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

Advanced Nuclear Technology: Equipment Reliability for New Nuclear Plants Projects: Industry Recommendations for Storage, Construction, and Testing

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PRODUCT DESCRIPTION

Results and Findings

This report contains the results of industry efforts to capture and communicate equipment reliability (ER) lessons learned during the construction and startup phase of a new plant project. This report 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 may choose to emphasize or even require the use of these recommendations.

Challenges and Objectives

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 new nuclear plants. 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 affect ER, making organization of ER recommendations difficult. Therefore, topics are addressed in the phases of the project in which they are encountered. Some cross-referencing between phases may be necessary to fully understand the topic.

The objective of this report is to capture and communicate the ER lessons learned to date as they relate to nuclear plant storage, construction, and startup activities.

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 in the construction and startup of systems, structures, and components for new nuclear plants. This includes suppliers of equipment, materials, and services. It is expected that project organizations will consider each of these recommendations and determine the extent to which each will be embedded in current and future projects.

EPRI Perspective

The 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. These lessons reside with the current fleet of operating nuclear plants, in the good practices of the teams of professionals currently involved in new plant projects, and in the experience of those who design, build, construct, and operate the current fleet of plants.

Approach

The report assumes that organizations involved in the construction and testing of new plants 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 in this report focus on the aspects of ER that can be included, strengthened, or expanded (as needed) within the current procedure structure of an organization. The report does not attempt to provide all of the details necessary to achieve the recommendations and implement the cited lessons learned.

This EPRI report focuses on storage, construction, and startup testing; previous reports dealt with design and procurement activities.

Keywords

Corrective action (CA)
Equipment reliability (ER)
Nuclear plant storage
Nuclear plant construction
Nuclear plant testing

ABSTRACT

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 and vital to the companies making the large investments required for new nuclear plants. One of the foundations of good performance is a sound process for establishing and sustaining plant equipment reliability (ER).

This report contains the results of industry efforts to capture and communicate ER lessons learned during the storage, construction, and startup phase of a new plant project. This report 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 may choose to emphasize or even require the use of these recommendations.

The 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. These lessons reside with the current fleet of operating nuclear plants, in the good practices of the teams of professionals currently involved in new plant projects, and in the experience of those who design, build, and operate the current fleet of plants.

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

It is expected that project organizations will consider each of these recommendations and determine the extent to which each will be embedded in current and future projects.

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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 and 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 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. These lessons reside with the current fleet of operating nuclear plants, in the good practices of the teams of professionals currently involved in new plant projects, and in the experience of those who design, build, and operate the current fleet of plants.

This report contains the results of industry efforts to capture and communicate ER lessons learned during the storage, construction, and testing 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 in the supply and installation of systems, structures, and components for new nuclear plants. This includes all major equipment suppliers and subsuppliers of equipment, materials, and services.

The report assumes that involved 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 in this report are intended to bring focus to aspects of ER that can be included, strengthened, or expanded (as needed) within the current procedure structure of an organization. This report does not attempt to provide all of the details necessary to achieve the recommendations and implement the cited lessons learned.

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

This technical update is a collection of good practices providing the best thoughts of the industry; however, its contents are not mandatory for any group. Companies associated with a new plant project may choose to emphasize or even require the use of these recommendations.

1.3 Report Structure

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

Just as this EPRI technical update report is dedicated to storage, construction, and testing, previous technical updates are dedicated to design (report 1021415) and procurement (report 1021416).

The design phase report contains information on:

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

The procurement phase report contains:

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

The current report contains information on the storage, installation, construction maintenance, and testing of ER components. The EPRI technical update format allows the reports and the revisions to report sections to be quickly created and posted for use.

1.4 Feedback on This Report

The topics in these reports are being developed by EPRI ANT during 2008 and 2009. The project team understands that the users of the interim reports will have comments and questions about report content. Please send these to the following contacts; your feedback is greatly appreciated.

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2
STORAGE OF ER COMPONENTS

2.1 Scope

This section covers the storage recommendations for components that have been determined by the project to be critical or important with respect to ER of nuclear power plants, including:

- Roles and responsibilities of the manufacturer, constructor, and owner
- Shipping and transportation considerations
- Storage and handling prior to and after installation

Note: Maintenance during storage is considered to be a subpart of storage as handled in this report.

Note: Storage and storage-related maintenance of all power plant equipment is important and should be properly accomplished. This report focuses on ER critical and important components and therefore does not directly address the needs of other components. Equipment classified as Run to Failure (RTF) can fail prematurely if not properly stored and maintained, resulting in complications during plant preoperational testing.

2.2 Recommendations for Storage and Handling of ER Critical and Important Components

2.2.1 General

- The physical protection and maintenance of each ER critical or important component is an essential step in achieving and maintaining the future revenue-producing capability of the nuclear unit under construction.
- The ER classification of each piece of equipment should be determined and should exist in the project master equipment list, in the procurement specification, and possibly in a separate ER-focused document. These classifications will have been established through a process similar to that described in Appendix 2.A of EPRI report 1021415, *Advanced Nuclear Technology: Equipment Reliability for New Nuclear Plant Projects: Industry Recommendations for Design*.
- Augmented storage requirements for ER critical and important components should exist in established project instructions. Compliance with these instructions should be routinely self-assessed and audited.

- The basic requirements for storage and handling of nuclear power plant components originates from Regulatory Guide 1.38, "Quality Assurance Requirements for Packaging, Shipping, Receiving, Storage, and Handling of Items for Water-Cooled Nuclear Power Plants," which identifies ANSI N45.2.2-1972, "Packaging, Shipping, Receiving, Storage, and Handling of Items for Nuclear Power Plants During the Construction Phase," as the reference standard that provides acceptable programmatic guidance for related activities. For new plant deployment, it is anticipated that these requirements will be continued through the implementation of NQA-1, "Quality Assurance Requirements for Nuclear Facility Applications," Basic Requirement 13, Subpart 2.2. The intent of this section is not to replace the guidance provided therein but to provide supplemental guidance and emphasis that relate specifically to ER components.
- The storage and handling of ER components from the time the component or materials leave the manufacturer can impact their performance and life expectancy in the future. It is important to understand that industry rules and guidance apply at the moment the component leaves the manufacturer and include all interim locations (for example, module fabrication shops), all on- and off-site storage locations, and transportation.
- **Note:** Obviously, proper storage at the manufacturing location is also important and should be performed according to established manufacturer requirements.
- Many opportunities exist for damage or introduction of damaging mechanisms throughout the shipping and storage process. Appendix 2.A provides information contained in EPRI report TR-107101, *Packaging, Shipping, Storage and Handling Guidelines for Nuclear Power Plants*, identifying potential damage mechanisms resulting from the improper handling of nuclear plant components.
- The new generation of nuclear plants may have a modular construction design that creates additional handling and storage issues. The modular concept may require the subcomponents and materials to be sent to a facility for fabrication and assembly before being sent to the plant site, increasing the likelihood of damage or defects due to mishandling, improper shipping, improper storage, or the introduction of foreign material. Necessary handling, storage, foreign material exclusion (FME) practices, and shipping requirements should be in place at the fabrication facility.
- Careful delineation of shipping and storage requirements and expectations during all project phases will be an important aspect of maintaining the quality and integrity for ER critical and important components. The existing fleet of plant operators has continued to stock and maintain spare parts and components in order to support plant operations; however, the scope and magnitude of this is much smaller than that needed to support a large-scale plant deployment effort. Additionally, suppliers, manufacturers, fabricators, and constructors of components for new plants will likely be unfamiliar with good practices and lessons learned from the efforts during the construction and operation of the current fleet. The recommendations in this report are intended to help convey industry lessons learned to new groups involved in new plant projects.

- Problems and deficiencies identified with the storage and handling of ER critical and important components should be entered into the supplier and project corrective action programs (CAPs) for tracking and corrective actions. Lessons learned should be communicated among all parties involved.
- Of particular importance is the storage of ER components prior to and upon completion of testing activities involving energizing and introduction and/or evacuation of fluids, gases, and other environmental factors/influences. This includes testing at the manufacturer, remote fabrication locations, and the construction site. Particular attention should be paid to maintaining proper storage levels and environmental conditions after completion of testing requirements, which are addressed in Section 4 of this report.
- Critical and important ER components should be uniquely identified and tagged from the time they leave the suppliers' facilities to promote visibility and awareness of the importance of the components. Color-coded tagging, banding, or other means of identification should be considered.
- Lubricants and consumables that will be used in conjunction with ER critical and important components need to be handled and managed in a manner consistent with the manufacturer's requirements and their importance as ER-related plant commodities.

2.2.2 Roles and Responsibilities

- Owner's oversight will be a key element to ensuring that ER components are properly handled and stored during delivery, remote fabrication, shipment, storage, and subsequent field-installed pre-operation storage. Before utilities assume ownership of systems and equipment, those items will be under the control and responsibility of vendors and engineering procurement construction (EPC) consortiums. A well-defined division of responsibility will be needed to ensure that the components are carefully controlled to minimize damage.
- Programmatic controls should be established that clearly define who is responsible for each portion of the proper storage and handling of components throughout the procurement, fabrication, and installation cycle. Included in this is responsibility for maintaining the components until turnover to the owner.
- Nuclear insurers have certain requirements that will also need to be adhered to in order to maintain liability requirements for major components. These should be clearly identified in interface agreements and in the detailed project procedures and instructions.

2.2.3 Shipping and Transportation Considerations

- Industry guidance exists on establishing packaging, shipping, handling, and storage requirements for nuclear plant components. Specifically, EPRI report TR-107101, *Packaging, Shipping, Storage, and Handling Guidelines Nuclear Power Plants*, provides a generic process for determining these requirements for various items used regularly in operating nuclear power plants.
  - The report contains specific, detailed recommendations for 183 components/items commonly found in nuclear power plants and includes the following:
    - A description of factors affecting shipping, storage, and handling of power plant components
    - A summary of experiences and lessons learned from material handling in support of the current fleet
  - Appendix 2.A of this report contains an example from TR-107101 that provides recommended shipping and storage requirements for various components in a power plant. TR-107101, as noted in Appendix 2.A, can be used to establish requirements for new plant ER-related items.
  - The information in TR-107101 can be used in procurement documents and equipment specifications submitted to vendors or to establish on-site storage requirements at fabrication shops and construction facilities.
- Clear communication and understanding of the requirements that ensure that ER-related equipment and material integrity is maintained once the items leave the manufacturer's facility should be delineated in procurement agreements and documentation.
  - Many of the components for new plants will come from international suppliers, which will pose new and different challenges to ensuring that they are protected and properly packaged and handled.
  - A proactive approach should be taken to make suppliers and organizations aware of the responsibilities by including these requirements in contracts and purchasing documentation and providing briefings and/or information where necessary.
  - Unannounced inspections should be considered.
- Proper securing and handling of components to preclude damage should be clearly spelled out in procurement documents and established as a hold point prior to shipment.
  - Shipping and handling can cause damage to components in a number of ways—not limited to packaging.
  - Environmental factors (such as heat, humidity, and dust) can impact sensitive electrical and control components.
  - Vibration from handling, transportation, and physical impacts can cause damage that will not necessarily be evident until testing activities can be performed, resulting in field repairs, adjustments, and project schedule impacts.

2.2.4 Storage and Handling Prior to and After Installation

- As previously identified, storage and handling requirements begin the moment that components and subcomponents leave the manufacturing process and continue to the time of turnover to plant operations. Storage and handling requirements apply during all of the following:
  - Shipment to component and subassembly organizations
  - Time while at these locations
  - Shipment to the site
  - Storage and handling prior to installation at the site
  - Storage after installation prior to pre-operation testing
  - Storage after pre-operation testing prior to startup testing (post-core load testing)
- Storage classifications and requirements for ER critical and important components should be identified in design and procurement documentation, and each responsible organization should have in place procedures and programs designed to ensure that these requirements are implemented and followed.
- Consideration should be given to the various environments to which the equipment could be exposed in fabrication and installation locations and in-transit (including temporary locations) situations. For example, shipping conditions will differ greatly from warehouse conditions. Construction environments will vary greatly between early and near-completion periods. For these reasons, the storage and handling of ER components must receive high visibility and oversight to ensure that the components are being properly maintained.
- Owner oversight of vendor and EPC activities to ensure that storage and handling requirements are being maintained should receive high priority for both critical and important ER components.
- For all ER components, vendor and project instruction–required conditions such as motor heaters/desiccant/covers/protection devices/periodic rotation of shafts/bearings/inert atmospheres should be identified and included as part of warehouse, storage, and pre-operations preventive maintenance procedures.
- All equipment protective devices, both external and internal, should be clearly identified as such by physical appearance and documentation to ensure removal prior to installing and/or running the equipment.
- Operating experience (OE) from storage-induced failures—both at the vendor site and at fabrication shops—as well as at the site should be entered into the project CAP for tracking and feedback.
- EPRI report NP-6896, *Guidelines for Determining In-Storage Maintenance of Items for Nuclear Facilities*, provides guidance for storage maintenance of many components commonly found in nuclear plants and can provide useful information for establishing programmatic requirements for new plant deployment efforts. The report contains information on recommended maintenance on typical power plant components sorted by type (for example, electrical, instrumentation, and mechanical). See Appendix 2.B for an illustration of the contents of the report.

- Shipping and storage considerations for specific components can be obtained by searching www.epri.com by component name to locate EPRI reports such as 1009698, *Shipping and Storage of Electric Motors*.
- Recent industry experience and guidelines on the movement and handling of nuclear power plant components can be found in EPRI report 1015271, *Nuclear Maintenance Applications Center: Material Handling Application Guide*. The report contains the following information that can be used to familiarize personnel at fabrication facilities and construction sites on proper material handling practices as well as precautions that should be used when handling critical and important components:
  - Section 2, "Material Handling System Application," describes material handling systems and outlines how they are used in the nuclear industry. It includes an overview of the functional design and operational aspects of material handling.
  - Section 3, "Material Handling Technical Description," provides technical descriptions of material handling equipment, including forklift trucks (diesel, gas, and electrically propelled), pallet trucks, stackers, industrial carts, scissor-lifts, and rope and pulley systems, for use in moving materials on-site.
  - Section 4, "Material Handling Equipment Inspection Criteria," provides inspection criteria for pre-use, visual inspection, and post-use of material handling equipment.
  - Section 5, "Material Handling Equipment Operation," provides guidelines for operating, traveling, steering, loading, raising the load, handling the load, parking, and unloading of material handling equipment in a safe manner.
  - Section 6, "Manual Handling of Materials," provides guidelines and approved practices for manual lifting and carrying of materials.
  - Section 7, "Personnel Qualifications and Training," provides recommendations for training operators of material handling equipment.

2.3 References

Packaging, Shipping, Storage and Handling Guidelines Nuclear Power Plants. EPRI, Palo Alto, CA: 1997. TR-107101.

Guidelines for Determining In-Storage Maintenance of Items at Nuclear Facilities. EPRI, Palo Alto, CA: 1991. NP-6896.

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Regulatory Guide 1.38, "Quality Assurance Requirements For Packaging, Shipping, Receiving, Storage, and Handling Of Items For Water-Cooled Nuclear Power Plants."

NUREG 0800, Section 14.2, Initial Plant Test Program – Design Certification and New License Applicants.

ASME NQA-1, Quality Assurance Requirements for Nuclear Facility Applications.

Advanced Nuclear Technology: Equipment Reliability for New Nuclear Plant Projects: Industry Recommendations for Design. EPRI, Palo Alto, CA: 2010. 1021415.

Shipping and Storage of Electric Motors. EPRI, Palo Alto, CA: 2004. 1009698.

Appendix 2.A Factors That Can Cause Damage to Nuclear Plant Components

2.A.1 Factors Related to Item Damage

The following information is extracted from EPRI report TR-107101, *Packaging, Shipping, Storage, and Handling of Nuclear Plant Components*, to illustrate the physical and environmental factors that can cause damage during the packaging, shipping, storage, and handling of critical and important components. (The tables are rendered as they appeared in that report.)

> Tables 3.1 through 3.3 present physical and environmental factors that may affect the type of packaging, shipping, storage, and handling specified by utility personnel. Other factors such as economic feasibility and regulatory requirements have been considered in developing the packaging, shipping, storage, and handling (PSS&H) recommendations. The factors that affect PSS&H recommendations can be grouped into the three following major categories:
>
> - Damage (Code D)
> - Identification (Code I)
> - Other (Code O)
>
> ### Item's Susceptibility to Damage*: Code D
>
> Items may be susceptible to various types of damage either in the long or short term. "Code D" factors describe the different types of damage an item may incur and how optimal packaging, shipping, storage, and handling could prevent that damage from occurring. These factors consider long-term deterioration of an item that may also be controlled and managed under each utility's shelf life or in-storage maintenance programs. These factors are coded with the prefix "D" for Damage.
>
> * Section 3 of EPRI NP-6896, *Guidelines for Determining In-Storage Maintenance of Items for Nuclear Facilities*, contains a more detailed description of the technical aspects of various storage related damage mechanisms.
>
> ### Need to Maintain Item Identification**: Code I
>
> Each item or group of items has varying means of identification. "Code I" factors describe issues related to the ease of identification of the item, which can impact how it is packaged and stored. These factors are coded with the prefix "I" for Identification.
>
> ** TR-107101 was published in January 1997, before the current industry programmatic emphasis on equipment reliability. The ER classification (or coded designation) for a component should be included in Code I and populated in each of the PSS&H tables consistent with the established classifications.

Other Factors: Code O

Some items—depending on their size, composition, and other characteristics—need to be packaged, shipped, stored, or handled in a manner that will minimize the chance of injuring plant personnel. Also, a number of items require in-storage maintenance or must be handled often and as such need to be packaged and stored in such a manner as to facilitate these activities. Some items, because of their very small size, may need to be packaged to minimize the potential for loss. Because of their general nature, these factors are coded with the prefix "O" for Other.

Table 3.1: Factors Related to Item Damage that Affect Packaging, Shipping, Storage, & Handling Recommendations

Type of Damage	Code
Corrosion, mold, or mildew damage from humidity/condensation	D-1
Airborne contamination (dust, salt, dirt, rain, snow, fumes)	D-2
Deterioration from light/UV, halogen exposure, or chemicals	D-3
Magnetic damage	D-4
Physical damage from other items in proximity	D-5
Physical damage during handling due to physical size, configuration/shape, (center of gravity, weight, support, etc.) & lifting requirements	D-6
Damage from intrusion of foreign objects into open ends	D-7
Thread damage	D-8
Damage caused by rodents/vermin	D-9
Physical distortion due to stacking	D-10
Damage from loss of pressurization during storage	D-11
Static electricity discharge damage	D-12
Damage caused from material incompatibility with contiguous products (CS/SS interface, elastomer interface, etc.)	D-13
Damage from excessive shock/vibration	D-14
Damage from improper horizontal/vertical orientation	D-15
Damage after breaking factory-sealed packaging	D-16
Deterioration from radiation	D-17
Deterioration from temperature	D-18
Susceptibility to explosion from sparks or flames	D-19

Table 3.2: Factors Related to Item Identification that Affect Packaging, Shipping, Storage, & Handling Recommendations

Issues Regarding Item Identification	Code
Need for ease of identification	I-1
Need for indication of use/consumption	I-2
Susceptibility to loss of item identification/tag (EQ, manufacturer's identification, post-installation testing requirements, acceptance requirements, heat number, etc.)	I-3

Table 3.3: Other Factors that Effect Packaging, Shipping, Storage, & Handling Recommendations

Other Factors to Consider	Code
Need for proximity control (physical spacing, hazardous materials, etc.)	O-1
Need for personnel protection	O-2
Need to package for performing in-storage maintenance	O-3
Need to package for shelf life maintenance or extension	O-4
Need to package for lifting and handling ease	O-5
Need to package for rotating shafts	O-6
Susceptibility to loss of item due to its small size	O-7

The following is an example from TR-107101 of how the above concepts are applied. An excerpt from Table 5.3 for mechanical components is provided for this illustration.

Tables 5.2–5.9 of TR-107101 contain PSS&H recommendations on 184 structural, mechanical, electrical, instrumentation, special, chemical, consumable, and component/equipment items.

Table 5.3: PSS&H Recommendations for Mechanical Items (continued)

5-10

Item No.	Name of Item	Recommended Minimum Packaging for Storage	Special Labeling, Tagging & Marking	Minimum ANSI Storage Level	Recommended Packaging for Shipping	Shipping Guidance	Special Notes and Handling Guidance	Factors Effecting PSS&H (Ref. Table 3.1 for codes)
8	Disc, valve, metallic	Open shelf storage, boxed or bagged	None	C	Individually wrapped and boxed	Enclosed carrier	Corrosion inhibitor may be considered for large items not boxed or bagged	D-1, D-2, D-3, D-5, D-13, I-1, I-3
9	Expansion joint, metallic	Open shelf storage	None	C	Crated or boxed with internal bracing	Open carrier, covered with tarpaulin as necessary	Corrosion inhibitor may be considered	D-2, D-3, D-6, I-3
10	Expansion joint, non-metallic	Open shelf storage, boxed, bagged, or covered	None	B	Wrapped, sealed, or boxed with internal bracing	Enclosed carrier	None	D-2, D-3, D-6, I-3, O-4
11	Filter, charcoal	Open shelf storage, boxed or crated, sealed as necessary	None	B	Individually sealed in a box or crate with internal bracing	Enclosed carrier	None	D-1, D-2, D-3, D-5, D-14, D-16, I-1, I-3
12	Filter, HVAC	Open shelf storage, boxed or bagged	None	B	Boxed	Enclosed carrier	Sealing may be considered for special-application filters	D-1, D-2, D-3, D-5, D-10, D-14
13	Fitting, compression	Open shelf storage, bagged or boxed	None	C	Multiple items per box	Enclosed carrier	None	D-2, D-3, I-3, O-7
14	Gasket, asbestos	Open shelf storage, bagged	Should include asbestos warning	B	Boxed	Enclosed carrier	Item is fragile and should be stored flat and not under heavy objects	D-1, D-2, D-3, D-5, D-10, D-14, O-2

Appendix 2.B Recommended In-Storage Maintenance Activities

2.B.1 Recommended In-Storage Maintenance of Selected Components

The following is excerpted from EPRI report NP-6896, *Guidelines for Determining In-Storage Maintenance of Items at Nuclear Facilities,* to provide examples of the recommendations contained therein for various plant components.

Recommended In-Storage Maintenance Activities

Component	Item	Typical Storage Level	In-Storage Maintenance Level	In-Storage Maintenance Frequency	Basis	Refer-ence	Packaging	Comments
<u>Electrical</u>								
Battery	Batteries, Lead Acid	B	Maintain Float Charge Monitor Electrolyte Level, float voltage, charge output, specific gravity, corrosion	C M	3.4 3.4	18 26, 18	5.4 5.4	Dry storage (with no electrolyte) requires no maintenance
Battery	Batteries, nickel cadmium (charged)	B	Deep cycle discharge and recharge	Q	3.4	13	NA	Refrigerated storage increases storage life
Battery	Batteries, nickel cadmium (un-charged)	B	NA	B	NA	NA	NA	Purchased dry and moist. Routine storage and handling apply
Battery	Capacitors, Electrolytic (aluminum)	B	See comments	See comments	3.4	27, 17	5.1	Pre-installation test after long storage – 3 years. Packaging may be required for minimizing water/electrolytic reaction. Refrigerated storage increases life

1. The definitions for the frequency of conducting the recommended in-storage maintenance activities are provided below:
   - C Continuously
   - M Monthly
   - Q Quarterly
   - S Semiannually
   - A Annually
2. The basis for the in-storage activity is provided in Section 3, "Factors Influencing In-Storage Maintenance Activities," which discusses how the in-storage activity mitigates the factor.
3. References for the in-storage maintenance activities, the frequency and the basis for the activity, and the use of packaging methods to preclude in-storage maintenance are discussed in Section 7.
4. When storage or packaging methods may be used to preclude conducting in-storage maintenance activities, the appropriate subsection of Section 5, "Packaging Effects on In-Storage Activities," is referenced.

3 INSTALLATION AND CONSTRUCTION MAINTENANCE OF ER CRITICAL AND IMPORTANT COMPONENTS

3.1 Scope

This subsection covers the installation and construction maintenance recommendations for components that have been determined to be ER critical or important with respect to equipment reliability of nuclear power plants. This includes:

- Maintenance program during construction, testing, and pending turnover to owner (process, controls, and responsibility for maintenance)
- Component protection and cleanliness of ER components during installation and construction

Note: Installation- and construction-related maintenance of all power plant equipment is important and should be properly accomplished. This report focuses on ER critical and important components and therefore does not directly address the needs of other components. Equipment classified as RTF can fail prematurely if not properly installed and maintained, resulting in complications during plant pre-operational testing.

3.2 Recommendations for Installation and Construction Maintenance of ER Critical and Important Components

3.2.1 General

- Traditional construction practices result in the formal plant maintenance process beginning upon turnover of systems and components to the utility owner or operators. This practice leaves plant components and systems vulnerable to degradation or damage that, although it may be detected and corrected prior to final plant operation, could also be prevented by early implementation of a formal maintenance program for ER critical and important components.
- The physical identification of ER critical and important components is important. Color-coded tagging, banding, or other means that can be used to make their relative importance known during storage, installation, construction, and testing will aid in focusing proper attention and resources on maintaining these components in the proper condition.

- Suppliers, fabricators, and constructors may not have particular knowledge or awareness of the meaning of ER concepts or of the classifications of critical and important components. Providing an awareness of the key ER concepts and establishing a process to ensure that the material condition of the component is maintained until turnover to the owner's permanent maintenance program will be a vital element in ensuring the reliability of the systems and components of the plant. Section 2.2.1 of EPRI report 1021416, *Advanced Nuclear Technology: Equipment Reliability for New Nuclear Plant Projects: Industry Recommendations for Procurement*, specifically addresses some methods to create this awareness.
- Use of the CAP to identify and provide corrective measures to prevent repeat problems will be an important aspect of ensuring that the ER components are maintained properly during this time.

3.2.2 Maintenance Program During Construction and Testing and Pending Turnover

- Clearly defined roles and organizational responsibilities are required for maintaining ER critical and important components as the project transitions through the procurement, fabrication, storage, installation, testing, and turnover phases.
  - A formal process to identify roles and the transfer of "ownership" and responsibilities for the maintenance (both preventive [including predictive] and corrective) of plant equipment should be clearly spelled out in interface agreements, turnover manuals, and plant procedures between the EPCs, various subcontractors, and the utility owner/operator.
  - Ideally, the plant permanent maintenance organization agrees to the established roles and responsibilities and oversees the implementation of all involved groups.
- Maintenance of items should not be limited to items installed in the field. Required maintenance of items while in storage should be factored into the programs of the responsible organizations. For example, component distributors, module fabricators, and site installation and construction organizations should have a process for identifying and ensuring that any required preventive maintenance is performed on critical and important components.
- Integration into permanent plant processes for controlling and implementing maintenance activities will not only ensure that the critical and important components are being properly maintained during construction and testing and pending transfer, but also enable plant personnel to become familiar with the components prior to plant operation where access may not be as easy or safe. Once the plant begins operation, the environment and contamination levels may prevent easy access to the equipment. This involvement will also enable the development and "proof testing" of maintenance procedures and practices as well as facilitate the training of personnel.

Considerations should include the following:

- Critical and important components should be integrated into a maintenance program from the time they are received on site:
  - As the components, modules, skids, and so on are moved from the warehouse to the field, careful attention should be placed on ensuring that they continue to be properly maintained.
  - Degradation can begin while the components are being stored—both in a warehouse and in the field and during testing activities. Treating the component from the beginning as a piece of permanent plant equipment will help to ensure that it remains in good condition until plant commercial operation.
  - Cleanliness, lubrication, storage requirements, and integrity of components (that is, when components are disassembled for installation, testing, inspection, and so on) should be treated in a manner consistent with expectations at an operating facility.
  - Remember that preventive maintenance tasks performed during storage and those performed once pre-operational testing begins are different. The right preventive maintenance tasks should be used at the right time during the pre-core load life of the equipment.
- Controls for the bagging and storage of disassembled parts should be established. Likewise, for configuration control, records of any changes or replacement of parts made to the components prior to and after final turnover should be maintained.
- Maintenance records (for example, work packages) should be implemented from the outset to ensure that an accurate record of work done to the component is maintained.
- Test results including records of tests following component maintenance during construction and system testing are important.

* EPRI NP-6896, *Guidelines for Determining In-Storage Maintenance of Items for Nuclear Facilities,* describes the technical concerns associated with storage and post-installation conditions for plant equipment. Appendix A of NP-6896 provides recommended in-storage and post-installation preventive maintenance activities for 51 electrical, mechanical, and instrumentation items.

3.2.3 Protection of ER Components During Construction

* ER critical and important components should be protected from installation and construction damage. Damage may occur during handling and movement of equipment necessary for installation, by impact from other activities, and/or the construction environment.
  - Rigging, hoisting, and lifting of ER components should be done under documented programs and consistent with the manufacturer's recommendations. See EPRI report 1007914, *Lifting, Rigging, and Small Hoist Usage Program Guide*, for typical program requirements.
  - Handling of ER components should be done under a documented program and be consistent with the manufacturer's recommendations. See EPRI report 1015271, *Materials Handling Applications Guide*, for typical program requirements.

  - Construction environments such as grit blasting to support painting, rain intrusion due to faulty drains, dust and dirt intrusion due to the status of nearby construction, and temperature or humidity excesses due to temporary HVAC will degrade ER components and should be avoided or effectively compensated for.
  - The use of temporary services (such as air, water, or power) that are not of the quality and quantity specified for ER-related components will cause damage. Temporary services should match documented requirements for ER components.
- The protection of fragile or environmentally sensitive parts of critical and important components during fabrication and construction activities will prevent damage and degradation prior to commercial plant operation. For example, instrumentation, tubing lines, soft elastomers, and materials that can be damaged by heat and elements should be removed and/or protected and controlled.
- Construction environments are often humid, dirty, hot, and so on and can affect sensitive components. Therefore, from the time components are received on site, a process for identifying proper storage environments for these sensitive components should be in place for tracking and control.
- During testing activities, some systems will be required to be physically complete and intact while adjacent systems may not. Sensitive components may be installed to facilitate testing activities but then have to be removed upon completion of these tests and/or properly protected.
  - By integrating the control and maintenance of critical and important components early in a formal maintenance program, the documentation of activities such as removal and reinstallation can be more easily accomplished.
- Construction environments are often places of high activity where the use of equipment such as scaffolding, ladders, or platforms is needed. However, measures should be put in place to protect sensitive ER-related permanent plant equipment from being stepped on or otherwise used, resulting in damaged instrumentation lines, cables, transmitters, and so on. Training and measures to make site personnel aware of this should be considered to mitigate the improper practices that can result in such events.
- EPC and the owner's oversight should include observation points to be attentive to these issues and to identify and correct them as they are identified. By using the CAP, repeat events can be factored into prevention measures to preclude the problems from impacting the reliability of equipment that is being installed and also after turnover to the owner while other construction activities are still underway.
- Preventing dirt, debris, and foreign material from entering components and the system during fabrication, installation, and testing and pending turnover is important to ensure the reliable operation of nuclear power plants. The entry of foreign material into primary or secondary plant systems, equipment, and components can cause ER-related equipment degradation, lost generation, fuel cladding damage, and increased radiation levels. It is better to keep it clean than depend on cleaning it later.
- Good FME practices used throughout the project will pay large dividends in the end: better to keep systems and components clean while the project is in progress than to suffer the consequences of poor FME practices later on.

- The establishment of a cleanliness program is a project-wide initiative that requires the involvement of many project personnel in order to be effective.
- Previous practice used in prior nuclear plant builds that relied on flushing and cleaning should not be counted on as the sole means of providing clean equipment and systems because it places an additional burden on startup testing and an over-reliance on such efforts to adequately remove foreign material.
- EPRI report 1016315, *Nuclear Maintenance Applications Center: Foreign Material Exclusion Guidelines*, provides a comprehensive overview of technical considerations required to develop, implement, and manage an FME program at a commercial nuclear power plant. Although from the outset, fabrication and construction environments represent significant challenges, lessons can be taken from the experiences gained in operating facilities and factored into practices during new plant deployment.
- Covers, lids, and other devices that prevent the entry of foreign material into components should be an integral part of a program of protection for the equipment during this phase.

3.3 References

Packaging, Shipping, Storage and Handling Guidelines Nuclear Power Plants. EPRI, Palo Alto, CA: 1997. TR-107101.

Guidelines for Determining In-Storage Maintenance of Items at Nuclear Facilities. EPRI, Palo Alto, CA: 1991. NP-6896.

Nuclear Maintenance Applications Center: Foreign Material Exclusion Guidelines. EPRI, Palo Alto, CA: 2008. 1016315.

Nuclear Maintenance Applications Center: Material Handling Application Guide. EPRI, Palo Alto, CA: 2007. 1015271.

Advanced Nuclear Technology: Equipment Reliability for New Nuclear Plant Projects: Industry Recommendations for Procurement. EPRI, Palo Alto, CA: 2010. 1021416.

4
TESTING OF ER CRITICAL AND IMPORTANT COMPONENTS

4.1 Scope

This section covers the construction testing and pre-operational testing recommendations for components that have been determined to be critical or important with respect to ER of nuclear power plants. In this report, the following testing phase descriptions are used, consistent with current NRC definitions:

- Construction testing: installation, setup, and component initial operation
- Pre-operational testing: testing of portions of systems and combinations of systems
- Startup testing: testing commencing with initial fuel load

Construction testing includes the following areas:

- Testing of components, modules, assemblies, and skids
- Installation checks
- Use of permanent plant ER critical and important equipment during construction
- Use of permanent plant ER critical and important equipment with “temporary services”
- Chemistry and layup considerations

Pre-operational testing includes the following areas:

- Functional requirements versus design requirements
- Collection of baseline data
- Precautions for initial pre-operational tests
- Inclusion of plant personnel in testing
- Establishment of a system health report program

4.2 Construction Testing Recommendations

4.2.1 General

- Post-installation and -fabrication preparation (checks) of ER critical and important components plays an important role in ensuring that components will operate reliably, meet design and operational requirements, and are capable of being maintained properly in the future. These checks should be thorough to ensure that the components are ready for the rigors of testing activities without being damaged.
- Because modular design and pre-fabrication are a part of the new plant construction process, some initial testing and checks will be performed at the fabrication facility by that organization. Vendor surveillance activities should verify that these meet project expectations and that all testing documentation is supplied with the equipment or component for storage in the owner's document management system.
- Participation of the owner or the owner's designees in the various testing and installation checks is an important element in ensuring that ER critical and important systems and their components receive the priority and attention required to meet their performance criteria.
- As ER critical and important systems and components complete the testing phases of the project and are turned over to the plant for initial system operations, the systems and components should be integrated into the appropriate permanent plant processes (such as operations practices, maintenance programs, and monitoring programs).

4.2.2 Testing of Modules, Subassemblies, and Skid-Mounted Equipment

- It is anticipated that many of the ER critical and important components will be installed as part of prefabricated modules, subassemblies, or skid-mounted equipment. Because of this, some of the initial setup and testing of the components, such as pressure tests and continuity checks, will be conducted at the vendors and manufacturers of these commodities. A clear definition of what tests are to be conducted by the suppliers, their objective, and their acceptance criteria should be clearly delineated in procurement documents. Owner witness and hold points should also be included.
- EPRI report 1021178, *Modularization of Equipment for New Nuclear Applications – Testing and Preservation*, contains current industry insights into testing activities that could occur in a modular fabrication facility. This report also contains cautions and limitations of modular testing that should be considered. Of particular relevance are the concerns and cautions raised about maintaining the tested condition through final placement and acceptance at the plant site.
- Performance objectives and acceptance criteria should be clearly defined and documented for ER critical and important components.
- Test results and conclusions for critical and important equipment should be documented and forwarded to the owner with the equipment when shipped to the plant sites. Subcomponent test data such as pump performance tests, valve tests, motor tests, and instrumentation and control tests conducted by the suppliers should be identified by component so that the data can be properly cataloged and stored at the site.

4.2.3 Installation Checks

- Components, subassemblies, and modules should be subjected to rigorous checks prior to and after installation but before initial test activities are begun. These checks should be defined and the results documented for future use. Examples of these checks, which should be performed prior to initial operation of ER critical and important components, include the following:
  - Shaft alignment and coupling installation
  - Valve and valve operator setup
  - Relief valve settings
  - Circuit breaker trip settings and mechanism setups
  - Protective relay settings
  - Verification of proper motor rotation
  - Control settings
  - Instrumentation set points
  - Cable continuity
  - Initial lubrication
- EPRI report 1009709, *Post-Maintenance Testing Guide*, provides guidance on the testing of many power plant components following installation and maintenance activities and can be used as a guide when establishing initial tests and checks on new plant components. Appendix 4.A provides an example of the content of this report.

4.2.4 Use of Permanent Plant ER Equipment During Construction

- As plant equipment is installed, there will be a tendency to use permanent ER systems and equipment to provide pre-testing support functions such as flushing water, electrical power, and compressed and instrument air. However, it is important to recognize the inherent risks associated with doing this. Damage to the equipment may result from conditions such as:
  - Operation with insufficient auxiliaries (see Section 4.2.5)
  - Operation at off-normal points and/or outside the operating range for extended periods of time
  - Operation without necessary equipment protection devices (for example, under-voltage relays, over-current relays, differential relays, pressure relief valves, and suction pressure protection) in place and calibrated
  - Inappropriate cycling of pumps, valves, and so on
  - Incorrect data collection based on off-normal conditions (power or hydraulic), that is, documenting incorrect noise signatures based on incomplete power and grounding connections
- Engineering evaluations should be conducted to ensure that the use of permanent plant systems and components during this time adheres to the design capabilities of the equipment and the system and that damage will not occur by their use. Additional protection should be considered, such as relief valves, circuit protection, and adjustments to control settings to prevent damage to the plant systems and components when operated in unusual configurations. Proper grounding, cooling, operation of pre-lube systems and space heaters, and availability of personnel safety systems should be evaluated.

4.2.5 Use of Permanent Plant ER Equipment with Temporary Services

- Based on construction sequencing and status, testing of permanent plant ER equipment will likely involve the use of "temporary services" such as temporary seal injection water, power, air, and HVAC. It is very important to ensure that when a temporary support service (auxiliary) is used, the service is of the same quantity and quality and offers the same or equivalent protective features and devices as required by the equipment vendor and/or the project specification. For example:
  - Temporary power service for electric motors may not be adequate. The resulting voltage drops during heavy startup currents can damage the motor insulation.
  - Adequate quality, flow capacity, and net positive suction head (NPSH) for ER pumps—not only for process flow but also for support systems such as seal injection and leak off—should be evaluated and ensured to be acceptable prior to operation of the permanent plant equipment.
  - Temporary water or fluid sources should be evaluated for conformance to quality standards consistent with the needs of the permanent equipment. For example, do not run raw water through permanent plant demineralized water systems or use construction air to supply permanent plant instrumentation and actuators if it does not meet the requirements (such as cleanliness, moisture content, and capacity) of the plant instrument air system.
  - Proper flow and temperature of cooling water to component auxiliaries such as lube oil or bearing coolers must be determined and adequately supplied.
  - Construction environments (for example, heat, humidity, and cleanliness) can be deleterious to permanent plant equipment when operated prior to the permanent plant ventilation systems being installed and operational. Therefore, a careful review of component needs should be conducted, and temporary systems should be of sufficient capacity (flow, heat removal capacity, and so on) to support operation.

4.2.6 Chemistry and Layup Considerations

- As ER critical and important systems and components enter into the construction testing phase of the project, fluid systems will begin to be flushed and filled. An important consideration at this time is the maintenance of proper water chemistry. Based on system materials and process requirements (that is, raw water or demineralized water), potential damage mechanisms can exist as fluid systems lie dormant for periods of time.
- A review of system design considerations and the need for chemistry control and maintenance should be conducted to ensure that ER systems and components are not exposed to harmful conditions. The chemistry management of flowing and stagnant systems should begin with the first introduction of fluid to the system. Some systems for consideration are the following:
  - Condensate and feedwater
  - Reactor coolant system (RCS) (including reactor vessel, pumps, and steam generators)
  - RCS makeup, letdown, and chemical control

  - Cooling tower/circulating water
  - Service water
  - Closed cooling water
  - Stator water cooling

- Prior to adding water to any plant system, it is important to confirm with the plant chemist that the water to be used is compatible with the materials and ultimate operation of the system. Likewise, do not allow a system to stand stagnant for an extended period of time (approximately two weeks) without discussing with the plant chemist the potential negative impacts to the system and taking any needed protective actions.
- The EPRI Chemistry Program and Balance-of-Plant Corrosion Programs have many products that contain precautions, recommendations, and plant processes for management of plant systems' chemistry. These programs can be accessed through www.epri.com.

4.3 Pre-Operational Testing Recommendations

4.3.1 General

- As test plans are developed, it is important that ER critical and important components be identified in the plans, the procedures, and the documentation.
- As these components move into pre-operational testing, elements of the plant's ER program should be in place to support the transition to a permanent mode of operation. This includes the identification and classification of ER components within plant processes as well as the use of preventive maintenance processes, condition monitoring programs, and system health reporting to begin implementing the programmatic requirements for the plant operation phases of startup testing and commercial operation.
- Section 4.4 of EPRI report 1021416, *Advanced Nuclear Technology: Equipment Reliability for New Nuclear Plant Projects: Industry Recommendations for Procurement*, discusses the identification of critical spares for ER components. As systems and components move from the construction testing into the pre-operational testing phase, the availability of critical spares to support testing activities—and eventually startup and operational testing—becomes important. Steps should be taken to ensure that these parts are available in the plant's parts inventory.
- As the plant progresses from construction through the pre-operational testing phase, an important element will be to capture important lessons learned and success stories as they occur. These should be entered into the project's CAP for documentation, dissemination, and future reference.

4.3.2 Functional Requirements and Design Requirements

- An important distinction is that the recommendations contained herein should not be confused with the Inspection, Test, Analysis, and Acceptance Criteria (ITAAC) Program (NUREG 0800, Section 14.3, "Inspections, Tests, Analyses, and Acceptance Criteria") that is a critical part of new plant licensing requirements. The recommendations in this report ensure that ER critical and important components are protected during this phase of plant pre-operational testing and verify that important functional requirements (again, as opposed to other licensing and design requirements) are being met.
  - Appendix 4.A of this report provides component-level tests that can be used to verify that individual components will operate properly following installation. These should be used in conjunction with vendor-provided information.
  - As part of the test plan for ER critical and important components, ER-related functional requirements at the system and component level should be identified, documented, included in the testing plans, and verified as part of the testing efforts.

4.3.3 Collection of Baseline/Testing Data and integration into Plant Database

- As ER critical and important systems and components are tested and started up, data are collected that will be used to confirm conformance to design and functional requirements. These data are used by the plant staff after the plant is operational to establish baseline performance standards for trending and comparison.
- To facilitate the data collection, careful planning should be done prior to the onset of testing so that the data gathered can be easily cataloged and entered into plant records and database systems. The data required to support trending during plant operations should be collected, and the data collection system should support the easy retrieval of information in the future to facilitate maintenance decisions, troubleshooting of plant problems, and long-range planning.
- System and component monitoring is an important element used by engineering and maintenance personnel when the plant is operational. Data needs identified in plant system monitoring and preventive maintenance programs should be collected as a baseline. Perspective on the types of data that are typical in these programs can be found in EPRI reports *System Monitoring by System Engineers: 37 System Monitoring Plans* (TR-107434) and *PMBD 2.0: Preventive Maintenance Basis Database, Version 2.0* (1014971).
- It is recommended that, as a minimum, the monitoring proposed for each major component in EPRI report 1016537, *Program on Technology Innovation: Advanced Nuclear Technology—Component Margins and Monitoring Database*, is captured as a baseline (see Appendix 4.B for examples).

4.3.4 Precautions for Initial Pre-Operational Tests

- Normal test processes and procedures should have precautions and steps in place to ensure that plant equipment is protected during initial energization and operation. ER critical and important components should receive additional attention because errors made during this period, while not causing immediately apparent problems, can create circumstances that lead to premature degradation and possible failure once plant operations have begun (see Sections 4.2.4 and 4.2.5 of this report).
- Vendor-supplied equipment should not be assumed to have been received in a condition that is “ready to go.” Initial operating steps for these components should receive careful review by experts and specialists to ensure that deleterious conditions are not present. This can include:
  - Ensuring that adequate water supply and NPSH are present prior to starting up pumps
  - Verifying that electric motors rotate in the desired direction when initially energized (bumped)
  - Ensuring that valve actuators (motor, air, and electric) and their settings are correct to prevent damage to the actuator or valve
  - Verifying that circuit breaker adjustments, mechanisms, and settings prior to energization
  - Checking that protective relays are functional with proper settings applied
  - Verifying that piping connections and welds are in place
  - Ensuring that shipping and packing material has been removed
  - Ensuring that installed blanks and covers are removed
  - Verifying that component external and internal movement prevention devices are removed

4.3.5 Inclusion of Plant Personnel in Testing

- The plant testing programs provide an excellent training opportunity for plant staffs to become knowledgeable of plant ER-related components and systems before conditions change. This can include:
  - Maintenance staff can train on and become familiar with maintenance steps and procedures while conditions and time permit. This includes validation or correction of maintenance procedure steps, planned PM tasks, and practices.
  - Operations staff can become familiar with operational requirements such as critical steps and evolutions and identify issues that could present problems when the plant is operational.
  - Engineering personnel can become familiar with systems and their components as well as internals of equipment that will no longer be accessible after systems are placed in service. Engineering can also witness testing that will serve as a basis for future monitoring and trending.
  - Training personnel can take digital photographs of components and areas that can be beneficial for future training and mockup activities.

4.3.6 Establishment of System Health Reporting Programs

- Development and use of accurate health reports for ER critical and important systems and components are fundamental activities used in the current operating fleet to understand and manage the overall status of plant equipment and processes. To help the plant to focus on ER issues and implementation of effective maintenance programs, the development a system and component health reporting program during testing for ER critical and important components is recommended.
- The benefits of doing this are twofold: 1) it helps to integrate the baseline data collected during startup testing (discussed in Section 4.3.3) to establish condition parameters known to exist when critical and important components are new and 2) it helps to establish and monitor performance trends from the beginning of plant operations.
- System and component health monitoring programs have been established for the current fleet in many forms and should be tailored to meet the needs of the owner/operator. Although EPCs may not be familiar with the format and content of these programs, guidance can be found in EPRI report 1009745, *System, Component, and Program Health Reporting: Utility Best Practices*.

4.4 References

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

System, Component, and Program Health Reporting. EPRI, Palo Alto, CA: 2004. 1009745.

System Monitoring by System Engineers: 37 System Monitoring Plans. EPRI, Palo Alto, CA: 1998. TR-107434.

PMBD 2.0: Preventive Maintenance Basis Database, Version 2.0. EPRI, Palo Alto, CA: 2007. 1014971.

Program on Technology Innovation: Advanced Nuclear Technology—Component Margins and Monitoring Database. EPRI, Palo Alto, CA: 2008. 1016537.

NUREG 0800, Section 14.3, Inspections, Tests, Analyses, and Acceptance Criteria.

Modularization of Equipment for New Nuclear Applications – Testing and Preservation. EPRI, Palo Alto, CA: 2010. 1021178.

Appendix 4.A Guidelines for Post-Installation Checks

4.A.1 Guidance for Establishing Post-Installation Testing for ER Critical and Important Components

The following is excerpted from EPRI report 1009709, *Post-Maintenance Testing Guide,* Revision 1, and can be used to help identify useful ways to test components after installation and prior to system startup testing activities.

For each component covered in the guide, a matrix provides various combinations of tests for each type of work activity performed. In addition, the guide offers a set of test definitions to assist in the efficient and consistent execution of post-maintenance testing. Although avoiding repetitive testing, the guide covers every inspection, check, or verification that occurs during or after the maintenance activity.

The following is an example (from Appendix A of the report) of the use of the guide to establish recommended post-maintenance testing for, in this case, a motor-operated valve. (The tables are rendered as they appeared in that report.)

Mechanical Equipment - Component Test Matrices

Equipment Code	Type of Equipment	Page
MAH	Air Handling Unit/Fan/Blower	A-39
MC	Coupling	A-41
MCD	Condenser	A-42
MCH	Crane/Hoist	A-43
MCP	Compressor	A-44
MD	Dryer	A-45
MDD	Damper/Ducting	A-46
MDE	Diesel Engine	A-47
MFP	Fire Protection Devices	A-49
MFS	Filter/Strainer/Demineralizer	A-50
MGT	Gearbox/Transmission	A-51
MGV	Governor, Hydraulic	A-52
MHD	Hydraulic Drive	A-53
MHX	Heat Exchanger	A-54
MP	Pump	A-55
MPP	Piping/Tubing/Welded Components	A-56
MPS	Pipe Support/Hanger	A-57
MRC	Refrigeration Unit/Chiller	A-58
MRF	Radiation Filter	A-59
MS	Snubber	A-60
MT	Turbine	A-61
MTV	Tank/Vessel/Accumulator	A-62
MV	Valve, Manually Operated	A-63
MVA	Valve, Air-/Pneumatic-Operated	A-64
MVC	Valve, Check	A-65
MVM	Valve, Motor-Operated	A-66
MVR	Valve, Relief/Safety	A-67
MVS	Valve, Solenoid	A-68

A-38

Appendices B, C, and D (Electrical, I&C, and Mechanical, respectively) of 1009709 are then used to provide recommended post-maintenance tests that will ensure that the component is in good working order. The table that follows (rendered as it appeared) is a continuation of the motor-operated valve example.

MVM – Component Test Matrix
Valve, Motor-Operated

Components:
Motor-Operated Valves

	Test Activities → / Test Code →	Maintenance/ Installation Check MVM-1	Valve Cycle/ Exercise Test MVM-2	Stroke Time Test MVM-3	Position Ind./Torque Switch Check MVM-4	Current Test MVM-5	Automatic Operation Test MVM-6
Work Activities	Packing Replacement or Packing Adjustments	X Note 1	X	X		X	
	Internal Valve Repairs	X Note 1		X Note 2		X Note 2	
	Motor Repair or Replacement	X	X	X	X	X	X
	Limit Switch Repair or Replacement	X		X Note 2	X		
	Torque Switch Repair or Replacement	X	X	X	X	X	
	Stroke Adjustments		X		X		
	Valve Replacement	X Note 1	X	X Note 2	X	X Note 2	X

General Note: Certain valves may require local leak rate testing. Refer to the station program and procedures. Certain valves may require valve diagnostic testing per licensing commitments. Refer to the station program and test procedures.
Note 1: Perform maintenance checks per the manual valve test guide and matrix (MV).
Note 2: Verify the stroke time/current tests as required by the ASME inservice test program requirements and technical specifications. Refer to the appropriate program and procedures.

Cross-References: Manual Valve (MV)

Appendix 4.B Recommended Monitoring Requirements for Components Examples

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

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.

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.				

5
SELF-ASSESSMENT OF PROJECT EQUIPMENT RELIABLITY HEALTH

5.1 Scope

Effectively incorporating equipment reliability (ER) principles and details during the storage, construction, and testing 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 storage, construction, and testing portion of a new plant project. In addition to the modules, general information on the logic and mechanics of self-assessment are provided.

5.2 Why Self Assess?

Self-assessment is simply a process by which an organization can determine that it is meeting 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 organization. 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-assessment 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.

5.3 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 if the expectations for the work being performed by any portion of a project are imbedded in its organization and operating structure and are, in fact, being accomplished.
  - If the expectation is not imbedded and/or is not being accomplished, then you need to change the expectation or correct the condition.
- 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, construction field engineering) assess another group (for example, warehousing) within the same overall organization.
  - Self-assessments should have a plan, include conclusions, and identify recommendations/action items with followup. These basic aspects should be documented in a final report.
  - Activities consist of interviewing group members who are involved with the topic of interest and looking at related completed/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 their 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/action items.
- Having an organization and individuals who are willing to be self-critical results in the greatest value from the exercise of self-assessment.
- Starting an assessment plan with detailed specific concerns extracted from industry operating experience and from the Project Corrective Action Program helps the assessment team and those being interviewed focus.

5.4 Storage-, Construction-, and Testing-Related Self-Assessment Modules

These self-assessment modules are based directly on the contents 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 engineering procurement and construction (EPC) contractors and subcontractors to gauge the ER health of their area of accountability in the storage, construction, and testing portion of a new nuclear plant project.

- Storage of ER Components – Appendix 5.A
- Installation and Construction Maintenance of ER Components – Appendix 5.B
- Testing of ER Components – Appendix 5.C

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 concerning the objective and/or focus area))

5.5 References

EPRI Advanced Nuclear Technology: Equipment Reliability for New Nuclear Plant Projects: Industry Recommendations for Design. EPRI, Palo Alto, CA: 2010.1021415.

EPRI Advanced Nuclear Technology: Equipment Reliability for New Nuclear Plant Projects: Industry Recommendations for Procurement. EPRI, Palo Alto, CA: 2010. 1021416.

Appendix 5.A – Storage of ER Components 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)** and those that assess implementation are designated with an **(I).**

The contents of Section 2 of this report (1021413) should be studied and used in conjunction with this module.

Note: The contents of this self-assessment module are best accomplished by extensive field observations and inspections. Detailed vertical slice investigations of selected components are recommended.

Topic 1: Shipping, Storage, and Handling of ER Components

Determine if the requirements for shipping, storage, and handling of ER critical and important components are clearly defined and implemented throughout all phases of component life.

Focus Area 1 – Defining Roles and Responsibilities for the Storage and Handling of ER Components

> The physical protection and maintenance of each ER critical or important component is an essential step in achieving and maintaining the future revenue-producing capability of the nuclear unit under construction. (2.2.1)
>
> The ER classification of each piece of equipment should be determined and should exist in the project master equipment list, in the procurement specification, and possibly in a separate ER-focused document. (2.2.1)
>
> Programmatic controls should be established that clearly define who is responsible for each portion of the proper storage and handling of components throughout the procurement, fabrication, and installation cycle. Included in this is responsibility for maintaining the components until turnover to the owner. (2.2.2)
>
> Nuclear insurers have certain requirements that will also need to be adhered to in order to maintain liability requirements for major components. These should be clearly identified in interface agreements and in the detailed project procedures and instructions. (2.2.2)
>
> Storage classifications and requirements for ER critical and important components should be identified in design and procurement documentation, and each responsible organization should have in place procedures and programs designed to ensure that these requirements are implemented and followed. (2.2.4)
>
> Owner oversight of vendor and EPC activities to ensure that storage and handling requirements are being maintained should receive high priority for both critical and important ER components. (2.2.4)

Objective: Determine if ER components are identified in project documents including the roles/responsibilities that the various parties involved (that is, suppliers, fabricators, shippers, etc.) have to ensure proper conditions and handling practices are maintained.

Sample Questions:

- Is the ER equipment classification of components identified in procurement and equipment specifications? **(P)**
- Do the procurement and equipment specifications delineate storage and handling responsibilities? **(P)**
- Are these requirements passed on to all levels and participants in the procurement and warehousing chain at the appropriate levels? **(P)**
- Are oversight and inspection provisions included and identified throughout the fabrication, manufacture, and shipping process? **(I)**
- Does each organization have documented responsibilities (in procedures or instructions) identified for the oversight and control of storage and handling of ER components? **(I)**
- Are the requirements of nuclear/equipment/property loss insurance organizations factored into programs at all levels of the supply chain? **(I)**
- As the project moves from construction to startup to turnover phases, are the responsibilities for each of the respective organizations clearly defined in procedures? **(I)**

Focus Area 2 – Shipping and Transportation of ER Components

The storage and handling of ER components from the time the component or materials leave the manufacturer can impact their performance and life expectancy in the future. It is important to understand that industry rules and guidance apply at the moment the component leaves the manufacturer and include all interim locations (for example, module fabrication shops), all on- and off-site storage locations, and transportation. (2.2.1)

Augmented storage requirements for ER critical and important components should exist in established project instructions. Compliance with these instructions should be routinely self-assessed and audited. (2.2.1)

Industry guidance exists on establishing packaging, shipping, handling, and storage requirements for nuclear plant components. (2.2.3)

Clear communication and understanding of the requirements that ensure that ER-related equipment and material integrity is maintained once the items leave the manufacturer's facility should be delineated in procurement agreements and documentation. (2.2.3)

Proper securing and handling of components to preclude damage should be clearly spelled out in procurement documents and established as a hold point prior to shipment. (2.2.3)

Objective: Determine if shipping and handling needs of ER components have been clearly defined, have been stipulated in project documents, and are being implemented in accordance with those requirements. Particular emphasis here will be on those portions of the supply chain prior to receipt at the project site.

Sample Questions:

– Do procurement documents define the requirements for shipping and handling of ER components? **(P)**

– Is a system of guidance and practices as recommended in Appendix 2.A of this report used to guide personnel to avoid the potential damage that can befall components, and are protection measures established based on the damage mechanisms? **(I)**

– Are these recommendations being adhered to by suppliers and shippers? **(I)**

– Are steps taken to protect ER components from damage during shipping? Are these defined in advance or determined prior to shipment? **(I)**

– Are industry lessons factored into shipping plans and implementation? Review cited references in the report for recommendations for given components to determine if practices address preventing problems. **(I)**

– Review in-practice storage of ER components. Are practices consistent with the recommendations outlined in Appendix 2.B for the applicable components? **(I)**

Focus Area 3 – Storage and Handling

The new generation of nuclear plants may have a modular construction design that creates additional handling and storage issues. The modular concept may require that the subcomponents and materials to be sent to a facility for fabrication and assembly before being sent to the plant site, increasing the likelihood of damage or defects due to mishandling, improper shipping, improper storage, or the introduction of foreign material. Necessary handling, storage, foreign material exclusion (FME) practices, and shipping requirements should be in place at the fabrication facility. (2.2.1)

Careful delineation of shipping and storage requirements and expectations during all project phases will be an important aspect of maintaining the quality and integrity for ER critical and important components. (2.2.1)

Critical and important ER components should be uniquely identified and tagged from the time they leave the suppliers' facilities to promote visibility and awareness of the importance of the components. Color-coded tagging, banding, or other means of identification should be considered. (2.2.1)

Consideration should be given to the various environments to which the equipment could be exposed in fabrication and installation locations and in transit (including temporary locations) situations. (2.2.4)

Objective: Determine if ER components receive additional, focused consideration with respect to maintaining and monitoring storage conditions.

Sample Questions:

- Are storage levels for ER components clearly defined and implemented at the various steps in the fabrication and installation process? **(P)**
- Are sensitive components protected during installation and fabrication? **(I)**
- For prefabricated modules, which will comprise many components, are the more stringent storage requirements adhered to? **(I)**
- Are the critical ER components identified clearly to ensure awareness and need for protection and handling care? **(P)**
- For selected components, review and evaluate storage conditions for the following situations to ensure that component protection is being maintained: **(I)**
  - Shipment to component and subassembly organizations
  - Time while at these locations
  - Shipment to the site
  - Storage and handling prior to installation at the site
  - Storage after installation prior to pre-operation testing
  - Storage after pre-operation testing prior to startup testing (post-core load testing)
- Sample components to ensure that vendor and project instruction–required conditions such as motor heaters/desiccant/covers/protection devices/periodic rotation of shafts/bearings/inert atmospheres are identified and included as part of warehouse, storage, and pre-operations preventive maintenance (PM) procedures. **(I)**
- Are the various conditions that will be seen by ER components (heat, humidity, etc) during the various phases of the project taken into account, and are protective steps taken? **(I)**
- For sample components installed in the plant, are the proper storage conditions being maintained? **(I)**
- For environmentally sensitive subcomponents and materials such as elastomers, lubricants, instrumentation, etc., are special steps being taken to adhere to the manufacturers' recommendations and life limitations? **(I)**

Objective: Determine if the manner in which ER components are handled during the fabrication, shipment, storage, and installation portion of the project is consistent with component supplier recommendations and good industry practices.

Sample Questions:

– Are material and component handling practices being used by the various organizations consistent with guidance from manufacturers and guidance provided in EPRI report 1015271? **(I)**

– Are rigging and installation procedures documented at the various locations in the supply chain process to ensure that ER components are handled in the proper manner in order to minimize damage? **(I)**

– Are the personnel who are lifting and handling ER components provided with training to ensure an awareness of the needs of the components that they are handling? **(I)**

– Is handling equipment (hoist, cranes, lifts, carts, etc.) maintained in accordance with industry standards and procedures? **(I)**

Appendix 5.B – Installation and Construction Maintenance of ER Components 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)** and those that assess implementation are designated with an **(I).**

The contents of Section 3 of this report (1021413) should be studied and used in conjunction with this module.

Note: The contents of this self-assessment module are best accomplished by extensive field observations and inspections. Detailed vertical slice investigations of selected components are recommended.

Topic 1: Maintenance of ER Components During Construction and Testing Phase

Determine how maintenance of ER critical and important components is addressed during construction and installation activities of the project and how responsibilities are defined and controlled during this period of transition to the plant operator.

Focus Area 1 – Maintenance Program for ER Components

Traditional construction practices result in the formal plant maintenance process beginning upon turnover of systems and components to the utility owner or operators. This practice leaves plant components and systems vulnerable to degradation or damage that, although it may be detected and corrected prior to final plant operation, could also be prevented by early implementation of a formal maintenance program for ER critical and important components. (3.2.1)

The physical identification of ER critical and important components is important. (3.2.1)

Suppliers, fabricators, and constructors may not have particular knowledge or awareness of the meaning of ER concepts or of the classifications of critical and important components. (3.2.1)

Clearly defined roles and organizational responsibilities are required for maintaining ER Critical and important components as the project transitions through the procurement, fabrication, storage, installation, testing, and turnover phases. (3.2.2)

Maintenance of items should not be limited to items installed in the field. Required maintenance of items while in storage should be factored in to the programs of the responsible organizations. (3.2.2)

Integration into permanent plant processes for controlling and implementing maintenance activities will ensure not only that the critical and important components are being properly maintained during construction and testing and pending transfer, but it will also enable plant personnel to become familiar with the components prior to plant operation, when access may not be as easy or safe. (3.2.2)

Objective: Determine if responsibility for maintenance of ER components is clearly defined and controlled.

Sample Questions:

– Is the responsibility for maintenance of ER equipment components, regardless of location and installation status, clearly defined and established? **(P)**

– Are personnel trained and aware of the designation of ER components and their significance? (Could be accomplished through training, procedures, etc.) **(I)**

– For ER components that are not yet received at the plant site, have the needs and responsibilities for maintenance of the equipment been delineated, and is it being implemented (for example, at the module construction facilities)? **(I)**

– Does a formal process to identify roles and the transfer of "ownership" and responsibilities for the maintenance (both preventive [including predictive] and corrective) of plant equipment exist (documented) between the EPCs, various subcontractors, and the utility owner/operator? **(I)**

Objective: Determine how maintenance of ER components is being accomplished during the construction and testing phase.

Sample Questions:

– Is ER equipment clearly designated as such at the construction site and at fabrication facilities? **(P)**

– Is the maintenance program for these components clearly defined and documented in procedures or guidelines? **(P)**

– Are instructions used to define maintenance steps in order to ensure that proper steps are being taken to implement manufacturers' recommendations? **(I)**

– Are the instructions consistent with and/or being used to develop permanent plant instructions?

– Are the maintenance activities consistent with the condition and status of the ER components? (For example, if equipment is being operated to support plant activities, are maintenance tasks consistent with the demands on the components?) **(I)**

– Are the permanent plant databases and work management systems being used to support the maintenance functions? **(I)**

– Are feedback and recommendations from maintenance personnel on the activities (such as accessibility, practicality, environmental conditions, etc.) being collected, entered into the plant CAP, and reviewed for improvement? **(I)**

– Are permanent plant maintenance personnel involved in the maintenance activities? **(I)**

– As the components, modules, skids, and so on are moved from the warehouse to the field, are procedures in place to ensure that they are properly maintained in their new location? **(I)**

- PM tasks performed during storage and prior to operations (including testing activities) may be different. Is this taken into account? **(I)**
- Are controls established for the bagging, identification, and storage of disassembled parts? **(I)**
- Are configuration control provisions established (that is, independent or QC verification) along with appropriate hold points for maintenance activities? **(I)**
- Are records (that is, maintenance work packages) maintained of activities performed on the equipment? **(I)**

Focus Area 2 – Protection of ER Components

The ER critical and important components should be protected from installation and construction damage. Damage may occur during handling and movement of equipment necessary for installation and by impact from other activities or the construction environment. (3.2.3)

The protection of fragile or environmentally sensitive parts of critical and important components during fabrication and construction activities will prevent damage and degradation prior to commercial plant operation. (3.2.3)

During testing activities, some systems will be required to be physically complete and intact, while adjacent systems may not be. (3.2.3)

Construction environments are often places of high activity where the use of equipment such as scaffolding, ladders, or platforms is needed. However, measures should be put in place to protect sensitive ER-related permanent plant equipment from being stepped on or otherwise used, resulting in damaged instrumentation lines, cables, transmitters, and so on. Training and measures to make site personnel aware of this should be considered to mitigate the improper practices that can result in such events. (3.2.3)

Preventing dirt, debris, and foreign material from entering components and the system during fabrication, installation, and testing and pending turnover is important to ensure the reliable operation of nuclear power plants. (3.2.3)

Good FME practices used throughout the project will pay large dividends in the end; better to keep systems and components clean while the project is in progress than to suffer the consequences of poor FME practices later. (3.2.3)

Covers, lids, and other devices that prevent the entry of foreign material into components should be an integral part of a program of protection for the equipment during this phase. (3.2.3)

Objective: Determine if provisions are being implemented to protect ER components from damage or deleterious effects that could be inflicted during fabrication, construction, and testing activities.

(Note: This area should be distinguished from and not confused with storage conditions as assessed in Appendix 5.A.)

Sample Questions:

- By inspection and observation, are ER components and equipment being adequately protected (including environmental concerns) during fabrication, construction, and testing activities? **(P)**
- Are fragile and environmentally sensitive components (such as instrumentation tubing, instruments, gauges, etc.) removed or protected during fabrication and construction activities? **(I)**
- Upon completion of testing activities, are sensitive components that were installed to facilitate testing removed and/or properly protected? **(I)**
- Where ladders, scaffolding, work platforms, or temporary supports are used, are ER components protected from damage? **(I)**
- Are ER components that have been installed protected from material and equipment handling activities that are moving in and around the construction site? **(I)**
- When permanent ER systems are operated for testing activities, temporary support systems maybe be utilized (air, cooling water, lubrication, etc.) because permanent components are not yet installed. Are provisions to protect ER components being used (for example, air and water filters, temporary HVAC to protect operating equipment, etc.)? **(I)**
- Are problems and deficiencies that are identified entered into the CAP to ensure understanding and appropriate actions to prevent recurrence? **(I)**
- Are provisions and practices being used to prevent the introduction of foreign material and objects into ER components? (Ideally, implementation of elements of permanent plant processes and requirements, as appropriate, will occur.) **(P)**
- By inspection, are covers, lids, and other devices that prevent the entry of foreign material into components an integral part of a program of protection for the equipment? **(I)**

Appendix 5.C – Testing of ER Components 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)** and those that assess implementation are designated with an **(I).**

The content of Section 4 of this report (1021413) should be studied and used in conjunction with this module.

Note: The contents of this self-assessment module are best accomplished by extensive field observations and inspections. Detailed vertical slice investigations of selected components is recommended.

Topic 1: Construction Testing of ER Components

Determine if the construction testing activities of ER critical and important components address recommendations and practices that ensure proper installation and long-term reliability.

Focus Area 1 – Testing of Modules and Subassemblies and Installation Checks

> Post-installation and post-fabrication preparation (checks) of ER critical and important components plays an important role in ensuring that components will operate reliably, meet design and operational requirements, and are capable of being maintained properly in the future. (4.2.1)
>
> Because modular design and prefabrication are a part of the new plant construction process, some initial testing and checks will be performed at the fabrication facility by that organization. (4.2.1)
>
> Participation of the owner or the owner's designees in the various testing and installation checks is an important element. (4.2.1)

Objective: Determine if the post-installation checks and construction testing for ER components are clearly defined and complete in order to ensure that the components are ready for the rigors of pre-operational testing activities.

Sample Questions:

General:

- Are ER components subjected to rigorous checks before and after installation, but before initial test activities are begun? **(P)**
- Are these checks clearly defined, and are the results documented for future use? **(I)**
- Compare the planned and completed activities with those recommended in Section 4.2.3 of the report and in EPRI report 1009709, *Post Maintenance Testing*. Are the testing activities consistent with these recommendations? **(I)**

- Are the checks and tests thorough enough to ensure that the components are ready for the rigors of pre-operational testing activities? **(I)**
- Are testing failures and deficiencies identified and entered into the plant CAP for evaluation and followup? **(I)**

Vendor Activities

- Do vendor surveillance activities verify that testing meets project expectations and that all testing documentation is supplied with the equipment or component? **(I)**
- Are the tests to be conducted by the suppliers clearly defined in project documentation, including their objective and their acceptance criteria? **(P)**
- Are owner witness and hold points identified in advance and adhered to? **(I)**
- Are performance objectives and acceptance criteria clearly defined? **(I)**
- Are subcomponent test data, such as pump performance tests, valve tests, motor tests, and instrumentation and control tests conducted by the suppliers, provided with the equipment when it is shipped? Is it technically reviewed by the owner or their representative? **(I)**

Focus Area 2 – Use of Permanent ER Equipment During Construction

As plant equipment is installed, there will be a tendency to use permanent ER systems and equipment to provide pre-testing support functions such as flushing water, electrical power, and compressed and instrument air. However, it is important to recognize the inherent risks associated with doing this. (4.2.4)

Objective: Determine if the use of permanent plant ER components during construction is carefully evaluated and if appropriate steps have been taken to protect the equipment.

Sample Questions:

- Have documented engineering evaluations been conducted that ensure that the use of permanent plant systems and components are consistent with the design capabilities of the equipment? **(P)**
- Have the risks identified in Section 4.2.4 (and others) been evaluated? **(I)**
- Have additional protection measures been used, such as relief valves, circuit protection, and adjustments to control settings, to prevent damage to the plant systems and components? **(I)**
- Have proper grounding, cooling needs, operation of prelube systems, and space heaters been evaluated and put into place? **(I)**
- Have the potential personnel safety hazards that might arise from the use of the equipment been evaluated? **(P)**

Focus Area 3 – Use of ER Equipment with Temporary Services

Based on construction sequencing and status, testing of permanent plant ER equipment will likely involve the use of "temporary services," such as temporary seal injection water, power, air, and HVAC. (4.2.5)

Objective: Review the use of ER components where permanent support systems are not installed or complete.

Sample Questions:

– Has a review of temporary power supplies for electric motors been evaluated for adequacy? **(I)**

– Have the flow and net positive suction head of water sources for ER pumps been evaluated for adequacy? **(I)**

– Has the quality of the water source for ER pumps been reviewed for potential long-term effects if it does not meet the permanent plant requirements? **(I)**

– Has the need of the support systems for ER components, such as auxiliary coolers, lube oil coolers, room HVAC requirements, etc., been evaluated? **(I)**

– Will the inadvertent interruption of any temporary service cause harm to the ER component? If so, how is the potential for such an event being minimized? **(I)**

Focus Area 4 – Lay-Up Considerations of ER Equipment

A review of system design considerations and the need for chemistry control and maintenance should be conducted to ensure that ER systems and components are not exposed to harmful conditions. (4.2.6)

Based on system materials and process requirements (for example, raw water or demineralized water), potential damage mechanisms can exist as fluid systems lie dormant for periods of time. (4.2.6)

Objective: Review the conditions that ER components are being subjected to during construction and pre-operational testing activities, with an emphasis on the internal effects from their use and idle conditions.

Sample Questions:

– Has a review of system design requirements and the need for chemistry control been conducted to ensure that ER systems and components are not exposed to harmful conditions? **(P)**

– Are permanent plant personnel involved in the decision/approval process? **(P)**

– Are the conditions controlled and monitored from the first introduction of fluid to the time of turnover to the client? **(I)**

– Are stagnant (idle or nonflowing) periods evaluated to ensure that no damage to ER systems or components occur during this time? **(I)**

– Are the fluid conditions monitored, documented, and managed during this period? **(I)**

Topic 2: Pre-Operational Testing of ER Components

Determine if pre-operational testing activities recognize ER components and their role in plant reliability, and as such, ensure that the performance requirements are verified while protecting the equipment from degradation.

Focus Area 1 – Functional and Design Requirements

As part of the test plan for ER critical and important components, ER-related functional requirements at the system and component level should be identified, documented, included in the testing plans, and verified as part of the testing efforts. (4.3.2)

Objective: Determine if ER components receive adequate testing to verify functional and design requirements.

Sample Questions:

– Are testing activities adequate to ensure that operation capabilities of ER components are tested and verified? **(P)**

– Are the tests of sufficient thoroughness for ER systems and components not included in “safety-related” functions ? (It would be important here to have a subject matter expert on the assessment team or available to review test plans and results.) **(I)**

Focus Area 2 – Collection of Baseline and Test Data

As test plans are developed, it is important that ER critical and important components be identified in the plans, the procedures, and the documentation. (4.3.1)

As ER critical and important systems and components are tested and started up, data are collected that will be used to confirm conformance to design and functional requirements. These data are used by the plant staff after the plant is operational to establish baseline performance standards for trending and comparison. (4.3.3)

Objective: Determine if baseline test data are being collected for ER components and documented and turned over to operations personnel.

Sample Questions:

– Are the data being collected consistent with future plant needs and in a format that will enable them to be easily transferred into plant monitoring plans and databases? **(I)**

– Are the planned test parameters consistent with requirements for the on-going monitoring of system and component health? **(I)**

Focus Area 3 – Pre-Operational Testing of ER Equipment Precautions

> Normal test processes and procedures should have precautions and steps in place to ensure that plant equipment is protected during initial energizing and operation. (4.3.4)

Objective: Review precautions and steps that should preclude damage during initial testing of ER components.

Sample Questions:

- Are ER components identified as such in the initial test procedures? **(P)**
- Do test procedures contain precautions designed to prevent damage to ER components? (For example, monitoring of pressures, temperatures, voltages, current, etc. See Section 4.3.4 for additional recommendations.) **(I)**
- Are deficiencies that are encountered identified and documented? **(I)**
- Do test instructions advise that activities should be halted when such conditions are encountered until they can be reviewed and evaluated? **(I)**
- Are persons who will operate the ER components familiar with the precautions, and do they understand their significance to the equipment? **(I)**

Focus Area 4 – Integration of Plant Operations Personnel and Programs

> The plant testing programs provide an excellent training opportunity for plant staff to become knowledgeable regarding plant ER-related components and systems before conditions change. (4.3.5)

Objective: Determine that plant operations staff (all organizations) are involved with initial testing activities for ER components and that the process integrates with permanent plant programs as appropriate.

Sample Questions:

- Are permanent plant personnel, such as operations, maintenance, engineering, chemistry, etc., involved with initial test activities? **(P)**
- Are steps taken to capture activities and information (for example, photographs, digital data, work space details, etc.) prior to plant operation that will be of benefit to future plant operations? **(I)**
- During accessible conditions prior to areas becoming off limits due to environmental changes, are mockups, training aids, etc., planned and prepared by operations staff? **(I)**
- As systems and components are operated, are they monitored, and are the data trended and fed into permanent plant databases and health reporting systems? **(I)**

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