ISSUE STATEMENT

Cast austenitic stainless steel (CASS) materials are prevalent in many safety-related nuclear power plant components, including the primary coolant piping system in pressurized water reactors. CASS components are also currently being designed for new power plant construction. The long-term performance of this material, however, is not fully understood. Volumetric examination of cast stainless steel piping is required, but no current reliable nondestructive evaluation (NDE) techniques exist. In addition, a comprehensive model to determine the maximum allowable flaw size for CASS is not currently available. A comprehensive strategy for assessing CASS materials is needed that includes the development of reliable NDE techniques or an alternative approach for continuing the use of CASS materials.

DRIVERS

Equipment Reliability

The ability to provide a reliable assessment of CASS materials will be essential for life extension and license renewal activities. There remains a level of concern with cast austenitic stainless steel components because of the possibility of thermal embrittlement over time and the limitations of current volumetric inspection techniques. Establishing a robust aging management approach for CASS components exposed to reactor coolant environments is currently constrained by a lack of data, operating experience, and proven NDE solutions.

Regulatory

Globally, regulators continue to push for technique improvements for examining cast austenitic stainless steel. Section XI of the ASME Boiler and Pressure Vessel Code requires that the pressure boundary system of light water reactors be inspected using a volumetric technique. Meeting this requirement is very challenging for cast austenitic stainless steel piping due to the material’s microstructure. The currently specified examination methods have proven to be unreliable in numerous studies performed at EPRI and other research facilities.

New Construction

Regulators have advised that relief from performing examinations of new components prior to service will not be accepted for the new build. As a result, the industry needs to address and overcome CASS inspection challenges to support the licensing, manufacturing, and operation of new power plants.

RESULTS IMPLEMENTATION

Upon completion of this work, it is expected that:

• A probabilistic fracture mechanics tool to determine the critical flaw size for cast austenitic stainless steel components will be developed. A quantitative model of CASS materials performance based on the understanding of its resistance to embrittlement and cracking will be available.

• A method will be available for determining the presence and severity of thermal aging of cast austenitic stainless steel materials in-situ and a timeline will be established for when a potential degradation issue may need to be addressed. An investigation of the severity of thermal aging embrittlement in CASS should identify which weldments are susceptible to more rapid crack growth.

• An approach to efficiently map the grain structure of the CASS material for subsequent examination technique enhancements will be accessible. Utility members will have access to computer models to better characterize the cast austenitic stainless steel components in their plants.

• Cast austenitic stainless steel mockups will be available for industry use in training, research, and qualification activities.

• A risk-informed inspection methodology to minimize the number of required examinations will be developed.

• NDE methods optimized for cast austenitic stainless steel examination will be available to provide more reliable results to the utilities.

• A technical basis for determining the integrity of cast austenitic stainless steel components will be established.
PROJECT PLAN

Research of the different inspection technologies of cast austenitic stainless steel components will be performed in order to identify the most effective technologies. The assessment of CASS includes the following major activities:

Resources

- Collaborate with utilities worldwide to obtain information regarding lessons learned and operating experiences involving CASS components.
- Procure representative cast austenitic stainless steel mock-ups for industry activities.
- Benchmark global NDE inspection capability and reliability.
- Investigate the underlying reasons for insufficient results when inspecting CASS with existing volumetric examination tools to allow breakthroughs in developing the next generation of inspection tools.

Technology Modeling

- Perform mechanistic studies on thermal aging of CASS and investigate crack initiation and propagation behavior in representative CASS materials.
- Prioritize the CASS components of most concern and determine the critical flaw size based on the material composition and environment.
- Develop and investigate computer models to simulate the material characteristics for CASS and the impact to NDE methods.
- Utilize mathematical modeling to further the understanding of the challenges surrounding volumetric examination of CASS.

Technology Transfer and Application of Results

- Develop NDE practices for the inspection of cast austenitic stainless steel components.
- Measure the reliability of the newly developed techniques through physical trials and simulation.
- Document capabilities in reports and procedures that can be transferred to vendors and utilities for field use.
- Host working group meetings, conferences, and round robins for researchers, inspection services vendors, and utilities.
- Transition the research into the initiation of a performance demonstration program to determine specific examination procedure capabilities and then transfer inspection technologies for field use.

RISKS

Risks Associated with Completing this Work

- The CASS material cannot be adequately characterized to support improvements in the NDE procedures.
- Representative CASS material cannot be found to support the research and demonstration activities.
- The critical flaw sizes determined by engineering analysis and modeling tools are too small to detect with NDE or the results are not applicable or implementable to a large number of power stations.
- The modeling results suggest that significant thermal aging embrittlement of CASS materials occurs earlier than 60 years.
- The resulting NDE techniques are not adequate to detect and size defects for all types of CASS materials.

Risks Associated with Not Completing this Work

- Existing power plants cannot continue to operate reliably and the construction of new plants is halted due to the lack of proven NDE methods for cast austenitic stainless steel components.
- Regulators may develop CASS examination requirements that are impossible to meet and may not be applicable to the majority of the nuclear fleet.
- Regulator confidence in the reliability of CASS inspections is greatly reduced.
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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<tbody>
<tr>
<td>0</td>
<td>Original Issue: August 2011&lt;br&gt;Roadmap Owner: Mark Dennis</td>
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<tr>
<td>1</td>
<td>Revision Issued: August 2012&lt;br&gt;Roadmap Owner: Mark Dennis&lt;br&gt;Changes: Seven roadmap milestones have been clarified in the flowchart. The start for some of the project tasks for the Materials Degradation/Aging APC has been moved to 2014 due to funding constraints. The end date for some of the research and development tasks under the Nondestructive Evaluation APC have been extended to 2015.</td>
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<td>2</td>
<td>Revision Issued: December 2012&lt;br&gt;Roadmap Owner: Mark Dennis&lt;br&gt;Changes: Update to flowchart.</td>
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<td>3</td>
<td>Revision Issued: August 2013&lt;br&gt;Roadmap Owner: Mark Dennis&lt;br&gt;Changes: Added task for probabilistic fracture mechanics (PFM) discussions with the NRC, a flaw tolerance ASME code case, and the incorporation of ASME code case N-824 into Appendix 3 to the flowchart. A task to incorporate research findings into xLPR was also added to the flowchart. Updated progress of existing tasks in the flowchart.</td>
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<tr>
<td>4</td>
<td>Revision Issued: January 2014&lt;br&gt;Roadmap Owner: Mark Dennis&lt;br&gt;Changes: Updated to reflect that “Research and Develop Inspection Modeling Techniques for CASS” as unfunded for 2014.</td>
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Assessment of Cast Stainless Steel

Utilities
- Assemble Reliable Data on Installed Components
- Gather Information on Lessons Learned & Operating Experiences (OE)

Nondestructive Evaluation
- Research & Develop Inspection Modeling Techniques for CASS
- Manufacture Realistic Mockups for Research
- Develop PFM Model to Determine Critical Flaw Size

Materials Degradation/Aging APC
- White Paper on CASS Materials
- Mechanistic studies on Thermal Aging and Fracture Toughness of CASS (PSCR)

Government
- Gather Information on Lessons Learned, Operating Experiences, and Regulatory Update
- PFM Discussions with NRC

Vendors
- Flaw Tolerance ASME Code Case N-824 / Appendix 3 Incorporation of N-824

Code
- Gather Information on Lessons Learned & Operating Experiences

Legend
- Key Milestone
- Complete Milestone
- Funded Work
- Unfunded Work
- Milestones:
  1. ASME Code Case N-824: Ultrasonic Examination of Cast Austenitic Piping Welds from the outside surface
  2. Determine Next Steps
  3. CASS Component OE Available for Industry Use
  4. CASS Mockups Available for Industry Use (Research & Demonstration)
  5. Technology Transfer to Vendors
  6. Best Practice
  7. Prediction Model and Inspection Guidelines

Incorporation of CASS Results into xLPR