EPRI ELECTRIC POWER RESEARCH INSTITUTE

**MRP** Materials Reliability Program_____MRP 2014-017

(via e-mail)

July 11, 2014

To: MRP Integration Committee and Assessment TAC

Subject: MRP-227-A utility FMECA template

The Materials Reliability Program (MRP), as managed by the Electric Power Research Institute (EPRI), issued an inspection and evaluation guideline, MRP-227-A. The inspections in the guideline are based on an inspection sampling aging management process for currently operating U.S. pressurized water reactor (PWR) internals components. The guideline was developed to comply with industry material degradation aging management requirements. The safety evaluation issued on the original technical report by the U.S. Nuclear Regulatory Commission contained eight applicant/licensee action items.

The enclosed document was prepared by Westinghouse to assist applicants/licensees in addressing the action item(s) related to Failure Mode, Effects and Criticality Analysis. The objective of this document is to provide a simple, non-proprietary guideline for a failure modes, effects, and criticality analysis (FMECA) that is compliant with the original MRP-191 generic FMECA. The original generic FMECA forms the foundation for the MRP-227-A inspection sampling recommendations for managing aging in currently operating U.S. Combustion Engineering (CE) and Westinghouse PWR plants.

Sincerely,

B. C. Rudell
Chairman, Integration Committee
EPRI-Materials Reliability Program

Anne Demma
Program Manager
EPRI- Materials Reliability Program

Attachment: Letter dated May 23, 2014 "Transmittal of MRP-227-A Guideline on Failure Modes, Effects and Criticality Analysis for Combustion Engineering and Westinghouse Pressurized Water Reactor Designs"



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Our ref: NSD-EPRI-14-5

May 23, 2014

**Transmittal of MRP-227-A Guideline on**
**Failure Modes, Effects and Criticality Analysis for**
**Combustion Engineering and Westinghouse Pressurized Water Reactor Designs**

Dear Mr. Amberge:

This letter officially documents transmittal of NRC Follow-up Items Related to Generic Applicability of MRP-227 project. This document is being provided as a deliverable of the EPRI Project Agreement MA 10001231, corresponding to Westinghouse Sales Order 101303.

If you have any questions, please contact the Westinghouse Project Manager, Jun C. Bae, at (860) 731- 1778.

Regards,
WESTINGHOUSE ELECTRIC COMPANY[1]

Anthony W. Nowinowski
Customer Project Manager

Attachment: LTR-RIAM-14-45

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# Attachment 1:

## MRP-227-A Guideline on Failure Modes, Effects, and Criticality Analysis for Combustion Engineering and Westinghouse Pressurized Water Reactor Designs

## BACKGROUND

The United States (U.S.) nuclear power industry, through the Materials Reliability Program (MRP), as managed by the Electric Power Research Institute (EPRI), issued an inspection and evaluation guideline, MRP-227-A [1]. The inspections in the guideline are based on an inspection sampling aging management process for currently operating U.S. pressurized water reactor (PWR) internals components. The guideline was developed to comply with industry material degradation aging management requirements. The safety evaluation [1] issued on the original technical report by the U.S. Nuclear Regulatory Commission contained eight applicant/licensee action items. These eight action items must be completed to comply with the plant-specific use and implementation of MRP-227-A [1]. U.S. utilities are currently engaged in documenting plant-specific compliance demonstration to these requirements for the period of extended operation. The objective of this document is to provide a simple, non-proprietary guideline for a failure modes, effects, and criticality analysis (FMECA) that is compliant with the original MRP-191 [2] generic FMECA. The original generic FMECA forms the foundation for the MRP-227-A inspection sampling recommendations for managing aging in currently operating U.S. Combustion Engineering (CE) and Westinghouse PWR plants.

A FMECA is a bottom-up approach to analyzing the effects on a system, assembly, or component that may arise from the occurrence (or postulated occurrence) of potential failures. As part of the FMECA, criticality rankings are assigned. The U.S. industry has very limited operating experience (OE) with regard to failures in the PWR internals components. A robust FMECA is an essential tool for anticipating failures, whether similar failures are already part of the industry OE or have had no precedent. The key to a successful reliability and preventive aging management maintenance program is a FMECA based on credible reference sources with wide-ranging input from a team of experts in specified contributing disciplines. The primary function of a FMECA is to consider each major part of the system, assembly, or component; how it may fail (the mode of failure); what the effect of the failure on the system would be (the failure effect); and how critical the consequence of failure is to effective management of the item. Management of the item in the current MRP-191 process includes both safety and commercial considerations. The general failure modes and effects analysis process in MRP-191 was adapted from ANSI/IEEE Standard 352 [3]. The objectives are to ensure that all conceivable failure modes and their effects on the operational success of the item under evaluation have been considered, to document the potential failures, to evaluate the magnitude of the effects, and to document the basis for decisions and evaluations determined as a result of the process. The basic questions that are typically addressed by a FMECA include:

1. How can each part conceivably fail?
2. What mechanisms might produce these modes of failure?
3. What could the effects be if the failures occur?
4. Is the failure in the safe or unsafe direction?
5. How might the failure be detected?
6. What inherent provisions are provided in the design to compensate for the failure?

When coupled with a screening process, the resultant FMECA provides a technical basis to categorize and rank reactor internals components on the basis of materials degradation and

functionality (including component consequence of failure considerations, plant reliability, and financial impacts). A FMECA essentially provides the intermediate step between the screening and initial categorization of the reactor internals components. The relationship of the FMECA to the overall functionality process, as used in the development of the sampling aging management strategy of MRP-227-A, was shown in MRP-191, Figure 2-2 [2]. Figure 1 illustrates it here.

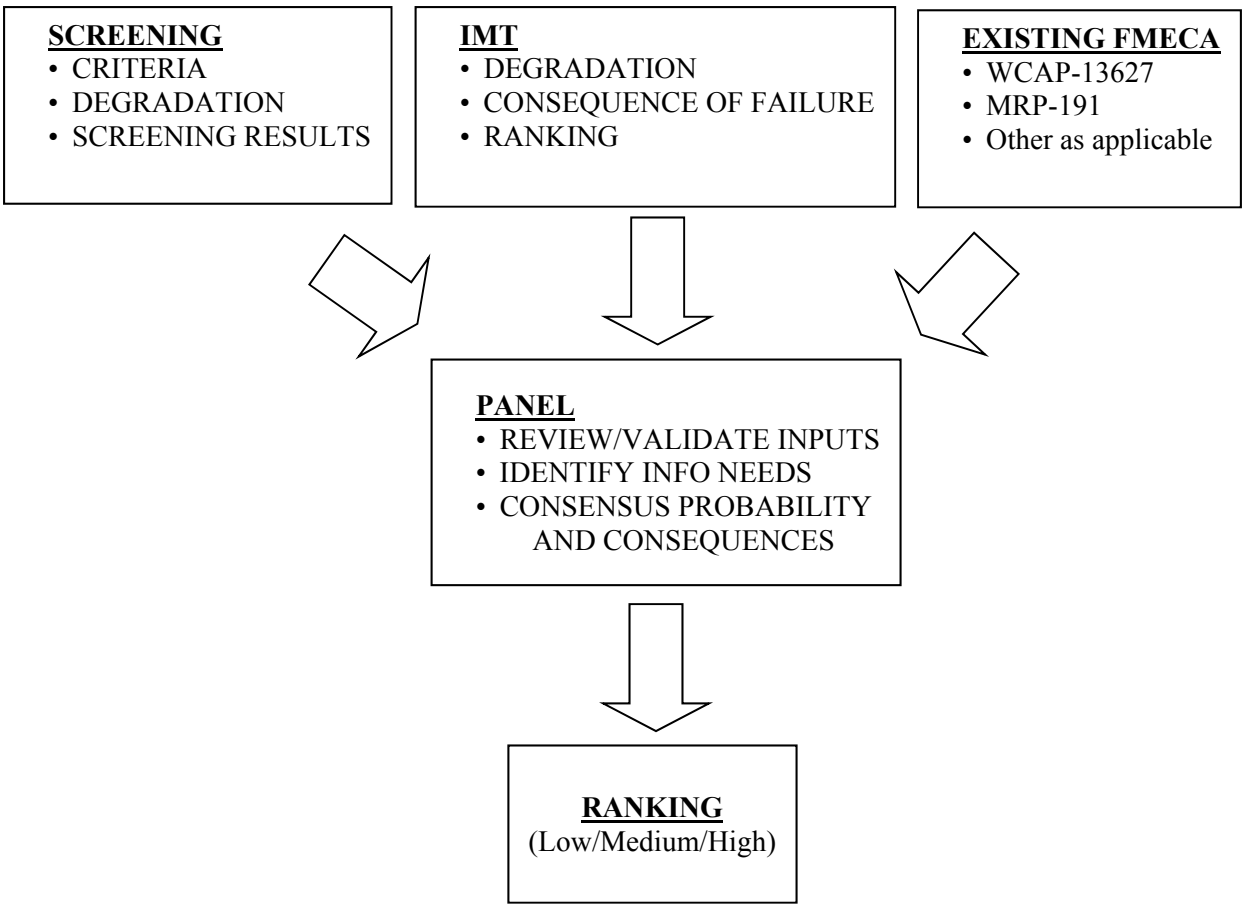


**Figure 1: MRP-191 General Outline of FMECA Process**

The FMECA used in the development of the industry sampling inspection strategy for managing aging in PWR internals is not a probabilistic risk analysis-based effort. It is semi-quantitative, using expert elicitation, and is conceptually considered to be a conservative method to ensure reliability and safety in the management of material aging in the current operating fleet of PWR internals. Steps for conducting a FMECA to assess differences from the data considered in MRP-191 for plant-specific implementation of MRP-227-A are provided in this guideline and are compliant with the generic industry process.

**GUIDANCE ON PLANT-SPECIFIC APPLICABILITY DEMONSTRATION**

The steps of this guideline serve to review and confirm plant-specific compliance with MRP-175 [4] screening results, as well as with MRP-191 generic categorization and ranking of the plant-specific reactor internals systems, assemblies, or components. Where items are determined to be different from those considered in the generic industry efforts, steps needed to affirm direct application of the MRP-227-A sampling inspection strategy or determine alternate strategies are outlined. There are five steps defined in the process:

1. MRP-227-A Compliance Demonstration
2. MRP-191 Component Materials and Environments Consistency Evaluation
3. MRP-175 Screening Consistency Evaluation for Identified Components that are not Consistent with MRP-191 Components
4. MRP-191 FMECA Update and Component Categorization and Ranking
5. PWR Internals Materials Aging Management Sampling Inspection Program Definition

Step 1: MRP-227-A Compliance Demonstration

Confirm compliance with MRP-227-A, Section 2.4 requirements. Specifically, confirm that the following are true for the unit under evaluation:

1. The unit has operated for fewer than 30 years with high-leakage core loading patterns followed by implementation of a low-leakage fuel management strategy for the remaining years of operation.
2. The unit operates as a base load plant or has reconciled any non-base load operational differences with the requirements for base load systematic operation.
3. The unit has implemented no design changes beyond those identified in general industry guidance or recommended by the original vendors.

Step 2: MRP-191 Component Materials and Environments Consistency Evaluation

1. Compile unit-specific data relative to the component listings contained in MRP-191 Tables 4-1, 4-2, 4-3, 4-4, and 4-5 for the applicable original vendor design.
2. Confirm that unit-specific data is identical to relevant MRP-191 inputs, specifically noting the following:
   a. Screening inputs in MRP-191 Tables 4-6 or 4-7 as applicable for the design.
   b. Component modifications that would affect the physical composition, fabrication, or age of the item being considered (relative to the original equipment manufacturer designed and delivered installed configuration).
   c. Unit-specific operating events.
   d. Impacts of unit-specific operating events on the relative ranking of the component sample in its entirety.
   e. Isolated OE that could introduce localized degradation. Examples of items to consider include: unit-specific operational history, fuel failures introducing increased levels of exposure in a localized area, physical impacts from loose parts, or non-design based transient events.

3. Affirmation of consistency with MRP-191 data or identification and quantification of any differences from the MRP-191 data.

Step 3: MRP-175 Screening Consistency Evaluation for Identified Components that are not Consistent with MRP-191 Components

Apply MRP-175 screening criteria to items identified in Step 2 that deviate from the MRP-191 data. Compare these deviations to the original generic results (MRP-191 Tables 5-1 and 5-2). Affirm consistency and note differences where applicable.

Step 4: MRP-191 FMECA Update and Component Categorization and Ranking

Document confirmation of direct applicability of the MRP-191 generic results or perform an updated MRP-191 FMECA. The process for performing an MRP-191 equivalent FMECA are provided in detail in MRP-191, Chapter 6. The steps are summarized here.

1. Collect and summarize relevant inputs to support screening and functionality assessments. Include unit-specific historical data, noting both uneventful operation and known incidents of component malfunction and failure, industry OE, and updated requirements or potential requirements that might impact relevant criteria for performing the assessments.
2. Assemble an expert panel that includes the following areas of expertise:
   a. component design, testing, and repair
   b. structural modeling and analysis
   c. thermal hydraulics and systems analysis
   d. neutron fluence and radiation analysis
   e. materials degradation and failure experience
   f. component inspection experience
   g. risk assessment
   h. inspection requirements
   i. system function and OE
   j. licensing and regulatory interaction
3. Provide all data to the expert panel for review.
4. Conduct an expert panel to assess the impact of unit-specific information on the MRP-227-A inspection sampling program. During the FMECA process, the responsibilities of the expert panel must include the following:
   a. Review all reactor internals components for completeness, applicability, and accuracy.
   b. Verify that component descriptions and inputs were adequate or identify what additional information is needed to perform the evaluation.
   c. Verify that the likelihood and consequences identified for each component are reasonable and accurate.
   d. Consider additional insights provided by the expert panel that could change either the likelihood or consequences of degradation.
   e. Ensure that a consistent philosophy was applied equally to all components, individually and as a consistent sample.
   f. Create initial and final classification of items through a consensus process.

The review process used by the expert panel members for the FMECA evaluation of each individual component must include:

1. The geometry, location, and function of each item as explained by the designer or analyst.
2. Material and screened-in degradation mechanisms summarized by the materials analysts.
3. Relevant information from previous unit-specific or industry sources, as applicable, considered and evaluated.
4. Failure or degradation experience or other known information that would affect the degradation likelihood category, provided by knowledgeable panel members.
5. A consensus degradation category developed by the panel, or an action item defined to locate missing information that was needed by the panel to make their decision.
6. The effects and consequences of degradation or component failure, or other known information that would affect the damage category, provided by knowledgeable panel members.
7. A consensus damage category developed by the panel or an action item defined to pursue additional information that was needed by the panel to make their decision.
8. Application of definitions as contained in MRP-191 Tables 6-2, 6-3, and 6-4 as the basis for categorization and ranking of the components.
9. Categorization and ranking of components and inspection sample selection as detailed in MRP-191 Chapter 7 affirmed by the expert panel using the defined consensus process.

Step 5: PWR Internals Materials Aging Management Sampling Inspection Program Definition

Affirmation of the MRP-227-A sampling program definition or redefinition of aging management inspection requirements based on the results of the revised FMECA process.

Formal documentation of all aspects of conducting and confirming execution of these steps under plant specific quality assurance safety grade compliance documentation is required.

## CONCLUSION

To demonstrate plant-specific applicability of the MRP-227-A sampling inspection strategy for managing aging in reactor internals, licensees must demonstrate that the criteria forming the basis of the MRP-227-A inspection sampling strategy for managing material aging degradation for PWR internals in currently operating CE and Westinghouse designs are applicable to the unit under consideration.

This report provides guidelines to demonstrate plant-specific applicability of MRP-227-A and to evaluate the impact of potential unit-specific data on the applicability of the MRP-227-A inspection recommendations. A plant-specific evaluation demonstrating compliance with the criteria defined in this report, with the criteria defined in MRP-227-A, Section 2.4, and with any additional plant-specific regulatory commitments for managing aging in the reactor internals will be sufficient to demonstrate the applicability of the MRP-227-A inspection sampling strategy for management of material aging-related degradation in currently operating CE and Westinghouse designs.

## REFERENCES

1. *Materials Reliability Program: Pressurized Water Reactor Internals Inspection and Evaluation Guidelines (MRP-227-A)*. EPRI, Palo Alto, CA: 2011. 1022863.
2. *Materials Reliability Program: Screening, Categorization, and Ranking of Reactor Internals Components for Westinghouse and Combustion Engineering PWR Design (MRP-191)*. EPRI, Palo Alto, CA: 2006. 1013234.
3. ANSI/IEEE, Standard 352-1987, "IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Safety Systems," IEEE, 1987.
4. *Materials Reliability Program: PWR Internals Material Aging Degradation Mechanism Screening and Threshold Values (MRP-175)*. EPRI, Palo Alto, CA: 2005. 1012081.