Welding & Repair Technology Center

Program Overview

Program Description

High-quality, reliable welds are critical to safe nuclear plant operation. Because of the safety significance of welds in many metal components and plant systems, the nuclear power industry must be confident in the quality and integrity of welds when joining various metals and using different welding systems. While maintaining this commitment to quality and safety, nuclear power plants also are interested in productivity improvements and new technology applications that can provide cost savings in terms of maintenance and operations.

The Welding & Repair Technology Center (WRTC) develops advanced materials, joining, and repair technologies for nuclear power plants, contributing to reduced operation and maintenance costs and improved plant availability. The program also supports technical interactions with code and regulatory entities to reduce the time and cost associated with implementing new technologies and repair rules.

Research Value

Research results from the Welding & Repair Technology Center help nuclear power plants find faster, less costly ways of making repairs using novel welding techniques or by applying existing techniques in new situations. Research results also are commonly used to support technical justifications that enable utilities to pursue regulatory relief from code requirements, typically saving time and money. WRTC participants gain access to the following:

- Repair options for key components, supplemented by application guidelines, procedures, and training
- Materials, welding, and repair experts across the Electric Power Research Institute (EPRI) and the nuclear industry
- Direct support during implementation of critical plant repair applications involving material interactions, weld process control, and code requirements
- Techniques for reducing repair costs, reducing component downtime, and increasing plant availability
- Demonstrated repair techniques and technologies that improve material performance and enable component life extension

Approach

The Welding & Repair Technology Center combines extensive laboratory capabilities with detailed familiarity with industry and regulatory needs to investigate and evaluate welding and repair techniques. WRTC staff can replicate welding setups in the field—power supplies, weld heads, and other equipment—to create realistic welding environments in the laboratory. Through participation in many American Society of Mechanical Engineers (ASME) and industry technical committees, WRTC staff can then ensure that the program’s research results can support code requirements. The WRTC has the ability to accomplish the following:

- Develop, test, and evaluate safe, effective, and reliable repair techniques that contribute to shorter outages and meet or exceed all code, regulatory, and design requirements
- Ensure broad dissemination and application of industry lessons learned and benchmarking practices
- Provide information exchange and peer review of current and past repair applications
- Develop and assess technologies that enable repairs to be made more quickly while the plant is off-line
- Develop and assess technologies that enable repairs to be made while the plant is on-line

Accomplishments

EPRI's Welding & Repair Technology Center supports nuclear power industry efforts to develop and apply welding and repair techniques that ease regulatory concerns, reduce maintenance costs, and improve productivity. WRTC activities have specifically accomplished the following:
• Provided technical guidance for conducting detailed root-cause analysis to support repair option selection for critical pressure components.
• Evaluated nickel high chromium weld filler materials for resistance to typical welding related defects, such as direct digital control (DDC), hot cracking, and general weldability. Alloy 52 type materials and derivatives have been evaluated to support alloy selection, and grading to distinguish heat-to-heat variations.
• Demonstrated the feasibility of in-vessel underwater laser beam weld repair of critical nickel alloy welds, eliminating the need to drain the reactor vessel. Areas that have been addressed include seal welding capabilities, temper bead welding, hot cracking susceptibility.
• Developed a roadmap to assist power plant personnel in conducting failure analyses for various components or for directing other organizations responsible for such work, with a focus on metallurgical and mechanical aspects. The report provides a roadmap of the sequential steps for the investigation and a guide to the laboratory equipment used.
• Provided technical support for implementing new technologies, including application guides for advanced welding methods, guidelines for installing and examining dissimilar metal weld overlays, and repair/mitigation of socket weld fatigue failures.
• Supported development of realistic code rules, including new code cases to reduce post-weld examination hold times and use dissimilar metal weld overlays for stress corrosion cracking mitigation.
• Developed guidance for overlay applications based on lessons learned, best practices, and weld studies to support current technology. Also supported development of new and higher production welding processes such as gas-metal arc welding and dual wire feed gas tungsten arc welding.
• Conducted testing to determine the way in which concrete and reinforcing steel are affected by exposure to boric acid in concentrations typical of spent fuel pool chemistry. Improved understanding of the degradation mechanisms and degradation rates will support life extension decisions.
• Evaluated the application of new repair techniques for high-density polyethylene piping, which is gaining traction as an alternative to steel in low-energy applications.

Current Year Activities
Welding & Repair Technology Center research and development for 2011 will focus on developing repair and fabrication technologies to reduce outage time and expand the availability of repair options that may be performed during plant operation. WRTC also will provide technical support to address the challenges of new plant construction. Specific efforts will include the following:
• Conduct failure analysis and stress measurements to assist utilities in repair decisions that are cost effective, reduce downtime, and improve quality
• Evaluate advanced filler/welding materials (Alloy 52M) for critical plant repair applications
• Develop training for new repair and replacement engineers
• Evaluate welding methods for small bore piping and alternative joining methods for socket welded joints
• Provide benchmarking support for utility repair and replacement programs
• Identify repair/mitigation options that address buried piping issues, fuel pool leakage and components susceptible to stress corrosion cracking

Estimated 2011 Program Funding
$3.3 million

Program Manager
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## Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P41.01.05.01</td>
<td>WRTC Information Exchange and Welding Conferences (base)</td>
<td>This project supports member access to Welding and Repair Technology Center expertise through meetings and information products. Members also may receive case history information for unique repair/replace applications, including welding qualification (PQR) database support, procedure review, repair/welding program assessments, benchmarking activities, research and development results, and specific code support.</td>
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<tr>
<td>P41.01.05.02</td>
<td>WRTC Codes &amp; Standards (base) (QA)</td>
<td>This project supports Welding and Repair Technology Center activities in the development of ASME (American Society of Mechanical Engineers) code cases, revisions, and technical interpretations to address repairs of a wide range of components. The project also engages other code organizations, as needed, to expand the availability of repair options.</td>
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<tr>
<td>P41.01.05.04</td>
<td>WRTC Subscriber Requested Assistance (supplemental)</td>
<td>Subscriber Requested Assistance provides members with technical support in a broad range of repair-related areas, including materials and joining evaluations, benchmarking of welding and repair programs, and process and procedure development. Members determine the workscope of the individual projects.</td>
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<tr>
<td>P41.01.05.05</td>
<td>WRTC Advanced Weld Application (supplemental)</td>
<td>This project provides Weld Repair and Technology Center (WRTC) members with advanced welding and repair technology to reduce the time and cost of repairs or modifications to critical plant components.</td>
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<td>P41.01.05.06</td>
<td>WRTC Benchmarking and Guidelines (supplemental)</td>
<td>This project assembles valuable case history and lessons-learned data and distributes it to WRTC members to assist in the implementation of repair and replacement activities.</td>
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<td>P41.01.05.08b</td>
<td>Repair and Replacement Options for High-Cycle Fatigue Failures in Socket Welds (QA)</td>
<td>This project supports the revision of guidelines for repair and replacement of socket welds susceptible to high-cycle fatigue failures. This includes code-approved technologies to enable on-line repair of defective socket welds in operating nuclear plants and validation of modified weld joint geometries.</td>
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<tr>
<td>P41.01.05.c</td>
<td>Weld Mitigation Interest Group (supplemental)</td>
<td>The Weld Mitigation Interest Group provides a forum for exchanging industry experience, solutions, and technology. The group evaluates emerging repair options that could reduce the time, cost, and radiation exposure related to welding operations; provide enhanced inspectability; expand repair options to include inlays, onlays, and underwater laser beam welding; validate filler metal weldability; and document industry experience.</td>
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WRTC Information Exchange and Welding Conferences (base) (065821)

Key Research Question

Nuclear plant staffs have been reduced, reducing the time available for personnel to participate in technology transfer activities, stay abreast of changing codes and regulations, and monitor improved repair technologies and processes. Accelerated technology transfer would help plant personnel meet immediate needs and provide peer support among repair personnel.

Approach

This project supports member access to Welding and Repair Technology Center (WRTC) expertise through meetings and information products. Members also may receive case history information for unique repair/replace applications, including welding qualification (PQR) database support, procedure review, repair/welding program assessments, benchmarking activities, research and development (R&D) results, and specific code support.

Impact

Potential benefits include the following:

- Immediate access to repair experts
- Peer support from the repair community through focused workshops
- Access to welding and repair procedures to meet new challenges
- Review/evaluation of new repair and welding procedures
- Support on repair issues and implementation of WRTC technology

How to Apply Results

Project results directly support utility member needs for ready access to repair and welding information. Products are aimed at supporting technology transfer of R&D results to WRTC subscribing members.

WRTC Codes & Standards (base) (QA) (065822)

Key Research Question

The continued downsizing of plant staffs and increasing travel restrictions make it difficult for nuclear power plants to maintain the required level of contact with code organizations and other technical bodies. Such engagement is necessary to ensure technical revisions permit the implementation of new repair methods, welding procedures, and weld materials within acceptable safety limits.

Realistic code rules for welding and repair and the availability of technical support can assist nuclear plants in pursuing regulatory relief and obtaining regulatory approval of new code rules.

Approach

This project supports Welding and Repair Technology Center (WRTC) activities in the development of ASME (American Society of Mechanical Engineers) code cases, revisions, and technical interpretations to address repairs of a wide range of components. The project also engages other code organizations, as needed, to expand the availability of repair options. As part of this work, WRTC provides technical information to appropriate regulatory bodies in support of new and emerging technologies.

Examples of this work include boiling water reactor control rod drive leakage repair, pre-emptive dissimilar metal weld overlay to address Alloy 600 repair applications, and use of specialized methods to seal leakage while under power. Activities also support code updates and revisions to American Welding Society (AWS) structural and pipe/tubing codes, National Board Inspection Code (NBIC), and international codes.
Impact

Potential benefits include the following:

- Provide technical basis supporting code and regulatory rules that permit the use of innovative repair techniques, materials, and technology for critical reactor components
- Reduce the cost and complexity of repairs through the availability of practical code rules
- Reduce reliance on highly skilled staff in the application of more complex requirements
- Engage code and regulatory bodies during the development of new technologies to reduce the time and cost for implementing new technologies and repair rules

How to Apply Results

The results of this project will be implemented through adoption of new code rules and by modifications in regulations related to repair activities.

WRTC Subscriber Requested Assistance (supplemental) (045710)

Key Research Question

Nuclear plant staffs have been reduced, reducing the time available for personnel to participate in technology transfer activities, stay abreast of changing codes and regulations, and monitor improved repair technologies and processes. Accelerated technology transfer would help plant personnel meet immediate needs and provide peer support among utility repair personnel.

Approach

Subscriber Requested Assistance facilitates technical support for application of Welding Repair and Technology Center (WRTC)-developed technology products. Through this feature, members also may receive assistance for unique repair/replace application needs, including welding qualification database support, procedure review, repair/welding program assessments, benchmarking activities, and specific code support.

Impact

- Immediate access to EPRI repair experts
- Peer support from the larger nuclear repair community
- Access to welding and repair procedures to meet new challenges
- Support in applying new repair and welding procedures and implementing WRTC technology

How to Apply Results

Subscriber Requested Assistance projects directly support utility member needs. Each product is tailored to meet the request of a participating utility or utility group.

WRTC Advanced Weld Application (supplemental) (065815)

Key Research Question

Advanced repair technologies and processes can improve plant availability while improving the quality/reliability of repairs. New materials and increasing challenges to maintain existing plant components have increased the value of welding as a repair option. Repair and replacement of existing pressure systems, for example, relies heavily on welding technology. Development and demonstration of advanced welding processes is needed to evaluate limitations, identify the range of applications, and ensure weld performance meets quality requirements.

Approach

This project develops advanced repair equipment and technologies to meet emerging issues in power plant repairs. Recent examples include cleaning of contaminated surfaces, fuel pool repairs, and use of weld
overlays for repair of Alloy 600 components. This project also develops and evaluates advanced equipment and processes such as laser cleaning systems and wave-form controlled gas metal-arc welding systems for underwater or overlay welding applications. Other studies will include use of these advanced repair systems to support improvement of special methods such as temperbead welding to further reduce critical path time for repairs.

Impact

Potential benefits include the following:

- Reduce the time and cost of performing repairs by improving the deposition rate of welds for repair/replacement applications
- Extend the life of repaired components through advanced technology for repairs
- Reduce the cost of post-repair examinations and future monitoring through improved repair quality
- Develop specialized processes such as temperbead welding to reduce repair cost and critical path time and provide alternatives to repair techniques based on original construction code rules

How to Apply Results

Members implement repair techniques and products on-site using their own staff or by sharing the methods with vendor organizations. A number of the developments from this project will be approved by code and regulatory agencies, further assisting in implementation.

WRTC Benchmarking and Guidelines (supplemental) (065816)

Key Research Question

The development of repair and replacement technology for power plants is an evolutionary process that requires continuous sharing of experience from nuclear plants, vendors, and research organizations. These experiences and case histories are often passed along from outage to outage within a utility or a specific vendor. Sharing this information across multiple plants informs decisions related to repair and replacement activities.

Approach

The Weld Repair and Technology Center (WRTC) supports upcoming repair and replacement activities by compiling and sharing best practices, experience information, and benchmarking data. This project continues those efforts by using a number of resources to acquire and distribute this information to members.

Impact

- Realize substantial time and cost savings through implementation of key products such as Welding Best Practices and the Repair & Replacement Program Checklist. In many cases, these documents also assist in ensuring compliance with the latest code or regulatory requirements.
- Access to the WRTC Sharepoint site, which provides continuously updated information on utility procedures, administration documents, repair and replacement programs, welding programs, experience reports.
- Provide peer support and benchmarking activities through information exchange services, SharePoint website, and issues meetings.

How to Apply Results

This project is implemented by WRTC members through email and web-based communication and document-sharing tools. These tools provide quick access to case history information, technical reports, and procedures/practices used by other members. Members realize value by integrating such information into plant procedures or practices.
Repair and Replacement Options for High-Cycle Fatigue Failures in Socket Welds (QA) (049937)

Key Research Question

Failures of small-bore piping connections (2-inch and smaller) continue to occur at nuclear power plants, resulting in degraded plant systems and unscheduled plant downtime. Fatigue-related failures are generally detected as small cracks or leaks, but in many cases the leak locations are not isolable from the primary reactor coolant system and result in extended outages. These failures are typically accelerated by poor weld quality at the root and toe locations (lack of fusion, undercut).

Approach

This project will support the revision of guidelines for repair and replacement of socket welds susceptible to high-cycle fatigue failures. This includes code-approved technologies to enable on-line repair of defective socket welds in operating nuclear plants and validation of modified weld joint geometries. The socket weld configurations will be evaluated through high-cycle fatigue testing, mockup testing, and finite element analyses. Consequently, an understanding of socket weld fatigue failures related to weld quality and design will be improved, and successful resolutions will be implemented to reduce costs associated with forced outages and repeat failures.

Impact

Potential benefits include the following:

- Improved weld geometry specifications that can enhance the reliability of socket welds through reduced failures and extended life of susceptible socket weld locations
- Online repair applications that can extend operating time, allowing permanent replacement of the repaired connection to be scheduled during a routine outage with little or no impact on power production
- Standardized test configuration and vibration fatigue test conditions that support American Society of Mechanical Engineers (ASME) code actions, overlay repair design criteria, and fitting and weld geometry modifications

How to Apply Results

This project provides test data and guideline information for modification of existing socket welds or use of improved weld geometries for new installations. The guidelines also address online repair methods that can prevent outages or derating through the use of code-approved techniques.

Weld Mitigation Interest Group (supplemental)

Key Research Question

New and emerging repair and mitigation technologies can provide safe, cost-effective options for nuclear plant owners. Evaluation of such technologies is necessary to ensure their application is safe, effective, and can meet code requirements. Candidate technologies may include the following:

- Underwater laser beam welding for inside diameter (ID) mitigation and repair
- High-deposition welding processes
- Inlay and only repair technologies for ID mitigation and repair
- Improved weldability of Alloy 52, a high-chromium filler material with high resistance to primary water stress corrosion cracking (PWSCC)
- Improved welding methods to enhance inspectability, weld quality, and productivity
Approach

The Weld Mitigation Interest Group evaluates emerging repair options that could reduce the time, cost, and radiation exposure related to welding operations; provide enhanced inspectability; expand repair options to include inlays, onlays, and underwater laser beam welding; validate filler metal weldability; and document industry experience.

The Weld Mitigation Interest Group provides a forum for exchanging industry experience, solutions, and technology. The Interest Group produces a Stress Corrosion Cracking Repair and Mitigation Handbook to support effective management of primary system components susceptible to stress corrosion cracking (SCC). Related products include evaluation of advanced welding technologies and a database of high-chromium filler metal weldability tests.

Impact

Potential benefits include the following:

- Availability of proven, cost-effective repair and mitigation techniques.
- Consistent approach for compiling operating experience and addressing regulatory issues.
- Identification of high-priority research activities to address weld overlay issues.

How to Apply Results

Participants use technology evaluation results to analyze repair options for future plant application. The Mitigation Handbook provides specific guidance that can be incorporated into management and inspection plans for primary systems components susceptible to SCC. Workshop participation provides access to industry experts on weld repair and mitigation.