PWR Reactor Internals Degradation Management

ISSUE STATEMENT

Reactor pressure vessel internal components in pressurized water reactors may be affected by extended operation related degradation effects. These include general material effects such as wear, fatigue and stress corrosion cracking, as well as irradiation-induced effects such as irradiation-assisted stress corrosion cracking, embrittlement, creep and void swelling. As the PWR plants continue to operate, the probability of one or more degradation mechanisms occurring in the internals and structural attachments to the vessel wall increases.

The implementation of degradation management plans for various plant components – including the reactor internals – can enhance long-term safety and reliability of PWRs, but advances are needed in three areas:

- Development of inspection and evaluation guidelines based on irradiated material data and degradation modeling
- Improvement of inspection techniques
- Development of evaluation, repair and replacement strategies and techniques.

DRIVERS

Regulatory Drivers: Regulatory commitments associated with license renewal typically require plants to implement a reactor internals degradation management program that follows industry guidance. The Inspection and evaluation guidelines for reactor internal components (MRP-227) provide the basis to fulfill this commitment. This document has been submitted to the U.S. Nuclear Regulatory Commission for review and safety evaluation. Other countries have similar regulatory commitments even though the regulators and regulatory processes are different.

Regulators also may require approval of repair and replacement strategies and techniques for PWRs, such as the NRC required before it allowed welding to be performed on irradiated BWR internals (see BWR and PWR irradiated material welding roadmap).

Limitations of Inspection Technology: Inspection of reactor internal components will use established techniques to the extent practicable. Because of the limited of experience with these inspections, however, it will be important to assess accessibility and tooling issues, regulatory acceptance of visual inspection techniques, and the applicability of additional techniques for specific degradation mechanisms.

Plant Safety and Operability: The internals are not pressure boundary components.. However, internals do perform safety-related functions.

Limitations on Available Repair/Replacement Guidance: The availability of evaluation, repair, replacement and mitigation methodologies for reactor internal components is limited. There is an immediate need to develop uniform guidance for the design and qualification of repairs and/or replacement for reactor internals, as well as to develop component and condition-specific repair/replacement options (e.g., mechanical repair techniques). Information should be readily available to support an informed decision whether to continue with a component inspection, evaluation, repair and replacement management strategy versus full reactor internals replacement.

RESULTS IMPLEMENTATION

Implementation of research results will be accomplished through a number of key products:

- A degradation management strategy for reactor internal components, including inspection and evaluation guidelines and inspection plans.
- Regulatory approval of the degradation management strategy.
PWR Reactor Internals Degradation Management

- Tools to implement the degradation management strategy, such as supporting technical basis documents, templates for utility programs, inspection plans and license submittals.
- Assessment of existing nondestructive evaluation (NDE) methodologies that could support the degradation management strategy (inspection standard).
- Evaluation methodologies and acceptance criteria to evaluate the significance of degradation observed in reactor internal components with respect to operability and safety.
- Updated inspection and evaluation guidelines (MRP-227) based on the results of testing, models, and crack growth curves (see the BWR and PWR Irradiated Materials Testing and Degradation roadmap).
- NDE technologies optimized for specific application to reactor internal components.
- Design and component-specific evaluations of components most susceptible to degradation (e.g., bolt loading pattern evaluations).
- Repair and replacement techniques for susceptible components using mechanical repair designs and weld repair techniques (see BWR and PWR irradiated material welding roadmap); and new replacement materials (see the BWR and PWR Irradiated Materials Testing and Degradation roadmap).
- Results of plant inspections and operating experience to periodically evaluate the reactor internals degradation management strategy (components to be inspected and inspection frequency, as well as component repair and replacement guidance).
- Methodology for evaluating full reactor internals replacement versus inspect/repair management strategy.

PROJECT PLAN

Both EPRI and the PWR Owners Group (PWROG) have significant involvement in the Reactor Internals Management effort.

EPRI's Materials Reliability Program has the lead in developing and maintaining the inspection and evaluation guidelines. This includes issuance of the guidelines, dialog with the NRC to support the safety evaluation review, and update of the guidelines to incorporate improvements gained through field inspection results and ongoing testing and modeling research. EPRI also has the lead in collecting irradiated material testing data (see the BWR and PWR Irradiated Materials Testing and Degradation roadmap), documenting the results of field inspections, and validating, refining and updating the materials model. Finally, the Materials Reliability Program has the lead in assessing repair/replacement needs and developing weld and mechanical repair and replacement guidance as needed (see BWR and PWR irradiated material welding roadmap).

Working with the EPRI Nondestructive Evaluation Program, the Materials Reliability Program has the lead for providing NDE system qualification requirements and qualifying inspection techniques for reactor internal components. This includes both evaluations of current techniques for use in these applications, as well as development of new or enhanced techniques for plates and bolts. EPRI will also update the inspection standard (MRP-228) as necessary.

In support of inspection planning, the PWROG has the lead in developing baseline plant drawing and fabrication records on a generic basis, for developing a generic methodology for evaluation and disposition of internals inspection results, and for evaluating existing operating experience and analysis results to develop a ranking of component susceptibility (risk). The PWROG also has the lead in developing component-specific evaluation guidance (for example, for guide card wear).

RISKS

The accessibility of some components may limit the effectiveness of current examination methods to provide reliable inspections. Further, it will be a challenge to reliably inspect all of the internal components because of the variability between individual plants. For example, bolt head design affects the ability to transmit ultrasound and there are many head designs.

Comprehensive repair and replacement strategies will require significant coordination and input from nuclear steam supply system vendors. Proprietary information and commercial considerations must be carefully managed to ensure sufficient information is available to the industry on a generic basis, while protecting vendor interests.
The NRC is currently evaluating the adequacy of the visual examination approach used by BWRs. Since PWR reactor internals degradation management will rely on similar techniques, there is a risk that these concerns could be transferred to PWR reactor internals as well. To mitigate this risk, EPRI is participating in a round robin test of visual examination techniques with the NRC. Methods other than visual testing to examine plates will be investigated if conditions placed on visual inspections could impact inspection schedules.
Reactor Internals Management Roadmap

Materials Reliability Program (MRP)

Issue MRP-227 R-0 and
Submittal Templates

MRP-227 R-A

Determine 227 applicability to LTO

MRP-227 R-1

Irradiated Materials Testing (1)

Validate / Refine Modeling

Assess Repair Replacement Needs, Develop guidelines as needed (2)

MRP 228 RD

Develop / Improve NDE Technologies (plates and bolts)

MRP-228 R-1

NRC Review and SER on Criteria

NRC Review and SER on MRP-227

Acceptance Evaluations, Data Requirements and Methodologies

Baseline Information & Fabrication Records

Operating Experience, Risk Ranking and Response Planning

Implementation Manuals & Workshop

Component Inspection and Evaluation Support, e.g., Guide Cards

Emerging issues – NRC Support

Industry Coordination

Legend

Key Milestone
Funded Work
Unfunded Work

(1) See “BWR and PWR Irradiated and Testing Degradation Models” Roadmap for MRP activities
(2) See “Welding of Irradiated Materials for BWR and PWR Internals” Roadmap for MRP activities