Failure Events Listing for Medium-Voltage Motors (partial list)

Failure Location	Degradation Mechanism	Degradation Influence	Failure Timing	Discovery Methods
Bearings, antifriction	Wear	Excessive mechanical loading	Random: based on loading but could be very rapid	Vibration, bearing temperature, acoustic monitoring, or increased current
Bearings, antifriction	Wear	Incorrect or mixed lubricant	Random	Oil sampling, oil level and color, bearing temperature, vibration, acoustic monitoring, or increased current
Bearings, antifriction	Wear	Insufficient lubricant	Random	Oil sampling, oil level and color, bearing temperature, vibration, acoustic monitoring, or increased current
Bearings, antifriction	Wear	Maintenance-induced errors such as improper fit, handling, or installation	Random, but rapid	Vibration, bearing temperature, or acoustic monitoring
Bearings, antifriction	Wear	Misalignment during initial assembly or wear of other components	Expect to be failure-free for a few months	Vibration, bearing temperature, acoustic monitoring, or increased current
Bearings, antifriction	Wear	Normal wear	Expect to be failure-free for 10–15 years	Vibration, insulation resistance checks, or acoustic monitoring
Bearings, antifriction	Wear	Soft foot	Random: based on loading but could be very rapid	Vibration, bearing temperature, or acoustic monitoring
Bearings, Kingsbury type	Wear	Babbitt imperfection or cold spot	Random	Oil analysis, bearing temperature, vibration, acoustic monitoring, or bearing inspection
Bearings, Kingsbury type	Wear	Circulating electric currents	Expect to be failure-free for 0.5–2 years	Oil analysis, insulation resistance checks, vibration, or acoustic monitoring
Bearings, Kingsbury type	Wear	Degraded lubricant: duty cycle, contamination, temperature; the greater the DT, the shorter the life	Expect oil to be failure-free for 18–24 months for normal conditions	Oil sampling, oil level and color, bearing temperature, vibration, or acoustic monitoring
Bearings, Kingsbury type	Wear	Excessive mechanical loading	Random: based on loading; could be very rapid	Oil sampling, bearing temperature, vibration, acoustic monitoring, or increased current
Sequence intentionally interrupted				
Electrical connections	High resistance	Contamination	Expect to be failure-free for years	Winding resistance, thermography, ductor testing, inspection, or motor analysis
Electrical connections	Insulation degradation	Improper installation of the insulation	Random	Insulation resistance or motor analysis

Table 2.A-1 (continued)
Example Failure Events Listing for Medium-Voltage Motors (partial list)

Failure Location	Degradation Mechanism	Degradation Influence	Failure Timing	Discovery Methods
Electrical connections	Loose	Age	Expect to be failure-free for 20–40 years	Inspection, electrical tests, or thermography
Electrical connections, brazed	High resistance	Cycling	Expect to be failure-free for 2–4 years	Winding resistance, thermography, ductor testing, or inspection
Electrical connections, brazed	High resistance	Improper installation	Random	Winding resistance, thermography, ductor testing, or inspection
Electrical connections, brazed	High resistance	Vibration and movement	Expect to be failure-free for 2–4 years	Winding resistance, thermography, ductor testing, or inspection
Feeder cables	Insulation degradation	Age	Expect to be failure-free for <40 years	Inspection or insulation tests
Feeder cables	Insulation degradation	Contamination, especially water	Expect to be failure-free for years	Inspection or insulation tests
Feeder cables	Insulation degradation	Damage	Random	Inspection or insulation tests
Feeder cables	Insulation degradation	High temperature	Expect to be failure-free for years, based on degrees above rating	Inspection or insulation tests
Feeder cables	Insulation degradation	Improper testing	Random	Inspection or insulation tests
Feeder cables	Insulation degradation	Manufacturing defect	Random	Inspection or insulation tests
Filters, air coolers	Clogged or dirty	Environment	Expect to be failure-free for only months	Inspection or winding temperature
Frame, enclosure, and mounting	Clogged air passages or screens	Environment	Expect to be failure-free for 3–5 years	Winding temperature, inspection, or thermography
Frame, enclosure, and mounting	Clogged air passages or screens	Oil leaks	Random	Winding temperature, inspection, or thermography
Frame, enclosure, and mounting	Cracked	Damage: personnel error	Random	Inspection or vibration
Frame, enclosure, and mounting	Cracked	Structural resonance	Random	Inspection or vibration
Frame, enclosure, and mounting	Deformation	Damage: personnel error	Random	Vibration, bearing temperature, or inspection
Frame, enclosure, and mounting	Deformation	Voids in base	Random	Vibration, bearing temperature, inspection
Frame, enclosure, and mounting	Loose or damaged	Vibration	Random	Inspection or vibration
Frame, enclosure, and mounting	Soft foot	Imperfections in motor base	Random	Inspection or vibration
Frame, enclosure, and mounting	Soft foot	Improper installation	Random	Inspection or vibration
Gaskets	Leakage	Age or material defect (cracks or porosity)	Expect to be failure-free for years	Inspection
Gaskets	Leakage	Personnel error	Expect to be failure-free for 6 months	Inspection

Table 2.A-1 (continued)
Example Failure Events Listing for Medium-Voltage Motors (partial list)

Failure Location	Degradation Mechanism	Degradation Influence	Failure Timing	Discovery Methods
Machine fits	Damaged or misaligned	Personnel error	Random	Inspection
Motor leads	Insulation degradation	Age	Expect to be failure-free for <40 years	Inspection or insulation tests
Motor leads	Insulation degradation	Contamination	Expect to be failure-free for years	Inspection or insulation tests
Motor leads	Insulation degradation	Damage	Random	Inspection or insulation tests
Motor leads	Insulation degradation	High temperature	Expect to be failure-free for years, based on degrees above rating	Inspection or insulation tests
Sequence intentionally interrupted				
Stator: windings, blocking, bracing, surge rings (includes wedges)	Insulation degradation	Heat above rated	Expect to be failure-free for years, depends strongly on amount of heat	Insulation tests or winding temperature
Stator: windings, blocking, bracing, surge rings (includes wedges)	Insulation degradation	Manufacturing defect	Random	Insulation tests or inspection
Stator: windings, blocking, bracing, surge rings (includes wedges)	Insulation degradation	Movement during start	Expect to be failure-free for 6–12 years	Insulation tests or inspection
Stator: windings, blocking, bracing, surge rings (includes wedges)	Insulation degradation	Radiation	Expect to be failure-free for <40 years	Insulation tests or inspection for embrittlement
Stator: windings, blocking, bracing, surge rings (includes wedges)	Insulation degradation	Vibration	Expect to be failure-free for >6 years	Inspection for dusting or insulation tests
Stator: windings, blocking, bracing, surge rings (includes wedges)	Loose blocking and bracing	Duty cycle	Expect to be failure-free for <40 years	Insulation tests or inspection
Stator: windings, blocking, bracing, surge rings (includes wedges)	Loose blocking and bracing	Electrical and surge transients	Random	Insulation tests or inspection
Stator: windings, blocking, bracing, surge rings (includes wedges)	Loose blocking and bracing	Manufacturing defect	Random	Insulation tests or inspection
Stator: windings, blocking, bracing, surge rings (includes wedges)	Loose blocking and bracing	Movement during start	Expect to be failure-free for <40 years	Insulation tests or inspection
Stator: windings, blocking, bracing, surge rings (includes wedges)	Loose blocking and bracing	Number of starts	Expect to be failure-free for 15–20 years	Insulation tests or procedural compliance

Table 2.A-1 (continued)
Example Failure Events Listing for Medium-Voltage Motors (partial list)

Failure Location	Degradation Mechanism	Degradation Influence	Failure Timing	Discovery Methods
Stator: windings, blocking, bracing, surge rings (includes wedges)	Loose blocking and bracing	Vibration	Expect to be failure-free for >6 years	Inspection for dusting or insulation tests
Stator: windings, blocking, bracing, surge rings (includes wedges)	Loose wedges (mostly found in vertical motors)	Gravity in vertical motors	Expect to be failure-free for years	Inspection or borescope
Stator: windings, blocking, bracing, surge rings (includes wedges)	Loose wedges (mostly found in vertical motors)	Loss of resin bond	Expect to be failure-free for years	Inspection or borescope
Stator: windings, blocking, bracing, surge rings (includes wedges)	Loose wedges (mostly found in vertical motors)	Vibration	Expect to be failure-free for years	Inspection or borescope
Surge capacitors	Bushing damage	Contamination	Expect to be failure-free for 2–7 years	Inspection or power factor testing
Surge capacitors	Bushing damage	Personnel error	Random	Inspection or power factor testing
Surge capacitors	Insulation degradation	Age: duty cycle	Expect to be failure-free for 10–15 years	Insulation resistance, high pot, or power factor testing
Surge capacitors	Insulation degradation	Voltage transients and surges	Random	Insulation resistance, high pot, or power factor testing
Surge capacitors	Leakage	Age	Expect to be failure-free for 10–15 years	Inspection, insulation resistance, or high pot testing
Surge capacitors	Leakage	Heat above rated	Expect to be failure-free for 10 years	Inspection, insulation resistance, or high pot testing
Surge capacitors	Leakage	Personnel error	Random	Inspection, insulation resistance, or high pot testing

Note: Experience has shown that people knowledgeable about a component can complete the level of detail shown in 8 to 16 person-hours. This example was taken from EPRI report 1014971, *PM Basis Version 2.0*.

Appendix 2.B – ER Requirements Evaluation Table

Table 2.B-1 provides an example ER requirements evaluation table.

Table 2.B-1
Example ER Requirements Evaluation: Identify Deficient Vendor Responses

ER Requirement (according to spec or RFP)	Vendor A Bid Compliance	Vendor A Comments	Vendor B Bid Compliance	Vendor B Comments
Listing of failure events	Committed: yes	Partial listing provided	Committed: yes	*No example provided*
PM tasks for each failure mode provided	Committed: yes	*Generic PM program to be provided*	Committed: yes	PM tasks will be provided to address each failure event
PM task content provided	Committed: yes		Committed: yes	
Time intervals for PM task and supporting logic provided	*Included: partial*	*Typical time intervals provided; no supporting logic will be provided*	Committed: yes	Time intervals supported by failure data and field data will be provided
Condition monitoring variables, technology, and action level provided	*Included: partial*	*Variables and technology provided; no commitment to provide action levels*	Committed: yes	Variables and technology provided; committed to provide action levels
Maintenance instructions for PM and corrective maintenance provided	*Committed: partial*	*Corrective only to be provided*	Committed: yes	PM and corrective to be provided
Critical spare parts identified	*No*	*Generic spare parts list to be provided*	Committed: yes	Generic spare parts provided; critical spare to be identified later
(Continue with ER requirements)				

Note: This is a simplified example to convey the concept. An actual table would more complex.

Appendix 2.C – Vendor Surveillance

2.C-1 Examples of Vendor Surveillance ER-Related Activities

Activities associated with vendor surveillance can include many facets. These are designed to ensure compliance with design and procurement requirements and should not be limited to quality assurance program requirements. They should include the following:

1. Ensure that operating experience (OE) was factored into the design and manufacturing (for example, an OE review of vendor service bulletins and similar industry equipment or system experience).
2. Review the manufacturer's corrective action process (CAP), including any previous CAPs directly related to items being procured or any recent human performance issues.
3. Maintain material compliance with design specifications and traceability, and review certified material test reports.
4. Observe manufacturing processes.
5. Observe and review test plans and procedures for software, subcomponents, and final acceptance testing.
6. Review the material and test evaluation (M&TE) (calibration) program controls and implementation.
7. Perform a visual inspection for conformity to design of the components being supplied.
8. Assess foreign material exclusion (FME) controls for adequacy.
9. Witness functional/performance/NDE testing and inspection.
10. Spot-check dimensions (if applicable).
11. Review design documents produced by the vendor for conformance with design requirements and specifications.
12. Evaluate the vendor packaging/shipping/storage program and processes.
13. Evaluate vendor schedule and cost adherence versus procurement agreements.
14. Audit vendor personnel qualifications and records.

Appendix 2.D – Example of ER-Related Procurement Checklist

Note: All critical and important components are not equal. This sample checklist emphasizes the need to determine the level of procurement effort to be applied to a component and the documentation needed to show that it occurred.

Establishing the Bidders List

1. The vendor has successfully provided the component on this or other nuclear projects.

☐ Applicable? ☐ Accomplished?

2. Contacts have been made with other user's projects to evaluate vendor performance.

☐ Applicable? ☐ Accomplished?

3. Potential vendors have been visited, and their operations have been observed.

☐ Applicable? ☐ Accomplished?

Request for Proposal and Specification

1. Provisions are required for access to necessary OEM information if the vendor becomes unavailable.

☐ Applicable? ☐ Accomplished?

2. Deliverables are to be provided in a format that can be easily migrated into the plant's asset management system.

☐ Applicable? ☐ Accomplished?

3. A requirement to notify the purchaser of changes to materials or margins that affect component performance or lifetime is included.

☐ Applicable? ☐ Accomplished?

4. Detailed PM requirements have been included.

☐ Applicable? ☐ Accomplished?

5. A detailed ER requirements table has been included for completion by the vendor, to be submitted with the proposal.

☐ Applicable? ☐ Accomplished?

6. Requirements for the final documentation packages have been established and included.

☐ Applicable? ☐ Accomplished?

7. Necessary access for vendor surveillance and witnessing of tests and processes has been established.

☐ Applicable? ☐ Accomplished?

Design Involvement Post-Award

1. A component failure modes table and related PM tasks (predictive and time-based) for use in a PM program have been submitted and reviewed.

☐ Applicable? ☐ Accomplished?

2. PM and corrective maintenance instructions and a spare parts listing have been submitted and reviewed.

☐ Applicable? ☐ Accomplished?

3. A single-point vulnerability analysis and mitigating actions have been submitted and reviewed.

☐ Applicable? ☐ Accomplished?

3
PERFORMANCE MONITORING DURING PROCUREMENT

3.1 Scope

This section describes the actions recommended during the procurement phase of a new plant project to ensure that ER performance-monitoring objectives and requirements are accomplished.

3.2 Recommendations for Performance Monitoring During the Procurement Phase

3.2.1 General

- During the basic design phase, expectations were established for the project's infrastructure for performance monitoring and for the monitoring of individual systems and components. It is essential that these expectations are translated into individual procurement documents (for example, specifications, RFPs, and contracts).
- The translation of project performance-monitoring expectations is best accomplished by line-of-sight tracking that connects expectations with actions.
  - You get what you inspect, not what you expect.
- The requirements tracking discussed in this module are *flow-down*; that is, line-of-sight tracking of ER performance-monitoring requirements from the project's general documents flows into design- and procurement-specific documents and then into vendor activities and supplied products.

3.2.2 Project Performance-Monitoring Functional Specification Implementation During Procurement

- The project should maintain visibility of ER performance-monitoring requirements to ensure that the project expectations as detailed in the performance-monitoring functional description or specification are translated into project design and procurement documents (see Appendix 3.A for an example).
- The ER performance-monitoring requirements should be periodically reviewed by the design team and with the project owner to ensure the requirements are being effectively implemented on the project.

- Information should be provided to each involved vendor to promote understanding of how their scope of supply fits into the project's overall performance-monitoring functional specification. This allows vendors to raise compatibility and interface concerns.

3.2.3 Component and System Monitoring Performance-Monitoring Requirements' Implementation During Procurement

- ER performance-monitoring requirements should be established for each contracted portion of the plant's performance-monitoring capability (see Appendix 3.B for an example). The requirements for the contracted scopes should connect back to and fulfill the expectations of the project-wide requirements discussed previously.
- The vendor surveillance plans as discussed in Appendix 2.C of this report should include the verification of key elements of the ER performance-monitoring requirements.
- Component-specific monitoring requirements should be established by the vendor.
- Vendors should use service advices and other OE available to them when establishing monitoring recommendations.
- Recommended monitoring requirements for 25 components are contained in the EPRI report 1016537, *Program on Technology Innovation: Advanced Nuclear Technology—Component Margins and Monitoring Database* (see Appendix 3.C for examples).

3.3 References

EPRI report 1016537, *Program on Technology Innovation: Advanced Nuclear Technology—Component Margins and Monitoring Database*

Appendix 3.A – Performance-Monitoring Requirements: Project

Table 3.A-1 shows an example table for a project's ER-related performance-monitoring requirements line-of-sight tracking.

Table 3.A-1
Example Table for a Project's ER-Related Performance-Monitoring Requirements Line-of-Sight Tracking

Project Requirement	Implementing Specifications	Other Implementing Design Documents	Last Review Date
[A]	[B]	[C]	[D]

[A] = Specifics extracted from the project performance monitoring functional description or specification

[B] = Procurement specifications and installation specifications

[C] = Design standards and instructions; installation and testing requirements

[D] = The date that the linkage of items [A], [B], and [C] was last reviewed and confirmed

Appendix 3.B – Performance-Monitoring Requirements: Procurement

Table 3.B-1 shows an example table for procurement-specific ER-related performance-monitoring requirements line-of-sight tracking.

Table 3.B-1
Example Table for Procurement-Specific ER-Related Performance-Monitoring Requirements Line-of-Sight Tracking

Procurement Requirement	Key Vendor Implementing Details	Vendor Surveillance verification
[A]	[B]	[C]

[A] = Specifics extracted from the procurement specification and contract

[B] = Documented vendor actions that translate the procurement document requirements into the final product

[C] = Vendor surveillance report number and date for which the linkage of [A] and [B] was verified

Appendix 3.C – Example Recommended Component Monitoring Requirements

Table 3.C-1 shows an example recommended component monitoring requirements table.

Table 3.C-1
Example Recommended Component Monitoring Requirements

ANT Component Monitoring

Large Pump (500 Hp+) Monitored Parameter	Circulating Water	Service Water	Condensate	FW/Cond Booster	Feed Water	Startup FW	Heater Drain	RNS	FW GearBox
Individual Pump Flowrate	4	1	1	1	1	1	1	1	
Suction Temperature	5	5	5	1	1	-	1	-	
Discharge Temperature	1	1	1	1	1	1	1	-	
Suction Pressure	-	-	1	1	1	1	1	1	
Discharge Pressure	1	1	1	1	1	1	1	1	
Vibration Amplitude/Phase	1	1	1	1	1	1	1	3	1
Oil Analysis	3	3	3	3	3	3	3	3	3
Power Input	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2	
Note #1: Recommend Permanent Networked Instrumentation									
Note #2: Recommend Installed Instrumentation, Locally Accessible									
Note #3: Provisions to be made to install instrumentation without having to resort to machining, cutting, or draining the system									
Note #4: It is desirable to obtain this parameter. However, how best to do this needs to be addressed.									
Note #5: The desired parameter is measured independent of the system									
Oil Comment: Oil Lubricated Equipment to have Oil Sample Fittings, Thrust monitoring on all horizontal, journal bearing equipment. Oil Bath temperature for roller bearings. Oil Bath and Bearing metal temperature for Journal/Thrust Bearings. Thrust Bearing to be monitored on both sides (loaded/unloaded)									
Vibration Instrumentation: i) Machines with Roller Bearings: Bearing Housing, pad mounted Accelerometers. ii) Machines with Journal Bearings: Bearing Housing pad mounted Accelerometers and Proximity Probes installed at every accessible bearing location.									

Table 3.C-1 (continued)
Example Recommended Component Monitoring Requirements

ANT Component Monitoring				
Iso-Phase Bus Monitoring Parameters	**Busses**	**Bus Duct**	**Cooling Fans/Motors**	**Heat Exchanger**
Temperature Sensors (Recommend Fiber Optic or IR Thermometer) mounted to measure and monitor Critical Bus Joints.	1	1		
Vibration and Bearing Temperature Monitoring			1, 2	
Ground Fault Detector System (High Resistance Grounding or Ungrounded System During Backfeeding Operation).	1			
Heat Exchanger Leak Detector (Level Switch)				1
Dew Point Monitor		1		
Hydrogen Monitor at Generator Line and Neutral Terminations		1		
Inlet and Outlet Temperature (Air and Water)				1
Air Filter dP			1	
Water Leak Detector (Level Switch)		1	1	
Partial Discharge Detector/EMI (External to Generator)		3		
Air Flow (Makeup) for the purpose of leak detection.		1		
Isophase Contact Temperature Sensors (Recommend Fiber Optic or IR Thermometer).	1			
Note #1: Recommend Permanent Networked Instrumentation				
Note #2: Recommend Installed Instrumentation, Locally Accessible				
Note #3: Provisions to be made to install instrumentation without having to resort to machining, cutting, or draining the system.				

Note: These examples (large pumps and isophase bus duct) are taken from EPRI report 1016537, *Program on Technology Innovation: Advanced Nuclear Technology—Component Margins and Monitoring Database.*

4
PREVENTIVE MAINTENANCE IMPLEMENTATION DURING PROCUREMENT

4.1 Scope

This section identifies the role of suppliers in establishing plant component maintenance practices and recommendations for improving component ER. This includes the following:

- A process for identifying PM requirements for components and establishing a basis for these requirements, including the timing of tasks and predictive maintenance monitoring parameters
- Maintenance instructions and steps, including the in-process inspection points to be provided
- The spare parts list and the basis for this list (including criticality, lead time, and consumption)
- Tools and equipment needed to perform maintenance and testing

4.2 Preventive Maintenance Program Input from Component Suppliers

- For previous plant construction efforts, vendor maintenance recommendations typically came in the form of standard vendor manuals. Typically, these manuals lacked depth and detail and were generally written to provide a basis for warranty assurance rather than ER.
- Procurement specifications for plant components should clearly define and require the elements of PM task identification, frequency, and basis. Appendix 4.A provides the detailed steps that are recommended.
  - When one exists, the EPRI PM module for the component being procured should be provided to the vendor as an example of what the end product should consist of. The essential elements of an EPRI PM module are the following:
    - Equipment degradation table
    - PM task descriptions and effectiveness ratings
    - PM templates
  - When an EPRI PM module does not exist, one for a similar component should be supplied.
- Special effort will be required to ensure that suppliers understand and provide the information to support and implement an effective PM program. Suppliers will be the most knowledgeable on the technical aspects of their equipment, including failure mechanisms and the maintenance that should be performed to ensure reliability.

4.3 Maintenance Instructions

- The typical practice for vendors in the past has been to supply manuals that provide operational and maintenance information in random formats. For new plant components, additional direction should be provided to the vendors on required format and content to aid in populating the plant's maintenance program.
- Implementing instructions is an important aspect of a PM program. The requirement to provide detailed maintenance instructions should be included as part of the procurement documentation.
  - PM instructions for each recommended PM task
  - Corrective maintenance (CM) instructions for potential corrective tasks
- These instructions should include the following information:
  - Step-by-step guidance on performing the tasks
  - Tools and equipment needed
  - Precautions and special focus areas
  - Inspection points and critical dimensions, when appropriate
  - Recommendations on acceptance tests that should be performed following maintenance activities
  - Requirements to record as-found conditions and information
- Special training requirements needed to perform maintenance tasks should also be identified. Recommendations on training material content and mockups should be provided.

4.4 Identification of Spare Parts

- Supply of adequate spare parts is an important maintenance consideration. Spare parts should be recommended by the vendor as part of the deliverables for the purchase. The engineering procurement and construction (EPC) contractor must work closely with the owner to establish the optimum level of on-hand spare parts. Several aspects factor into this determination:
  - Critical nature of the parts
  - Lead time for parts
  - Cost of parts
  - Complexity of parts
  - Consumables required for planned PM activities
- The determination of spare parts for critical components should be performed by component suppliers. Appendix 4.B provides guidance on how this should be accomplished.

- Lead times should be considered in the development of spare parts lists. Even though they might not be for a critical component, parts that require special manufacturing processes or an extraordinarily long time to obtain should be identified so that consideration can be given as to whether it should be included on the spare parts list.
- Normal, routine maintenance as well as planned refurbishments will require a certain number and type of consumable parts (such as gaskets, seals, fasteners, and connectors), which should be identified by the supplier and used to establish stocking levels required to support maintenance activities and schedules.
- Storage requirements for spare parts provided with the equipment should be provided by the suppliers. There might be an extended period of time before these parts are likely to be used (because of time required for plant construction).

4.5 Maintenance Tools and Equipment

- Maintenance on components sometimes requires special tooling or equipment in order to be effectively performed. These should be identified in the vendor manuals and can be supplied by the component manufacturer. This equipment can consist of special rigs, tools, or adapters that are unique to the equipment being supplied.
- Other tools that are needed might be more standard in nature—not typically supplied by the manufacturer, but nonetheless required for maintenance activities. These can consist of the following items, which should be identified early after the procurement agreement process so that they can be incorporated into the final plant designs:
  - Hoisting equipment
  - Work platforms
  - Shielding
  - Personnel safety equipment
  - Services (such as air, water, and power)

4.6 References

EPRI report 1016693, *Guidance for Managing the Impact of Procured Item Quality Issues on Generating Asset Economic Performance*

EPRI report 1011861, *Nuclear Maintenance Applications Center: Considerations for Developing a Critical Parts Program at a Nuclear Power Plant*

EPRI report 1000702, *Preventive Maintenance Information Repository (PMIR): Functional Specification*

EPRI report 1014971, *PM Basis Version 2.0*

EPRI report NP-6630, *Guidance for Performance-Based Supplier Audits (NCIG-16)*

EPRI report 1018110, *Nuclear Maintenance Applications Center: Preventive Maintenance Basis Database 2.0 User's Guide*

EPRI report TR-106857-R1, *Preventive Maintenance Basis Project Overview Report Update*

Appendix 4.A – PM Development Program Process

The design organization is the project group responsible for establishing the basis of the plant PM program. Much of the information necessary to create the basis is produced by the individual component vendors.

The design organization must provide the vendors with sufficient information on PM-related deliverables so that input from all vendors of ER-related components can be integrated into the plant's ER databases and processes. This includes, as a minimum, formats, definitions, and expectations necessary to easily feed the vendors' work into the plant PM basis structure.

The procuring organization should be prepared to mentor individual vendors through the process to ensure usable and consistent ER deliverables.

Note: The following is similar to Appendix 4.A of EPRI report 1021415, Advanced Nuclear Technology: *Equipment Reliability for New Nuclear Plant Projects—Industry Recommendations for Design*.

- When using EPRI report 1014971, *PM Basis Database V2*, routinely use the Update function to download new components and revisions to component files.
  - Under Administration, select "Download from EPRI" to view new files available for download.
  - Current PM modules for 150+ components (nuclear and fossil) are contained in the database.
  - If needed, a software plug-in is provided with the PMBD V2 software that exports PMBD content in an XML structure.
- When one exists, the EPRI PM module for the component being procured should be provided to the vendor as an example of what the end product should consist of. The following are the essential elements of an EPRI PM module:
  - Equipment degradation table
  - PM task descriptions and effectiveness ratings
  - PM templates
- When an EPRI PM module does not exist, a module for a similar component should be supplied.
- See Appendix 4.C, "Extraction of PMBD Module Elements from the PMBD Software," for detailed steps.

Note: Section 3.2 of EPRI report TR-106857-R1 contains the 20 steps of the expert elicitation process used by EPRI to create the component modules of the PMBD. It is recommended that vendors review these steps before proceeding with the following process.

For components classified as critical or important, the following process should be used to develop PM recommendations. It is recommended that vendors accomplish this in the following manner:

1. Assign persons considered to be experts on the component, including EPC representation if applicable.
2. Assemble industry and company-related OE on similar components in the existing fleet, organized by failure types.
3. When addressing each of these steps, it is important to recognize that consensus on the elements is what is important—not necessarily total agreement.
4. The process is iterative in nature; in other words, it might be necessary to revisit previous steps as additional discussion and information is revealed about the component failures and the techniques used to prevent them.

- Define the boundaries of each component (that is, what is and is not included).
  Where does the boundary of the PM program, as it relates to the component, begin and end? The answer will establish which piece parts are included in the PM requirements and which are excluded.
- The procuring organization should provide the vendor with the following:
  - The component's classification: critical or important
  - The duty cycle and service condition
  - Special conditions of use, operation, speed, and environment that can influence component condition. The duty cycle might be high or low (or both), depending on the component's application and system requirements.
    Duty cycle reflects the degree of thermal and mechanical transient stresses on equipment. Consideration is given to factors such as the following:
    - Starting, stopping, and cycling
    - High temperatures, vibration, or wear of sliding surfaces encountered in continuous operation
    - Relocation and separation of lubricants and other effects that might result from prolonged inactivity

    Note: High and low duty cycles are not necessarily synonymous with continuous operation and standby operation, respectively, although sometimes it is indeed as simple as that—for example, with electric motors. Equipment that is alternated between periods of standby and continuous running, such as pumps and motors, are likely to be treated as high duty cycle because they are still operated continuously for an appreciable amount of the time. However, continuous operation does not always imply that there should be PM differences, depending on the amount of usage. When equipment is specifically designed for continuous duty, as are most reciprocating and rotary screw compressors, a more meaningful way to differentiate the effects of high and low duty cycles includes the degree of loading when the equipment is operating (including cyclical demand).

Note: Service conditions should be categorized as either severe or mild, or, as before (depending on application), components might be used in both conditions at a plant. *Severe service* can be defined by high or excessive humidity, excessive temperatures (high or low) or temperature variations, excessive environmental conditions (for example, salt, corrosive materials, high radiation, spray, or steam), and high vibration. *Mild service* can be defined by a clean area (not necessarily air-conditioned), temperatures within OEM specifications, and normal environmental conditions.

- The vendor should develop the equipment degradation table.

  Note: Equipment degradation tables as extracted from the EPRI PMBD can be used as a starting point for this list. See the introduction to this appendix (4.A) for details.

  Understanding how a component can fail is a key to identifying appropriate preventive tasks to preclude this failure.

  The table should include the following information (see the example table that follows, Table 4.A-1):

  – Failure location (FL): where the degradation occurs
    - o It is important to be as specific as possible here in order to pinpoint the exact location of the anticipated failure, for example, the bearing/rolling element

  – Degradation mechanism (DM): why the failure occurs
    - o Understanding what the degrading mechanism is can help pinpoint the condition monitoring strategy or mitigating strategy that should be used, for example, wear, gasket failure, high resistance, or clogged orifice

  – Degradation influence (DI): what causes the DM to occur, for example, normal use, lack of lubrication, environment, or vibration
    - o Frequently, several degradation influences can cause a single degradation mechanism

  – Failure time codes: generally, the time code will be one of the following:
    - o Random; that is, there is no set time at which one would expect the failure.
    - o Continuous wear-out; this is more specific. It is required to define the expected time to first failure for continuous wear-out degradation influences.

  - Use all available service advice and OE feedback to establish time to failure.

    – Degradation progression (stressors): triggers or influences that affect the rate of degradation and therefore the time to first or early failure

Table 4.A-1 is an example from the EPRI PMDB that illustrates a portion of the degradation table developed for medium-voltage motors.

Table 4.A-1
Example Table from the EPRI PMDB, Illustrating a Portion of the Degradation Table Developed for Medium-Voltage Motors

Failure Location	Degradation Mechanism	Degradation Influence	Failure Timing	Degradation Progression
Baffles	Loose hardware	Manufacturing defect	Random	Random
Baffles	Loose hardware	Personnel error	Random	Random
Baffles	Loose hardware	Vibration	Random	Random
Bearing insulation	Broken or cracked	Improper handling	Random	Random
Bearing insulation	Insulation degradation	Contamination	Expect to be failure-free for 5–10 years	Continuous
Bearing metering orifice	Blocked	Contamination: debris	Random, but bearing failure quickly follows complete blockage	Random
Bearing metering orifice	Blocked	Personnel error	Random, but bearing failure quickly follows complete blockage	Random
Bearing seals	Wear	Environment: debris	Random	Random
Bearing seals	Wear	Excessive grease	Expect to be failure-free for months for excessive grease	Continuous
Bearing seals	Wear	Imbalance or misalignment	Random	Random
Bearing seals	Wear	Improper installation	Random: months	Random
Bearing seals	Wear	Incorrect lubricant	Random	Random
Bearing seals	Wear	Material defect	Random	Random
Bearing seals	Wear	Normal wear: duty cycle	Expect to be failure-free for many years for bearing life	Continuous
Bearing seals	Wear	Temperature excursions	Random	Random
Bearings: antifriction	Wear	Circulating electric currents	Expect to be failure-free for several years; might not progress to failure	Continuous
Bearings: antifriction	Wear	Degraded lubricant: duty cycle, contamination, temperature; the greater the DT, the shorter the life	Expect grease and oil to be failure-free for 24 months for normal conditions	Continuous

Note: Experience has shown that people knowledgeable about a component can complete the level of detail shown in 8 to 16 person-hours.

- List discovery or prevention opportunities for each FL/DM. These will include the following:
  - Condition monitoring techniques:
    - These generally include non-intrusive technologies, such as thermography, vibration analysis, and lube oil analysis
    - Can also include simple methods such as engineering or operation walkdowns or visual inspections
  - PM activities:
    - These are generally intrusive practices that include disassembly or opening of components, inspection and checks, and replacement of components that either periodically wear out or exhibit degradation
    - Can also be as extensive as a complete rebuild or refurbishment of the component. Full replacement of the component also falls into this category.
- Finalize PM task names for these FLs/DMs and assign task intervals:
  - The task interval should be selected based on its ability to head off the anticipated failure for which it is effective and at a frequency that will preclude the failure from occurring.
  - A frequency should be chosen that will maximize the number of failures that are being prevented.
- Assign intrinsic task effectiveness to each combination of FL/DM and PM task: high (~97%), medium (~80%), low (~50%), and blank (<50%):
  - *Task effectiveness* is the level of assurance that the task, acting alone, will identify the degradation prior to failure (in the case of condition monitoring techniques) or prevent the failure (in the case of PM activities).

Table 4.A-2 shows an example from the EPRI PMBD that illustrates the discovery and prevention opportunities developed for medium-voltage motors for the failure locations shown previously. The entire EPRI PMBD degradation table and PM task descriptions (see the example table that follows) shows the other content items recommended by this write-up.

Table 4.A-2
Example Table from the EPRI PMDB, Illustrating the Discovery and Prevention Opportunities Developed for Medium-Voltage Motors

	Discovery Methods									Prevention Task
Failure Location	**Thermography**	**Vibration Monitoring**	**Oil Analysis**	**Electrical Tests Online**	**Mechanical Tests Online**	**Electrical Tests Offline**	**Mechanical Tests Offline**	**System Engineer Walkdown**	**Operator Rounds**	**Refurbishment**
Baffles										L
Baffles										L
Baffles										L
Bearing insulation										L
Bearing insulation										M
Bearing metering orifice					H			M	M	L
Bearing metering orifice					H			M	M	L
Bearing seals								M	M	L
Bearing seals								M	M	H
Bearing seals								M	M	L
Bearing seals								M	M	L
Bearing seals								M	M	L
Bearing seals								M	M	L
Bearing seals								M	M	M
Bearing seals								M	M	L
Bearings: antifriction	L	M	H		H			L	L	L
Bearings: antifriction	L	M	H		H			L	L	H

Note: High = H, Medium = M, Low = L.

- Estimate the number of repair hours (wrench time only) for each FL/DM combination.
- Write a task objective statement for each PM task: this is intended to be a one-sentence statement of why performing this task is important.
- Calculate the number of PM person-hours required to perform each PM task.
- Outline the task content for each PM task. The task content should detect the conditions for which it is credited in the equipment degradation table. It should also list the major items that this task is intended to accomplish:
  - Inspections (such as loose or missing parts, critical dimensions, or attributes)
  - Steps to accomplish, including acceptable results or requirements such as cleaning, adjustments, and replacement
  - Important as-left conditions or attributes
  - The items that contribute to the risk of performing maintenance on this equipment (for example, tricky setups, left-handed threads, or incorrect parts)
- Identify principal failure locations and most probable causes.

4.A-1 Creation of Preventive Maintenance Template

The PM template is the consolidation of the contents of the equipment degradation table, the PM task content, and the PM effectiveness ratings in order to schedule plant preventive work associated with the component.

- The experts who created the supporting information should populate a PM template for the component that is consistent with the format shown in Figure 4.A-1. Primary considerations in doing this should be the following:
  - Component classification
  - Duty cycle
  - Environment
  - Equipment degradation table
    - Failure locations
    - Degradation mechanisms
    - Degradation influences
    - Degradation timing and progression
    - Discovery methods
  - PM task content description
  - PM task effectiveness

- After the template is drafted by the vendor, it—along with the supporting equipment degradation table—should be provided to the procuring organization. The procuring organization can then use the functions in the EPRI PMBD (that is, PM Program and Vulnerability) to optimize the timing and combinations of PM tasks. See EPRI report 1018110 for details on use of the PMBD Vulnerability function.
- The results of the PMBD evaluation of the vendor-supplied template should be shared with the vendor, and a final template should be agreed upon.
- The plant PM program documentation should be updated with the accepted template and degradation table.

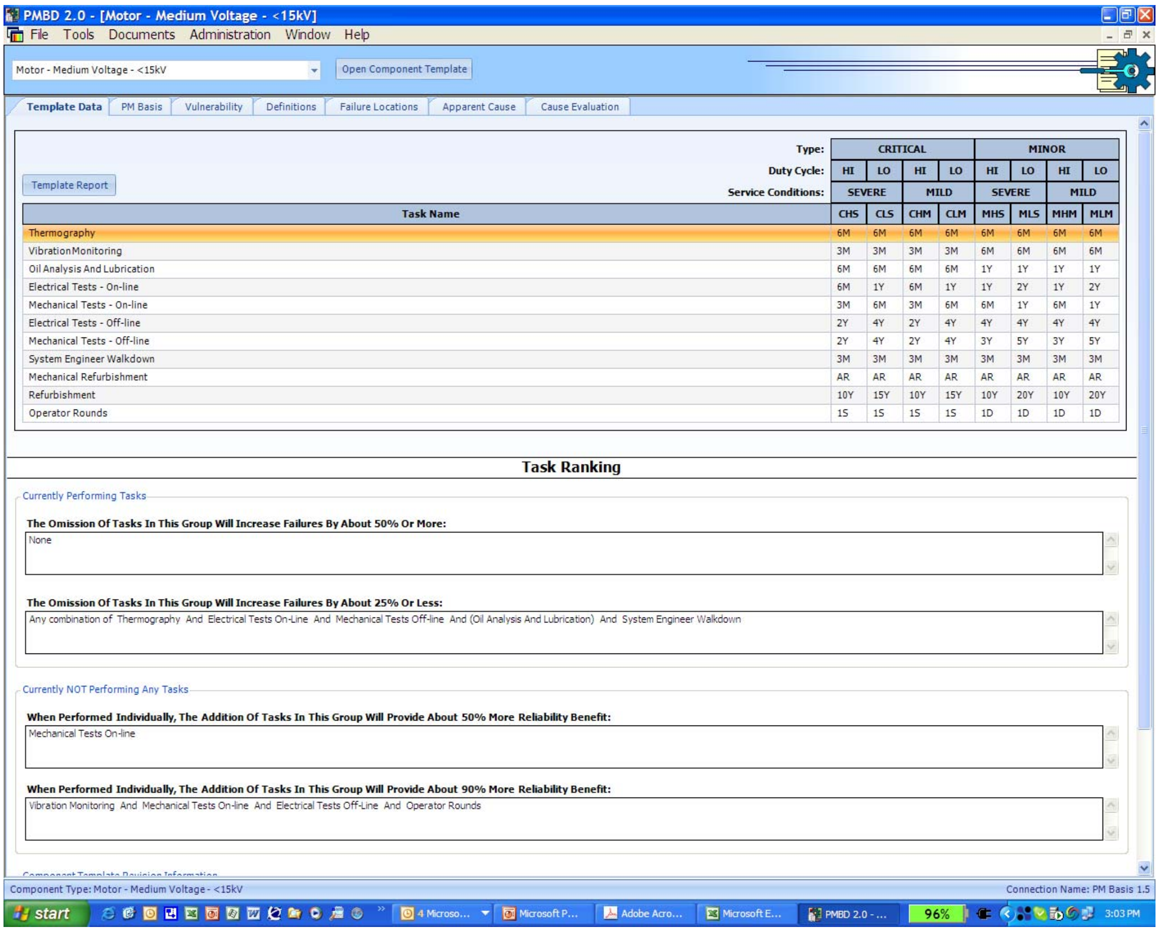

Figure 4.A-1
Screen Shot from the EPRI PMBD That Illustrates the Preventive Maintenance Template Developed for Medium-Voltage Motors

Each task should have a description and details of the steps required and the basis for these steps, as illustrated in Figure 4.A-2.

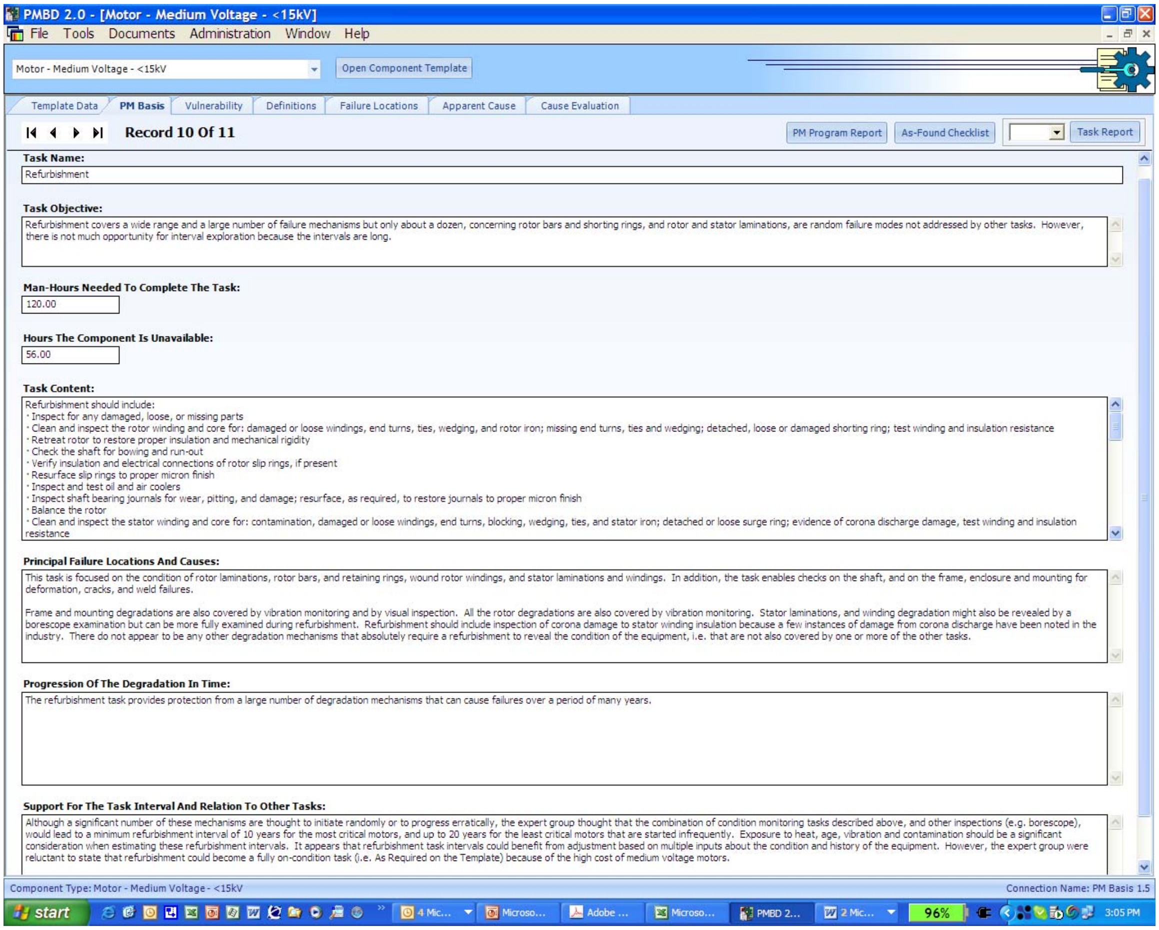

Figure 4.A-2
Screen Shot from the EPRI PMBD That Illustrates the Steps Required to Perform a Preventive Maintenance Task

Appendix 4.B – Relationship Between Spare Parts and Equipment Reliability

The following is excerpted from EPRI report 1011861, *Nuclear Maintenance Applications Center: Considerations for Developing a Critical Parts Program at a Nuclear Power Plant.* It demonstrates the relationship between spare parts and equipment reliability.

> A key concept that needs to be appreciated before beginning a critical parts program is the interface between that program and the site's ER efforts. In theory, the dollars and effort spent on enhancing ER should reduce the risk of equipment or plant unavailability by reducing or eliminating failures of critical components, as shown in Figure 4.B-1.

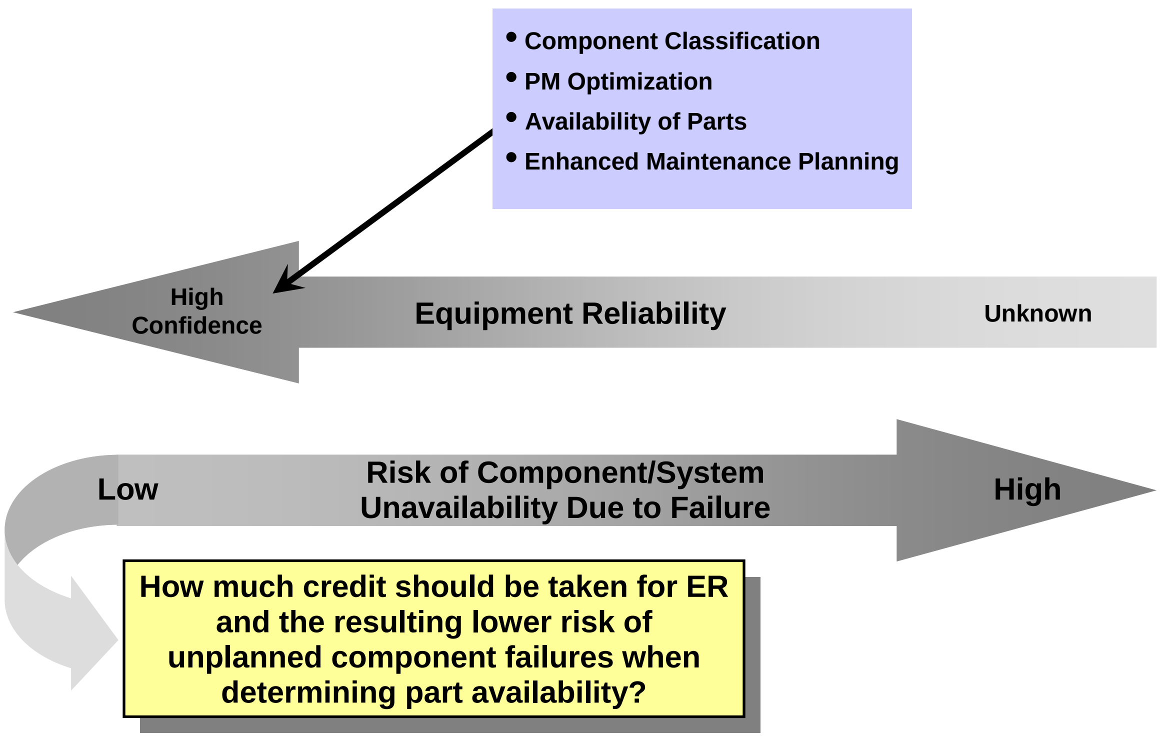

Figure 4.B-1
ER and the Resulting Risk of Component Unavailability (Figure 1-2 from EPRI report 1011861)

> Taking full account of the ER would, in theory, negate the need for replacement items (spare components and parts) associated with unplanned equipment failures and related corrective maintenance. However, this approach is risky because in spite of the best efforts to enhance ER, some equipment will still fail; subsequently, corrective maintenance will be needed.
>
> The supplier should have a comprehensive bill of materials (BOM) associated with critical and important components along with accurate part-level information associated with that BOM, which can be a good starting point for establishing the scope of items

that should be categorized as needed to support PM tasks. If a BOM is used as the starting point for identifying the scope of parts to undergo categorization, the scope can be refined by limiting the BOM listed items to be categorized to those needed for PM activities.

The following questions should be used to identify critical spare parts for critical and important components:

- Are intrusive PM activities performed on the component (critical or important) while the component is installed in the plant?
- Can the failure of the part impact the function of the host component?

If the answer to both questions is *yes*, the part is critical.

Appendix 4.C – Extraction of PMBD Module Elements from the PMBD Software

The EPRI PM module for the component being procured should be provided to the vendor as an example of what the end product should consist of. The following are the essential elements of an EPRI PM module:

- Equipment degradation table
- PM task descriptions and effectiveness ratings
- PM templates

When using EPRI report 1014971, *PM Basis Database V2*, routinely use the "update" function to download new components and revisions to component files.

- Under Administration, select "Download from EPRI" to view new files available for download.

Extraction of the three key elements—the degradation table, PM task content and effectiveness, and PM templates—can be accomplished as follows:

Degradation table (with task effectiveness data):

1. Click on the Vulnerability tab.
2. Click on "Perform Calculation."
3. Select "CHM" under "Select a Template Category."
4. Click on "Calculate."
5. Click on "Component Degradation Table."
6. After the component degradation table appears, it can be exported to Excel or XML.
7. This exported content contains the degradation table as well as the task effectiveness for the prescribed program task and intervals.

PM task descriptions:

1. Click on the PM Basis tab.
2. On the dropdown list next to "Task Report," select "All."
3. Click on "Task Report."
4. From here, the task description can be exported.

PM task template:

1. Click on the Template Data tab.
2. Click on the "Template Report" button.
3. From here, the template data can be exported.

Note: Contact the program manager for the EPRI Nuclear Maintenance Applications Center (NMAC) through www.epri.com or askepri@epri.com for information on potentially simpler methods to access the contents of the EPRI PMBD.

5 VENDOR CORRECTIVE ACTION DURING PROCUREMENT

5.1 Scope of Vendor Corrective Action

It is assumed that nuclear safety requirements for procured items are properly in place. The content of this section is focused on equipment designated as critical and important from an ER and plant performance perspective.

This section covers the application of corrective action programs (CAPs) in the procurement phase of a new plant project for the overall strengthening of the plant's ER. Specifically, it addresses the use of OE in the procurement phase and the management of the procurement phase CAP so that it is effective.

5.2 Recommendations for Vendor Corrective Action in ER-Related Procurement

5.2.1 General

- The term *corrective action program,* or *CAP,* as used in this report encompasses classical problem identification and resolution (PI&R) programs, nonconforming reporting systems, and defect trending.
- Industry expectations as documented in NEI 08-02, Problem Identification and Resolution for New Nuclear Plants During Construction, should be studied by users of this guidance and used as applicable.
- When procuring ER critical components, appropriate CAP program requirements should be imposed on primary and subtier suppliers.
- These requirements should address defects identified on similar equipment and should not be limited to the scope of supply for the immediate project.
- These requirements should also address the supply chain defects identified by the vendor (including inspections necessary to detect supply chain defects).
- Lessons learned from the operation of procurement-related CAPs within the project are to be shared freely with other groups within this and other projects (including projects in design, construction, startup, or initial operation phases) and with industry lessons-learned collection organizations such as EPRI and the Institute of Nuclear Power Operations (INPO).

- When necessary, lessons learned can be written so that information on the issue is disseminated without compromising proprietary information.
- To share OE internationally, contact should be made with projects located outside the United States.

5.2.2 Corrective Action Programs

- Supplier organizations might not have developed the rigor and thoroughness of CAPs in operating nuclear plants. As part of the procurement process, organizations should be diligent in ensuring that necessary CAP processes exist within the supplier's organization and that they are being effectively implemented. This might require mentoring of the selected vendor by the procuring organization.
- It is important for the CAPs of various levels of suppliers for a specific project to be linked. ER procurement-related issues identified through linkages with other project organizations' CAPs should be screened and addressed.
- Appendix 5.A provides an expanded discussion on linkage among CAPs.
- Procurement activities might include the audit of supplier and subtier supplier compliance by various industry, owner, and regulatory groups. Problems identified during these audits should be entered into the supplier's CAP and monitored to identify adverse trends by supplier, component type, application, and so on.

5.2.3 Use of Operating Experience

- OE that evolves from other new plant procurement activities (including international ones, where possible) should be screened and incorporated.
- Appendix 5.B presents a list of procurement-related OE sources and examples of their use.
- Receipt inspection of procured items is an important element that ensures that materials and components comply with design requirements and therefore maintain the required design margins. Deficiencies identified during this process should be entered into the CAP process for proper disposition and action to prevent recurrence of the problem.
- OEs and lessons learned from end-of-life procurement, installation, and operation of replaced plant equipment, such as power transformers, generators, heat exchangers, and large motors, should be reviewed and addressed as appropriate.

5.3 References

NEI 08-02, Problem Identification and Resolution for New Nuclear Plants During Construction

Appendix 5.A – Linkage Among Corrective Action Programs in Procurement Space

5.A.1 Expanded Discussion on Linkage Among Corrective Action Programs in Procurement Space

- New plant projects involve several levels of responsibility and accountability; owners, nuclear steam supply system (NSSS) suppliers, engineering, procurement and construction contractors, equipment suppliers, and construction subcontractors will each have some or all aspects of a PI&R program (that is, a CAP).
- Organizations supplying services or components that do not have a formal CAP process in place should have a process in which identified deficiencies are entered into a linked organization's CAP system.
- Linkage among these CAPs is intended to ensure that identified ER-related issues are shared to allow programs with broader project responsibilities to fully evaluate the extent of condition.
- In procurement space, it is particularly important that conditions identified by CAPs across the project are reviewed for procurement significance. Following are examples of procurement significance:
  - Fraudulent material identified by one equipment supplier receipt inspection might be present in material from other project suppliers.
  - Project receipt inspection report trends at the module fabrication location might highlight actions needed to preclude similar defective shipments made directly to the construction site.
  - Performance testing defects identified for one component might exist for others.
- Ensure that procurement-related items of note are entered into the related project organization's CAP. The following techniques might be used to achieve the linkage to identify procurement-related items of note:
  - Ensure that active CAPs within the project send to the responsible organizations CAP items identified as *vendor, shipping, supplier, and other like classifications.*
  - Ensure that active CAPs within the project send to the responsible organizations corrective actions that list *vendor or supplier.*
  - Assign a procurement-experienced person to review trends and defects documented in other project CAPs for procurement-related significance.

Appendix 5.B – Procurement-Related Operating Experience

5.B.1 Examples of Procurement-Related Operating Experience Use

- Plant root cause evaluations determined that scars on extraction steam metal expansion joints resulted in premature in-service failures. Procurement specifications, vendor handling instructions, and warehouse handling instructions were revised to eliminate scarring and other distress to metal expansion joints.
- The initial operation of the vertical service water pump on Unit 1 showed vibration above acceptable long-term operating levels. Stiffeners were added to the motor support skirt to bring the vibration within the desired range. Details were communicated to the manufacturer so that the Unit 2 pumps would be correct from the factory.
- Circulating water pump impellers were designed to be a certain thickness at the beginning of each volute. The actual thickness was much smaller. Impellers self-destructed after a short time (less than a month) because of the less-than-adequate minimum wall thickness in the beginning stages of each volute. Details were communicated to the manufacturer. Additional in-process inspections were put in place to prevent the problem on pumps under fabrication for other projects.

5.B.2 Sources of Procurement-Related Operating Experience

- EPRI report 1016195, *Program on Technology Innovation: Utility Requirements Document—Revision 9, Web Application and Technology Transfer*. Successful execution of large capital projects such as nuclear power plants depends on a concise vision, mission, and set of goals. The EPRI Utility Requirements Document (URD) provides a clear set of project requirements from the utility perspective, enabling more effective communication with NSSS vendors regarding expectations.
- EPRI Nuclear Maintenance Applications Center (NMAC) maintenance guides for specific components. NMAC documents provide a wealth of industry experience focused on specific components. During procurement, they should be consulted for OE and maintenance issues of critical components. EPRI report 1016388, *Nuclear Maintenance Applications Center: Complete Product List (February 2008)*, contains a list of all NMAC guides.
- EPRI report 1016537, *Program on Technology Innovation: Advanced Nuclear Technology—Component Margins and Monitoring Database*. The Design Margins and Performance-Monitoring Guidelines Database identifies factors that create or reduce equipment margins so that these factors can be accounted for in new designs. Also identified are system parameters that could enable condition assessment to maximize equipment availability and reliability and reduce operation and maintenance costs.
- NRC letters to utilities (see www.nrc.gov for NRC-related documents). Generic letters request that addressees 1) perform analyses or submit descriptions of proposed corrective actions regarding matters of safety, safeguards, or the environment and submit in writing that they have completed the requests with or without prior NRC approval of the action; 2) submit technical information that the NRC needs in order to perform its functions; or

3) submit proposed changes to technical specifications. By a generic letter, the NRC may also 1) provide the addressees with staff technical or policy positions not previously communicated or broadly understood or 2) solicit participation in voluntary pilot programs.

- NRC reactor safety focus areas. As part of OE monitoring, the NRC will periodically encounter certain reactor systems or management areas that could be improved. Currently, the NRC is working to improve and upgrade the following focus areas related to safety:
  - Control room habitability
  - Davis-Besse reactor vessel head degradation
  - Fire protection
  - Fitness-for-duty programs
  - Access authorization programs
  - Human factors
  - Operating reactor maintenance effectiveness
  - Multiple or repetitive degraded cornerstone column
  - PWR sump performance
  - Reactor pressure boundary integrity issues for PWRs
  - Reactor vessel integrity
  - Steam generator action plan
  - Groundwater contamination (tritium)
- NRC Reactor Operational Experience Results and Database. The NRC conducts risk studies of its reactor safety focus areas and compiles the results. The results and databases are available on the NRC website.
- NRC operating reactor oversight, including results. The reactor oversight process for power reactors uses a variety of tools to monitor and evaluate the performance of commercial nuclear power plants. The process is designed to focus on plant activities that are most important to safety.
- NRC events assessment. Each licensee must send information to the NRC about certain "reportable events" that occur at their facility or during the licensee's use of nuclear materials. The reported events are reviewed at NRC headquarters by a group of technical experts using plant-specific risk insights and OE to identify significant weaknesses in plant design, operation, or equipment. When problem areas are identified, the NRC coordinates the appropriate level of inspections with the regional offices to reach a satisfactory resolution. In certain cases, these reported events are addressed through generic communications to the industry and other interested or potentially affected parties and are made available to the public through the web.

6 SELF ASSESSMENT OF PROJECT EQUIPMENT RELIABILITY HEALTH

6.1 Scope

Effectively incorporating ER principles and details during the procurement phase of a project will pay maximum dividends throughout the project and when the plant begins power production.

This section contains the ER health self assessment modules for the procurement portion of a new plant project. In addition to the modules, general information on the logic and mechanics of self assessment are provided.

6.2 Why Self Assess?

Self assessment is simply a process by which an organization can determine that it is accomplishing the expectations and standards it has set for itself.

The management of any organization will establish expectations, standards, and goals that are linked to the goals of the greater project. These are normally translated into procedures, instructions, and documented processes. Managers "expect" that these are implemented; self assessment is an internal process for evaluating or "inspecting" what is actually happening.

Self assessing allows any level of management, supervision, or professional involvement to gauge the performance of their organization in a manner that allows them to take corrective actions and improve performance.

6.3 Self Assessment Fundamentals

The following are insights and concepts concerning self assessment that will allow anyone in a project organization to successfully accomplish a self assessment:

- The purpose of self assessment is to determine whether the expectations for the work being performed by any portion of a project are embedded in its organization and operating structure and are in fact being accomplished.
  - If the expectation is not embedded and/or is not being accomplished, the expectation needs to be changed or the condition corrected.

- Self assessments are typically accomplished by a small team (two to three people) from within the group being assessed, supplemented as needed by external persons for expertise and/or perspective. A typical self assessment will last from two to five days. The actual assessment is supplemented by one to two days of preparation and one day to finalize the report.
  - It is sometimes valuable to have members of one group (for example, procurement engineering) assess those of another group (for example, vendor oversight) within the same overall organization.
  - Self assessments should have a plan, include conclusions, and identify recommendations and action items with follow up. These basic aspects should be documented in a final report.
  - Activities consist of interviewing group members involved with the topic of interest and looking at related completed or in-progress work.
  - The team will assemble statements of fact (not opinions), look for common areas of concern among the facts, and draw conclusions. Frequent (daily) roll-up of the facts during the assessment causes the team to pursue additional information to refute or confirm its preliminary conclusions. Conclusions documented in the final report should be accompanied by the supporting facts.
- Successful self assessments have schedules for their conduct and due dates for completion of the recommendations and action items.
- Having an organization and individuals who are willing to be self critical brings about the greatest value from the exercise of self assessment.
- Starting an assessment plan with detailed, specific concerns extracted from industry OE and from the project CAP helps the assessment team and those being interviewed to focus.

6.4 Procurement-Related Self Assessment Modules

These self assessment modules are based directly on the content of this report. The modules are intended to be an aid. They are not intended to be all inclusive and should be added to and adjusted as needed to serve the objectives of the assessment being conducted. The questions posed in the self assessment modules are intended to be mental prompts and are not a substitute for the recommendations contained in the report. If there is any conflict between the self assessment modules and the report, the report is considered to be correct.

The following self assessment modules will allow owners, NSSS vendors, and EPC contractors and subcontractors to gauge the ER health of their area of accountability in the procurement portion of a new nuclear plant project.

- Appendix 6.A – Component Classification
- Appendix 6.B – Component Monitoring
- Appendix 6.C – Preventive Maintenance
- Appendix 6.D – Corrective Action

Each module is organized as follows:

- Report section (of interest)
  - Topics (within the section)
    - Focus areas (within each topic)
      - Objective (being assessed)
        - Sample questions (to extract facts on the objective and/or focus area)

6.5 References

EPRI report 1021415, *Advanced Nuclear Technology: Equipment Reliability for New Nuclear Plant Projects: Industry Recommendations for Design*

EPRI report 1021416, *Advanced Nuclear Technology: Equipment Reliability for New Nuclear Plant Projects: Industry Recommendations for Procurement* (the current report)

EPRI report 1021413, *Advanced Nuclear Technology: Equipment Reliability for New Nuclear Plant Projects: Industry Recommendations for Storage, Construction, and Testing*

Appendix 6.A – Component Classification (Procurement) Self Assessment Module

Note: The assessment questions included in this appendix fall into two general categories: those that assess core principles of the guidance within this report are designated with a **(P)**; those that assess implementation are designated with an **(I)**.

The content of Section 2 of the current report should be studied and used in conjunction with this module.

Topic 1: Identification and Use of Component Classification by Supplier

Determine whether component ER classification is part of the procurement process and whether suppliers are made aware of these requirements and are using the concepts and requirements.

Focus Area 1: Communications and Supplier Understanding of ER Expectations

> Effective communication about ER expectations between the design and procurement groups of the project and the selected vendors providing equipment and services related to ER is crucial.(Section 2.2.1)
>
> The procuring group should treat every vendor of ER-related components as though it is not proficient in providing material and components for a nuclear plant. Each vendor should be assumed to not fully understand the requirements for the application of components in nuclear plants and the documentation requirements until their performance proves otherwise. This is a direct lesson learned from both the existing nuclear fleet and new nuclear plants currently under construction. (Section 2.2.1)
>
> In some cases, the procuring organization may have to help the suppliers achieve compliance. (Section 2.2.1)

Objective: Determine how the design and procurement organizations ensure that potential and actual vendors are aware of and implement ER requirements.

Sample questions:

- Do the design specifications used for procurement define and identify the concepts of ER critical and important components? **(P)**
- How are vendors trained or indoctrinated on ER requirements? **(I)**
- Are orientation material and training provided to the vendors? **(I)**
- Are personal interactions undertaken to ensure understanding? **(I)**
- Are vendor programs reviewed to ensure that ER requirements are addressed and accomplished, not only in house, but also where applicable at the subtier supplier level? **(P)**
- If selected vendors are chosen, does the procuring organization make personal contact with the suppliers to mentor and ensure that an understanding of ER requirements is instilled? **(I)**

Focus Area 2: Application of Component Classification

All critical and important components are not equal. A graded approach can be used in determining the appropriate level of attention needed by a component during the procurement phase. (Section 2.2.1)

In addition to all other normal requirements, specifications should contain the following topics important to ER. (Section 2.2.2)

Objective: Determine whether procurement specifications are clear in delineating ER requirements.

Sample questions:

- Do procurement specifications identify that the subject of the specification is a critical or important item for the plant and the primary functions it will need to accomplish? **(P)**
- Are the ER functions and expectations clearly identified? **(P)**
- How are ER critical functions delineated and tracked to ensure that they are met? **(I)**
- Does a requirement to develop a list of projected failure events of the piece parts of the item exist in procurement documentation? Note that this will drive the preventive maintenance (PM) recommendations for the component, which will be addressed later. **(P)**
- Do procurement documents require PM (both time-based and predictive) or other mitigation tasks (for example, inspections) necessary to prevent or identify each failure from the supplier? **(P)**
- Are maintenance instructions necessary to implement the PM tasks required to be provided? **(I)**
- Is the supplier required to provide maintenance instructions necessary to accomplish corrective tasks? **(I)**
- Is a critical spares list, which would be necessary to accomplish the preventive and corrective tasks, required to be supplied? **(P)**
- Are factory functional test requirements, including witnessing of tests, acceptance criteria, and submittal of test plans for approval, included in procurement agreements? **(P)**
- Are project documentation requirements and a required documentation submittal schedule for the item included? (See final documentation requirements in Section 2.2.4.) **(P)**

Focus Area 3: Procurement Control and Documentation

Requests for proposal (RFPs) differ in structure and content. The ER-related recommendations discussed in the following paragraphs addressing bid lists, specifications, and proposal evaluations should be incorporated where applicable in RFPs. Where they are incorporated is not as important as ensuring that they are incorporated. (Section 2.2.2)

Objective: Determine whether ER requirements and expectations are being identified at the RFP stage.

Sample questions:

- Do RFPs for ER critical and important components identify that the equipment being requested is such (that is, critical or important), and do they contain details on the requirements? **(P)**
- Are provisions for supporting the equipment if the OEM decides to discontinue support for the product provided in the procurement documents? (These should include a complete set of design and manufacturing information held in escrow.) **(P)**
- Are procurement deliverables requested in a format that can be easily migrated into the planned or existing asset management (information) systems for the plant? **(P)**
- Do procurement documents contain requirements that the vendor notify the procuring group when changes are made to material or margins that could affect component performance or its lifetime? **(P)**
- Is an ER-related procurement checklist, similar to the one contained in Appendix 2.D of this report, completed during the project? **(I)**
- Do procurement documents require that any subcontracts planned for the work are identified? **(I)**
- Are the selected vendors required to notify the procuring organization of any new subcontracting after award? (ER requirements should be passed down to each subcontractor.) **(P)**

> Specific attention is needed in establishing the bidders list, preparation of specifications, and evaluation of bids. (Section 2.2.2)

Objective: Determine how the procuring organization is controlling vendor qualifications and procurement documentation, including ER requirements, and factoring these into bid evaluations.

Sample questions:

- Are bidders lists subjected to greater scrutiny for components that are ER critical or important to the plant? **(P)**
- Are only vendors with a track record of successful nuclear application of the components being considered? **(I)**
- Is it a practice of the procuring organization to contact members of projects who have recently used the potential vendors and question them about the vendor's performance, especially as it relates to quality? **(I)**
- Do appropriate personnel understand the portions of the work that will be performed in the vendor's shops and those that will be subcontracted and know to question any sub-subcontracting? **(I)**
- Is the number of bidders limited to the qualified few? **(I)**
- Are visits made to potential vendors to review and observe their operations? **(I)**

RFPs should contain an ER requirements table. Bid evaluations should be structured so that any deviations by a bidder to ER requirements are visible and called to the attention of the owner. (Section 2.2.2)

Objective: Determine how bids covering ER critical and important components are evaluated.

Sample questions:

- Does the procuring organization use a standard ER requirements evaluation table? (See Appendix 2.B for an example table.) **(P)**
- Are all bidders required to complete the table for their bid, displaying their extent of compliance with ER requirements of the specification and the RFP? **(I)**
- Are the bids reviewed by an evaluator with ER experience and knowledge? **(I)**
- Is the owner notified of vendor exceptions to ER requirements? **(P)**

Focus Area 4: Use of Industry Experience

A number of industry initiatives for improving the quality of procured items for the current fleet have been undertaken. (Section 2.2.1)

Objective: Determine whether industry experience is being evaluated and used by the procuring organizations.

Sample questions:

- Is the procuring organization familiar with references cited in this report? **(I)**
- How does the procuring organization become aware of industry OE and factor it into its procurement process? **(I)**
- Does it monitor current industry OE, and how are these events identified and tracked to ensure that they are factored in as required? **(I)**

Focus Area 5: Single-Point Vulnerability Management

During detail design of a procured component consisting of multiple subcomponents, a single-point vulnerability (SPV) analysis should be accomplished and documented. Single-point vulnerabilities are conditions that could defeat the primary functions of the component. (Section 2.2.3)

Objective: Determine whether SPV considerations are being included for ER critical and important components.

Sample questions:

- Do procurement documents require an SPV analysis to be performed to the subcomponent level for ER critical and important components? **(P)**
- How are the results of this analysis reviewed by the procuring organization and owner's representatives? **(I)**
- Is this review a formal part of the process, and are the results documented? **(P)**

> Where possible and practical, SPVs should be eliminated if the elimination results in a greater level of equipment reliability. SPVs remaining that could defeat the primary functions of the procured component should be identified to the procuring organization for acceptance. Mitigating steps for SPVs (for example, PM and inspections) should be recommended by the vendor. (Section 2.2.3)

Objective: Determine whether SPVs are eliminated when identified. Alternatively, if they are left in, determine how they are mitigated.

Sample questions:

- Are SPVs that remain in the design documented and tracked to resolution? **(P)**
- If they are allowed to remain, how does this factor into final design and operational guidelines? (For example, is it entered into the project corrective action process?) **(I)**
- When mitigation steps or recommendations are established, how are they tracked to ensure implementation? **(P)**

Focus Area 6: Component Monitoring Input by Vendor

> The vendor should recommend variables, monitoring points, and set points for predictive maintenance trending. The EPRI report 1016537, *Program on Technology Innovation: Advanced Nuclear Technology—Component Margins and Monitoring Database* should be considered for minimum monitoring requirements for specific components. (Section 2.2.3)

Objective: Determine whether supplier inputs on condition monitoring are being provided and factored into the final design.

Sample questions:

- Are equipment suppliers required to provide recommended predictive maintenance? **(P)**
- How are EPRI and industry guidance being used to establish parameters that will be monitored in the final design? **(I)**
- Are the equipment suppliers including in the design of the equipment being supplied the necessary design features to accomplish predictive maintenance they are recommending. **(I)**
- Is owner review and approval being obtained for these parameters and installed capabilities? **(P)**

Topic 2: Manufacturing Controls and Vendor Oversight

Determine whether adequate manufacturing controls are being implemented for ER critical and important components as delineated in procurement requirements and consistent with industry guidelines and practices.

Focus Area 1: Control of Materials

> Receipt inspection by the manufacturer of raw materials and subassemblies to ensure that manufacturing requirements are being met should be required. (Section 2.2.3)
>
> Deviations and proposed deviation resolutions occurring during manufacture (including assembly/field installation) involving critical and important ER functions should be reviewed by the procuring organization. An approval process for deviations that impact primary functions and other attributes that are associated with the basis for the system, structure, or component (SSC) being classified as critical should be established by the procuring organization with the supplier organization. (Section 2.2.3)

Objective: Determine whether supplier programs for ER components provide for increased focus during material receipt, storage, and fabrication processes.

Sample questions:

- Does the supplier's program (for ER critical and important components) provide for increased scrutiny, not just of the final product, but also throughout the manufacturing process? **(P)**
- Does the program identify components, subcomponents, and raw materials as being ER components throughout the manufacturing process? **(I)**
- Are deficiencies factored into the corrective action process? **(I)**
- Are raw materials and subcomponents stored in a manner consistent with ER component requirements? **(I)**

Focus Area 2: Oversight of Component Manufacture

> During the pre-award stage of the procurement, hold points in the design and manufacturing process for technical review and quality purposes should be reviewed for adequacy. Hold points of ER significance should be selected for witnessing by the procuring organization. (Section 2.2.4)
>
> The functional test should be approved by and witnessed by the procuring organization. (Section 2.2.4)

Objective: Determine whether hold points are being established for design and manufacturing processes at selected suppliers.

Sample questions:

- Do procurement requirements (prior to the awarding of contracts or purchase orders) call for the establishment of design and inspection points to ensure that ER requirements are being met? **(P)**
- Does the procuring organization establish inspection points for ER critical and important components? **(I)**
- Are shop functional testing hold points established for the test plan and for witnessing the test? **(I)**
- How are the results of these hold points documented and tracked to acceptance? **(I)**

> Source inspection guidelines highlighting ER-significant topics should be documented in a formal plan (the plan does not need to be specific to ER as long as ER requirements are covered) and should include the required detail for the following areas (see Appendix 2.C for additional vendor surveillance activities). (Section 2.2.4)
>
> The owner's acceptance reviews of the required vendor design deliverables related to ER should be accomplished by experienced, qualified reviewers. (Section 2.2.4)

Objective: Determine whether vendor inspections are adequately verifying that ER requirements are being met.

Sample questions:

- Do vendor inspections verify that the contents of the ER requirements table (see Section 2.2.3) are accomplished? **(P)**
- Do procuring organization's representatives witness vendor processes, including manufacturing processes? **(I)**
- Are witness testing and inspection results documented, and are these results retained as permanent records provided to the owner? **(I)**
- Do source inspections include a review of supplier design documents and drawings for compliance with procurement requirements? **(I)**
- Do source inspections review and audit manufacturer procedures and implementation? **(I)**

Focus Area 3: Vendor Corrective Action Program

> The vendor's problem identification and resolution processes should be evaluated, and entries related to the manufacture of the subject item(s) in the past several years should be reviewed. Any current human performance issues that might affect manufacturing of the items being procured should be reviewed. (Section 2.2.4)

Objective: Determine whether a corrective action program (or similar activity) is being implemented at the supplier level for ER components.

Sample questions:

- Does the supplier include ER critical and important components in its problem identification and resolution process? **(P)**
- How are past manufacturing problems on similar components factored into your project for ER critical and important components? **(I)**

Focus Area 4: Receipt Inspection of Vendor-Supplied Items

> The development of receipt inspection (for use at the job site) and source inspection (for the release of equipment to ship) guidelines will aid in ensuring the quality of vendor-supplied items. The assistance of equipment subject matter experts (SMEs) is essential in preparing effective receipt and source inspection templates. (Section 2.2.4)

Objective: Determine whether receipt and source inspections are being performed in accordance with established guidelines and by knowledgeable individuals.

Sample questions:

- Does the procuring organization use a structured process (including procedures and qualified personnel) to conduct receipt and source inspections for ER critical and important components? **(P)**
- Are SMEs or persons knowledgeable in ER-related equipment used for these inspections? **(I)**
- Are checklists that promote consistency, standardization, and documentation in inspection methods and content used for these inspections? **(I)**

Focus Area 5: Vendor Records and Documentation

> Deliverables should include, as a minimum, the data and information required to support the equipment throughout its lifetime. (Section 2.2.4)

Objective: Determine whether documentation and records ensure that ER requirements are met.

Sample questions:

- Do the records received for ER critical and important components contain OEM and part number information for each component along with complete bill of material information for each component? **(I)**
- Does the documentation package, prepared by the vendor, contain the ER required information identified in this report? (See Section 2.2.4 of this report.) **(I)**

Appendix 6.B – Component Monitoring (Procurement) Self Assessment Module

Note: The assessment questions included in this appendix fall into two general categories: those that assess core principles of the guidance within this report are designated with a **(P)**; those that assess implementation are designated with an **(I)**.

The content of Section 3 of this report should be studied and used in conjunction with this module.

Topic: *Philosophy on Component Monitoring of ER Components*

Determine whether actions recommended during the procurement phase of the new plant project are being implemented to ensure that ER performance monitoring objectives and requirements are accomplished.

Focus Area 1: Implementation of Design Requirements for Component Monitoring

> During the basic design phase, expectations were established for the project's infrastructure for performance monitoring and for the monitoring of individual systems and components. It is essential that these expectations are translated into individual procurement documents (specifications, requests for proposal [RFPs], and contracts). (Section 3.2.1)
>
> The project should maintain visibility of ER performance monitoring requirements to ensure that the project expectations as detailed in the performance monitoring functional description and specification are translated into project design and procurement documents (see Appendix 3.A for an example). (Section 3.2.2)
>
> The ER performance monitoring requirements should be periodically reviewed by the design team and with the project owner to ensure that the requirements are being effectively implemented on the project. (Section 3.2.2)

Objective: Determine how design requirements for the monitoring of ER critical and important components are being translated to procurement requirements.

Sample questions:

- Is there a clear line of sight for the implementation of ER monitoring requirements for the project? Can the requirements be linked from the performance monitoring functional description to the implementing specifications, design documents, and vendor implementation documents? **(P)**
  - Review equipment specifications for the inclusion of monitoring details and requirements.
  - Review vendor evaluations and inclusion of the monitoring requirements in the final vendor design. How is compliance tracked? (See Appendix 3.A and 3.B.)
  - Review the resolution, documentation, and acceptance of exceptions to the requirements

Information should be provided to each involved vendor to help them understand how their scope of supply fits into the project's overall performance monitoring functional specification. This allows vendors to raise compatibility and interface concerns. (Section 3.2.2)

ER performance monitoring requirements should be established for each contracted portion of the plant's performance monitoring capability (see Appendix 3.B for an example). The requirements for the contracted scopes should connect back to and fulfill the expectations of the project-wide requirements discussed previously. (Section 3.3.3)

Component-specific monitoring requirements should be established by the vendor.

Vendors should use service advice and other OE available to them when establishing monitoring recommendations.

Recommended monitoring requirements for 25 components are contained in EPRI report 1016537, *Program on Technology Innovation: Advanced Nuclear Technology—Component Margins and Monitoring Database* (see Appendix 3.C for examples). (Section 3.3.3)

Objective: Evaluate vendor awareness of the project expectations for monitoring the capability of ER critical and important components. Ensure that the vendor is establishing component-specific monitoring requirements.

Sample questions:

- Are vendor personnel (design and manufacturing) aware of the requirements outlined in the design specifications? **(I)**
- Are meetings being conducted (or have they been conducted) to discuss design requirements and expectations with the vendor? **(I)**
- Does the vendor have an understanding of the way in which monitoring data will be used and how the data integrate into plant operations? **(I)**
- Is the vendor using service advice and operating experience to establish monitoring recommendations? **(P)**
- Is the supplier aware of the recommendations contained in the report referenced in Appendix 3.C, and how are these recommendations being used to influence the final design? **(I)**

Appendix 6.C – Preventive Maintenance (Procurement) Self Assessment Module

Note: The assessment questions included in this appendix fall into two general categories: those that assess core principles of the guidance within this report are designated with a **(P)**; those that assess the implementation are designated with an **(I)**.

The content of Section 4 of this report should be studied and used in conjunction with this module.

Topic 1: Vendor Involvement in Development of Preventive Maintenance Program

Determine whether vendor involvement is used in the development of preventive maintenance (PM) requirements and future plant maintenance needs.

Focus Area 1: Input from Component Suppliers

> Procurement specifications for plant components should clearly define and require the elements of PM task identification, frequency, and basis. Appendix 4.A provides the detailed steps that are recommended. (Section 4.2)
>
> Where one exists, the EPRI PM module for the component being procured should be provided to the vendor as an example of what the end product should consist of. (Section 4.2)
>
> Special effort will be required to ensure that suppliers understand and provide the information to support and implement an effective PM program. (Section 4.2)

Objective: Determine whether vendor input has been required and used to establish PM recommendations for ER critical and important components.

Sample questions:

- Do procurement documents require the vendor to provide deliverables as identified in Appendix 4.A? **(P)**
- Has this process been established by the vendor? Is it being implemented? Will or does it result in useful and effective PM task identification? **(I)**
- Do the following essential PM deliverables exist? **(P)**
  - Equipment degradation table
  - PM task descriptions and effectiveness ratings
  - PM templates
- What sort of information, training, and/or indoctrination was or will be used to inform the supplier of the PM requirements to promote consistency and completeness on the project? **(I)**

- Were existing EPRI PM modules used to provide an example and baseline for the PM task identification? **(P)**
- Do the PM tasks address these anticipated failure mechanisms? **(P)**

Focus Area 2: Maintenance Instructions

> The typical practice for vendors in the past has been to supply manuals that provide operational and maintenance information in random formats. For new plants' components, additional direction should be provided to the vendors to aid in populating the plant's maintenance program. (Section 4.3)
>
> The requirement to provide detailed maintenance instructions should be included as part of the procurement documentation. (Section 4.3)
>
> Special training requirements needed to perform maintenance tasks should also be identified. Recommendations on training material content and mockups should be provided. (Section 4.3)

Objective: Determine whether vendor input has been required to support the development of maintenance instructions that will be used to maintain ER components during plant operations.

Sample questions:

- Are detailed maintenance instructions (both preventive and corrective; not merely generic manuals) required (in procurement documents) to be provided by the component suppliers? **(P)**
- Are the instructions being provided in a format that will support the timely preparation of maintenance procedures and instructions? **(I)**
- Are the instructions being provided when the equipment is shipped to support storage and preoperational PM tasks? **(I)**
- Does the content of the PM instructions planned or provided match the PM task scope and content established by Appendix 4.A? **(P)**
- Has a standard format for maintenance instructions been established for the project and used to promote consistency and ease of translation into plant procedures and documents? **(P)**
- Are mockup and training aid recommendations and details included as part of the vendor-supplied items? **(I)**
- Do the procurement documents request information on available training by supplier representatives? **(I)**

Topic 2: Parts and Equipment Required to Support Maintenance

Determine whether parts and equipment needed to support the maintenance of ER critical and important components are being identified and supplied.

Focus Area 1: Identification of Spare Parts

Supply of adequate spare parts is an important maintenance consideration. Spare parts should be recommended by the vendor as part of the deliverables for the initial purchase. (Section 4.4)

The determination of spare parts for critical components should be performed by component suppliers. (Section 4.4)

Lead times should be considered in the development of spare parts lists. (Section 4.4)

Normal, routine maintenance as well as planned refurbishments will require a certain number and type of consumable parts (that is, gaskets, seals, fasteners, and connectors), which should be identified by the supplier and used to establish stocking levels required to support maintenance activities and schedules. (Section 4.4)

Storage requirements for spare parts provided with the equipment should be provided by the suppliers. (Section 4.4)

Objective: Determine whether spare parts for ER components are being addressed "up front" using vendor input.

Sample questions:

- Is the identification of necessary spare parts by the suppliers included in procurement requirements? Does the identification include consideration of factors identified in Section 4.4 of this report? **(P)**
- How are critical spares identified? Is a process used for the identification and how does it compare to that outlined in Appendix 4.B? **(I)**
- Is there a good correlation between the most frequent failure modes and degradation locations for the equipment, the PM tasks, and the spare parts recommended? **(P)**
- Are lead times considered and documented in spare parts determinations and then factored into PM and CM maintenance needs and stocking levels established accordingly? **(I)**
- Are consumables that are required to support routine maintenance identified and documented so that plant personnel can include them in stocking considerations? Was vendor input used for this determination? **(I)**
- How have storage requirements for spare parts been documented and factored into plant warehousing capabilities? **(I)**

Focus Area 2: Identification of Tools and Equipment Required for Maintenance

Maintenance on components sometimes requires special tooling or equipment in order to be effectively performed. These should be identified in the vendor manuals and can be supplied by the component manufacturer. (Section 4.5)

Other tools that are needed might be more standard in nature, not typically supplied by the manufacturer, but nonetheless required for maintenance activities. These can consist of items as listed below, which should be identified early after the procurement agreement process so that they can be incorporated into the final plant design. (Section 4.5)

Objective: Determine whether tools and equipment needed for performing anticipated maintenance have been identified and considered.

Sample questions:

- Are suppliers required to identify special tools and equipment needed to perform maintenance? Has this been done? **(P) (I)**
- Have tool lists or required equipment needed to conduct routine maintenance activities been identified and documented? Has their use (including key cautions) been included in maintenance instructions? **(I)**

Appendix 6.D – Corrective Action Program (Procurement) Self Assessment Module

Note: The assessment questions included in this appendix fall into two general categories: those that assess core principles of the guidance within this report are designated with a **(P)**; those that assess implementation are designated with an **(I)**.

The content of Section 5 of this report should be studied and used in conjunction with this module.

Topic: Vendor Corrective Action Program for ER Critical and Important Components and Incorporation of Industry Operating Experience

Although corrective action programs (CAPs) are often well-established for nuclear safety items, the focus of this module is to determine whether similar focus is being placed on equipment designated as *critical* or *important* from an ER and plant performance perspective. In addition, vendors and suppliers might not always have a full understanding of the requirements of a program other than an in-house quality control program (that is, ISO 9000 or equivalent), so additional focus to ensure understanding and implementation is warranted.

Focus Area 1: Implementation of Corrective Action Programs at Vendors and Suppliers for ER Critical and Important Components

Industry expectations as documented in NEI 08-02, Problem Identification and Resolution for New Nuclear Plants During Construction (Section 5.3.1) should be studied by those using this guidance and used as applicable. (Section 5.2.1)

When procuring ER critical components, appropriate CAP program requirements should be imposed upon primary and subtier suppliers. (Section 5.2.1)

These requirements should also address the supply chain defects identified by the vendor (including inspections necessary to detect supply chain defects). (Section 5.2.1)

Lessons learned from the operation of procurement-related CAPs within the project are to be shared freely with other groups within this and other projects (including projects in design, construction, startup, or initial operation phases) and with industry lessons-learned collection organizations. (Section 5.2.1)

Supplier organizations might not have developed the rigor and thoroughness of CAPs in operating nuclear plants. As part of the procurement process, organizations should be diligent in ensuring that needed CAP processes exist within the supplier's organization and that they are being effectively implemented. (Section 5.2.2)

It is important for the CAPs of the various levels of suppliers for a specific project to be linked. ER procurement-related issues that are identified through linkages with other project organizations' CAPs should be screened and addressed. (Section 5.2.2)

Procurement activities might include the audit of supplier and subtier supplier compliance by various industry, owner, and regulatory groups. Problems identified during these audits should be entered into the supplier's CAP and monitored to identify adverse trends by supplier, component type, application, and so on. (Section 5.2.2)

Objective: Determine whether appropriate CAP program elements are being used at the vendor level (all tiers of suppliers) for ER critical and important components.

Sample questions:

- Because new plant projects involve several levels of responsibility and accountability, including vendors and equipment suppliers, each should have some or all aspects of a PI&R program (that is, CAP) in place. **(P)**
- If the supplying organization does not have a formal CAP process in place, does it have a process that ensures that identified deficiencies are entered into a linked organization's CAP system? **(P)**
- Are deficiencies that are identified across the project reviewed for procurement significance? **(I)**
- The following are examples of procurement significance:
  - Fraudulent material
  - Project receipt inspection report trends at a lower supplier level
  - Performance testing defects identified for one component that might exist for others
- Ensure that procurement-related items of note are entered into the related project organization's CAP. **(I)**
- Are active deficiencies within the project sent to the responsible organization's CAP and identified as *vendor, shipping,* or *supplier* and other like classifications? **(I)**
- Is a procurement-experienced person assigned to review trends and defects documented in other project CAPs for procurement-related significance? **(I)**

Focus Area 2: Use of Industry Operating Experience at Supplying Organizations

OE that evolves from other new plant procurement activities (including international ones, where possible) should be screened and incorporated. (Section 5.2.3)

Receipt inspection of procured items is an important element that ensures that material and components comply with design requirements and therefore maintain the required design margins. Deficiencies identified during this process should be entered into the CAP process for proper disposition and action to prevent recurrence of the problem. (Section 5.2.3)

OEs and lessons learned from the end-of-life procurement, installation, and operation of replaced plant equipment, such as power transformers, generators, heat exchangers, and large motors, should be reviewed and addressed as appropriate. (Section 5.2.3)

Objective: Determine the extent to which vendors and suppliers of ER critical and important components factor industry and company experience into design and manufacturing processes.

Sample questions:

- Are the expectations for the suppliers to use industry operating and manufacturing experience delineated in procurement requirements? **(P)**
- Does the supplier have a process for the identification, review, and implementation of lessons learned as well as input from supplier organizations that pertains to the component being supplied? Review the implementation. **(I)**
- Do the supplying organizations have a formal and documented receipt inspection program for ER components, and is it being implemented? **(I)**
- How does OE filter down through the supply chain for ER components? Is the information passed down through a formal process? Are a response and resolution from the lower tier supplier required? **(I)**

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Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com