**ISSUE STATEMENT**

Weld alloys 52 and 52M are used extensively for repair and mitigation of primary water stress corrosion cracking (PWSCC) in Alloy 82/182 dissimilar metal welds joining critical reactor coolant system components. Alloy 52 and 52M are also specified for use in new PWR designs. Unfortunately, the weldability and crack susceptibility of alloys 52 and 52M varies widely with minor variations of element composition within the ASME material specification limits. Further, crack susceptibility and weldability depend on weld dilution by the base material and on welding process parameters. These issues have caused extensive in-process repair and rework of alloys 52 and 52M welds, extending refueling outages and costing the nuclear power industry tens of millions of dollars in unexpected maintenance and lost power generation. Research and testing are needed to understand and appreciate the limitations of welding with 52 and 52M for dissimilar metal applications and to develop guidelines to minimize potential for repair and rework.

**DRIVERS**

Significant drivers include:

*Outage Schedule and Cost Impact*

The use of 52 and 52M for PWSCC mitigation and repair has caused the loss of tens of millions of dollars in electricity production. Industry experience shows that refueling and maintenance outages are often extended due to repeated re-welding and in-process repair of alloys 52 or 52M. Until the weldability and crack susceptibility of 52 and 52M are fully understood and adequate composition limits and process controls are implemented to minimize problems, the continued use of these weld metals will likely continue to cause outage schedule extensions and the associated lost plant availability and lost revenue.

*Regulatory Impact*

The U.S. Nuclear Regulatory Commission (NRC) and other global nuclear regulatory agencies are concerned with the poor weldability and crack susceptibility of weld alloys 52 and 52M. The NRC currently requires the use of 52 or 52M weld metal for repair and mitigation of 82/182 welds and for new PWR nuclear component fabrication.

**PWSCC Mitigation**

Most of the smaller diameter piping dissimilar metal welds have been mitigated by structural weld overlay. The majority of remaining dissimilar metal welds are large-bore, which will require significantly more welding. Welding mitigation options for large-bore applications – such as inside diameter inlays, outside diameter overlays, underwater laser welding, and excavation weld and repair – are considered high risk activities due to known weldability issues with 52 and 52M.

**Lack of Consolidated Welding Guidelines**

Despite years of effort to optimize welding process parameters and develop specialized welding equipment, the problems with alloys 52 and 52M continue to plague the nuclear industry. Successful welding is often based on narrow welding process variations or on the superior weldability of a single heat of 52 or 52M. Moreover, the optimized welding process parameters or specialized welding equipment developed by a vendor are proprietary. As a result, the reasons for the better than average, or less than optimum, weldability of a specific heat of 52 or 52M are not well understood.

**RESULTS IMPLEMENTATION**

The products developed from this research will help welding engineers understand the weldability issues and crack susceptibility of 52 and 52M when used for PWSCC repair and mitigation or for new component fabrication. Further, the tools developed will provide utilities, vendors, and fabricators with information that will help minimize rework, improve weld quality, and enhance schedule compliance. Key project deliverables are:

- Index of weldability and crack susceptibility of commercially available high chromium nickel-base weld metals (52, 52M, 52MSS, 52i, low Fe 52MSS, etc.). The index will reflect the relative weldability between commercially available weld metal specifications and between heats within these specifications.
- Matrix of base metal and weld metal composition thresholds and limits that can be used to minimize weldability and cracking problems
- Evaluation of alternative welding processes (gas metal arc welding (GMAW), laser beam welding (LBW), hybrid welding, etc.) that can be successfully used with high chromium nickel base weld alloys
• Bases documents (as required) and data to inform ASME code cases and NRC evaluation of new welding processes and/or other commercially available high chromium nickel-base weld alloys
• Final report with data, results, and guidelines

PROJECT PLAN

The project will follow a logical approach for evaluation of high chromium nickel-base weld alloys. Major project tasks are listed below:

Perform Weldability Testing to Understand and Rank the Weldability
• Computational modeling and laboratory weldability testing
• Dilution studies
• Mockup weld testing

Assess Influence of Base Metal Composition to Weldability Problems
• Develop threshold levels or charts to evaluate influence of base metals on weldability and crack sensitivity
• Assess and validate by weldability testing and mockups with NDE

Evaluate Welding Processes and Influence of Process Parameters
• Assess existing, modified, and new welding processes
• Develop process parameters for existing and for promising new welding process technologies
• Evaluate welding process and parameters by mockup testing and final NDE

Application Plan
• Engage leading welding vendors (WSI, WEC, Areva, etc.) to advance existing welding processes and evaluate new welding processes with success potential
• Inform ASME Code rules and engage regulatory agencies for assessment of new welding processes

RISKS

For both the operating domestic PWR fleet and new PWRs being constructed, the risk associated with not performing this work includes substantial rework and associated schedule delays due to weldability issues. Understanding the weldability and crack sensitivity of high chromium nickel-base weld metals is integral to successful fabrication or mitigation and/or repair. For operating PWRs, the risk is focused on the potential impact on PWSCC repair or mitigation of large-bore piping welds.

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: Greg Frederick |
| 1        | Revision Issued: August 2012  
          Roadmap Owner: Greg Frederick  
          Changes: Within flowchart, added milestones for topical reports. To date 5 milestones completed. |
| 2        | Revision Issued: August 2013  
          Roadmap Owner: Greg Frederick  
          Changes: Updated flow chart. |
| 3        | Revision Issued: January 2014  
          Roadmap Owner: Greg Frederick  
          Changes: Added two milestones and added milestones legend. 9 milestones completed. |
| 4        | Revision Issued: December 2014  
          Roadmap Owner: Greg Frederick  
          Changes: Completed milestone 11. |
Alloy 52 Nickel-Base Filler Metal Weldability Solution

Milestones:
1. CASS Set 1
2. CASS Set 2
3. Dilution Study Tech Report
4. Initial Mock up Mag Stir
5. Tech Update ANT
6. Latest Evaluation
7. Sensitivity Tech Update
8. Measures to minimize hot cracking
9. Weldability Tech Report
10. Weldability Report Update