ISSUE STATEMENT

Poor foreign material exclusion (FME) practices can lead to fuel cladding failures. A 2012 Fuel Reliability Program self-assessment concluded “Debris fretting is projected to become the leading cause of nuclear fuel failures.” Between 2000 and 2012, 24 PWRs in the U.S. experienced debris-related fuel failures in 38 cycles. In the same period, 22 BWRs (63% of the fleet) experienced this type failure mechanism in 42 cycles. In the case of BWRs, five units had to shut down mid-cycle on seven occasions to offload leaking assemblies. Since 2008, debris failures have caused more than 90% of the fuel failures observed in U.S. BWRs and are the dominant mechanism in non-U.S. BWRs. Debris-related failures are expected to be the dominant failure mechanism in U.S. PWRs by 2014.

DRIVERS

- **Nuclear Safety**: Fuel cladding is the first barrier to a fission product release to the general public and all reasonable actions to maintain the integrity of this barrier should be taken.
- **Personnel Radiological Factors**: Even small breaches of the fuel cladding can cause increased plant radiation fields and increase worker contamination events. Keeping worker integrated doses As Low As Reasonably Achievable (ALARA) is the cornerstone of a good radiological health program.
- **Operational Drivers**: Fuel failures drive up operating costs and can lead to unplanned outages, particularly in BWRs. These effects can impact public confidence and increase regulatory scrutiny.
- **Industry Commitment**: In 2006, utility chief nuclear officers pledged to support an initiative to drive industry to zero fuel failures (referred to as the “Zero by 2010” initiative). This commitment remains in effect and is now referred to as “Driving to Zero”.

RESULTS IMPLEMENTATION

Upon completion of this work, it is expected that:

- Alternate products that have been developed will be used where appropriate in lieu of wire brushes for most applications. Strands of small wire from wire wheels and brushes used during maintenance activities are one of the most common foreign materials causing fuel cladding failure.
- Utilities will incorporate FME techniques and culture into their business practices. Utilities will ensure material and service providers institute standards that preclude the introduction of foreign material into components and systems.
- Utilities will implement a program that systematically searches for and removes existing debris from plant systems and components. Areas of high risk and potential for debris accumulation need to be identified and resources committed to search and removal.
- Fuel suppliers will continue development of and improve debris filters and debris fretting resistance designs for their fuel products. Controlled testing will be conducted prior to introducing these products into commercial reactors. Once introduced commercially, a period of performance monitoring will be required to assess improvement gains.

PROJECT PLAN

A defense-in-depth approach is required to eliminate fuel failure caused by foreign material. Four strategies are needed to eliminate debris-related fuel cladding failures.

**Eliminating the Introduction of Foreign Material**

- Plant personnel must improve their implementation of FME programs and practices. Twenty percent of all Maintenance Areas for Improvement are related to FME. In February 2011, INPO released Revision 1 of 07-008, *Guidelines for Achieving Excellence in Foreign Material Exclusion (FME)*. Utility gap analyses that benchmarked existing programs against the new Guidelines were analyzed and follow-up actions are being developed and implemented by utilities.
- Utilities should provide training to newly assigned FME program Coordinators, collaborate to implement new best FME practices and products and enhance training where needed for site personnel. Additionally, annual FME Coordinator training is available to EPRI NMAC members and vendors who provide refueling services or supply fuel.
- Utilities will revise *Nuclear Maintenance Applications Center: Foreign Material Exclusion Guidelines* – Product ID 1016315, in 2014 to address items identified following the utility gap analysis of INPO 07-008, Rev. 1, and address techniques identified from Fuel Reliability’s 2012 self-assessment area-for-improvement (AFI) response team.
• EPRI has researched and developed a high performance High Filament Retention (HFR) wire wheel for use where alternatives cannot be used. Utility implementation is in progress.

• EPRI has developed new video-format training on wire brush fundamentals and use. EPRI has reviewed and accepted for continued training use the timeless principles expressed in Foreign Material Exclusion – Striving for Industry Excellence – Product ID 1014962.

• EPRI has developed standardized FME procurement requirements for material and service purchases. Utilities will incorporate these standardized FME procurement requirements into the appropriate material and service purchases. Material and service providers will incorporate FME techniques and culture into their business practices.

Process and Methods for Unrecovered Foreign Material
• Utilities will implement a program that systematically searches for and removes debris from plant systems and components. This program should include borescope, robotic camera, velocity flushes, tank inspections and periodic inspection of other locations where debris might settle or accumulate.

• EPRI has developed guidance that includes a decision tree process for utilities to address when below-the-reactor-vessel-core-plate inspections for foreign material should be performed in BWRs (Product ID 1024917) and in PWRs (Product ID 1026776). These inspections are high risk but potentially high reward activities.

Debris Resistant Fuel
• Fuel vendors continually upgrade their fuel products to improve performance. Bottom nozzle debris filters have evolved over time and the latest generation products filter very small debris. The new generation debris filters are currently being placed in service and require monitoring for effectiveness.

• Some BWRs have installed strainers in feedwater and other similar systems to filter out debris that would otherwise reach the reactor vessel. These installations warrant monitoring for effectiveness and broader application.

• Fuel suppliers have and continue to improve manufacturing processes for foreign material exclusion during fabrication as well as designing improved debris filter features in their assembly designs as the result of the Zero-by-2010 initiative. These improvements will be monitored to ensure their effectiveness.

• EPRI is working with Korea Hydro and Nuclear Power Company and Korea Nuclear Fuel Company to assess standardized practices for testing debris-filtering capabilities of fuel assembly designs, including all types of variable-sized debris and hydraulic conditions. These results will be used to recommend an industry standard test protocol for consistent performance evaluations of existing and new assembly debris filter designs.

Debris Resistant Plant Features
• Plants with chronic debris failures will assess whether additional plant system enhancements are necessary to address the failures. EPRI studies have shown that pump-forward BWRs can be at particular risk for this failure mechanism as heater drains are not returned back to the condenser for filtration by condensate polishing. Pump-forward BWRs represent 25% of the U.S. fleet but account for >50% of BWR failures. One system enhancement that has been implemented by BWRs is reducing the mesh size of feedwater pump suction strainers.

RISKS
There can be a long lag time between in-cycle identification of a fuel failure and determining the cause of failure. This, coupled with the fact that more than two or more cycles of defect-free fuel performance is needed to assess the effectiveness of actions taken to prevent failures; it may take several fuel cycles (up to 6 years) to determine if other measures are needed to address this Roadmap issue. Therefore, implementing parallel and multiple activities is necessary if results are desired in a shortest time frame possible.

Implementing a program that systematically searches for and removes debris from plant systems and components has moderate risks. The costs associated with developing and staging contingency activities and resources can be high. Planned on-line and outage activity durations, as well as worker dose, also might be increased if foreign material is discovered in a system or plant component.
**RECORD OF REVISION**

This record of revision will provide a high level summary of the major changes in the document and identify the Roadmap Owner.

<table>
<thead>
<tr>
<th>REVISION</th>
<th>DESCRIPTION OF CHANGE</th>
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| 0        | Original Issue: August 2011  
Roadmap Owner: Lee Rogers and Jeff Deshon |
| 1        | Revision Issued: December 2011  
Roadmap Owner: Lee Rogers and Jeff Deshon  
Changes: Minor edits and updates |
| 2        | Revision Issued: August 2012  
Roadmap Owner: David Ziebell and Jeff Deshon  
Changes: Updated issue statement/flowchart (project plan) to 2012 FRP self-assessment and progress to date. |
| 3        | Revision Issued: December 2012  
Roadmap Owner: David Ziebell and Jeff Deshon  
Changes: Updated Issue Statement, minor edit to last paragraph of Project Plan, small updates to flow chart, including completed task. |
| 4        | Revision Issued: August 2013  
Roadmap Owner: David Ziebell and Jeff Deshon  
| 5        | Revision Issued: December 2013  
Roadmap Owner: David Ziebell and Jeff Deshon  