WRTC Overview

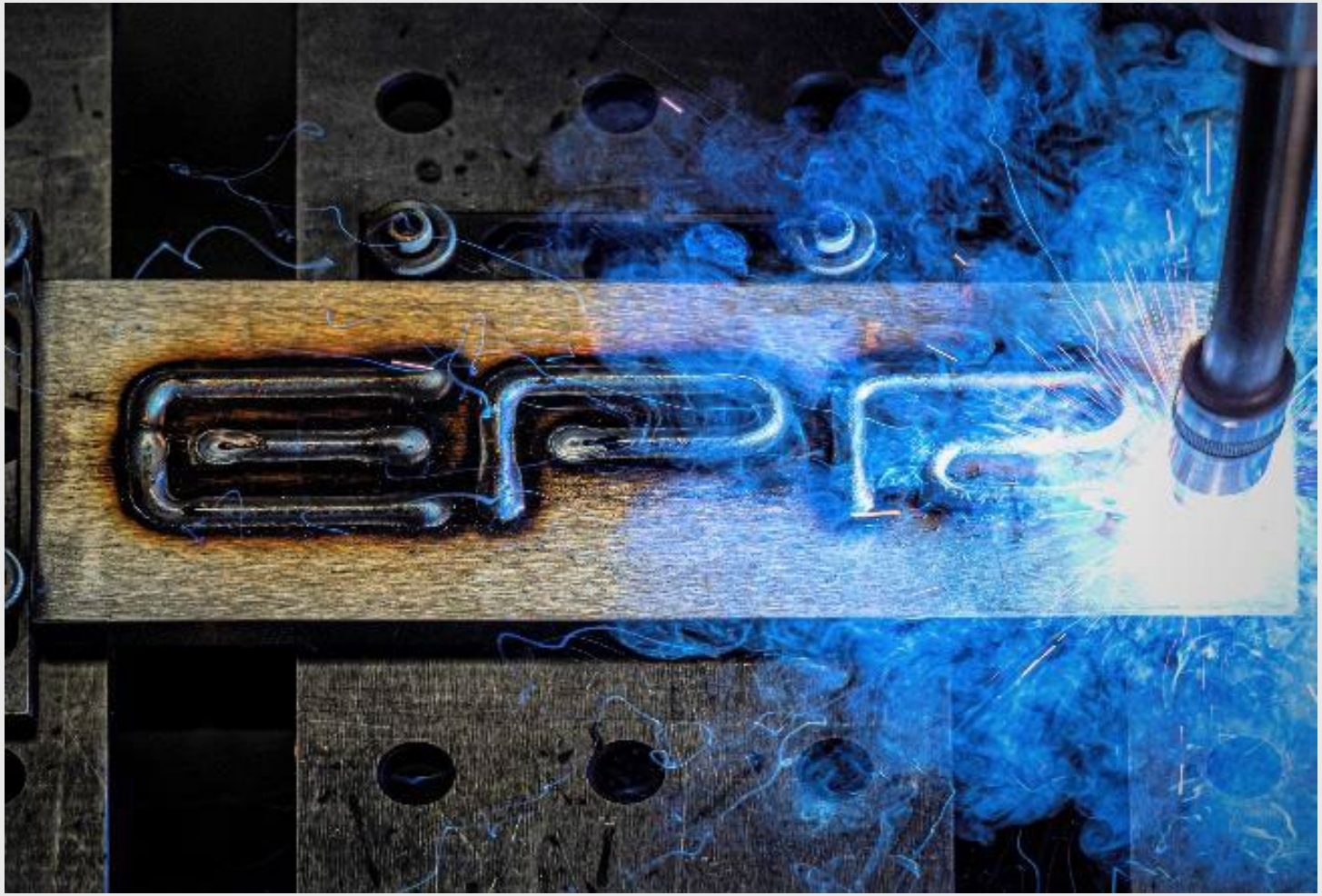
NSRP -Joint Welding Technology and Electrical Technologies Panel Meeting

Nick Mohr, Program Manager
EPRI – Welding & Repair Technology Center (WRTC)

September 17 – 7, 2024

WRTC Overview

- Team
- Members
- RFA review
- Select Project Status Updates
- Meetings



WRTC TEAM

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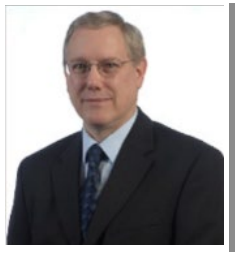
Lead for RFA 5 & 8



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Background Welding Processes

- **NRC liaison, Jim Cirilli, Sr. Technical Executive**
- **Advance Manufacturing liaison, David Gandy, Sr. Technical Executive**
- **WRTC Extended Team:**
  - **Joseph Weicks – ASME Codes and Training**
  - **Dana Couch – Training Development**

***Primary WRTC contact for ASME Section XI, **Primary WRTC contact for ASME Section IX**

WRTC Base and/or Supplemental Funding Members

United States (TAC)

- 22 of 22 U.S. Utility Organizations participate in WRTC (all operating BWR and PWRs)

International Participation (TAC)

- CANDU Owners Group (COG) – Canada, Romania
- CEZ A.S. – Czech Republic
- Chubu Electric Power Co., Inc. – Japan
- Chugoku Electric Power Co., Inc. - Japan
- Comision Federal de Electricidad (CFE) - Mexico
- Electricite de France S.A. (EDF/MAI) – France
- Emirates Nuclear Energy Corporation - United Arab Emirates
- Eskom - South Africa
- Kansai Electric Power Co, Inc – Japan
- Kernkraftwerk Leibstadt AG (KKL) - Switzerland
- Korea Hydro and Nuclear Power Co. - Korea
- Kyushu – Japan
- MVM Hungarian Electric (Paks) – Hungary
- Nucleoelectrica Argentina S.A. – Argentina
- Shikoku Electric Power Co – Japan
- State Nuclear Power Technology Company (SNPTC) - China
- The Tokyo Electric Power Company, Incorporated (TEPCO) - Japan
- FORO – Spain
- Vattenfall – Sweden
- OKG - Sweden
- Krško – Slovenia
- China National Nuclear Power (CNNP)
- Rolls Royce Power Engineering - United Kingdom
- TaiPower – Taiwan
- JAPC - Japan

Supplemental Non-Utility Memberships

- IHI Corporation – Japan
- Framatome (AREVA) – Germany, France, US
- Flour
- KAPL/Bettis – Naval Nuclear Labs
- Doosan Heavy Industry – Korea
- WSI – US
- Liburdi Dimetrics
- Structural Integrity Associates
- Westinghouse (In Process)

WRTC – Research Focus Areas (RFA)

WRTC organizes research/development work into 8 RFAs

- Each RFA has projects with related scope
  - ~ 50 ongoing projects across all WRTC
- Mix of Tactical (short term) and Strategic (fundamental) Research

1 **Weldability and Welding Alloy Development**

Focuses on key welding alloys, fabricability, and guidance documents

2 **Degraded and Irradiated Materials Repair Solutions**

Focus on the weldability thresholds for repair options, and measurement of the helium effects on weldability

3 **Optimized Joining, Fabrication, and Repair Processes**

Technology transfer for innovative technologies, techniques, and processes, either to support joining processes, code acceptance, or data collection.

4 **Repair Solutions for Structures**

Focuses on supporting spent fuel pools, canisters, tanks, and non-metallic repairs and mitigation

5 **Small Bore Piping Issues**

Focus on alternative to socket welds, small bore failures, remedies and training, and code repairs

6 **Code and Standards**

Technical bases of Code and Regulatory acceptance, optimization, and expansion of current Code

7 **Tactical Implementation of Repair Methods and Training**

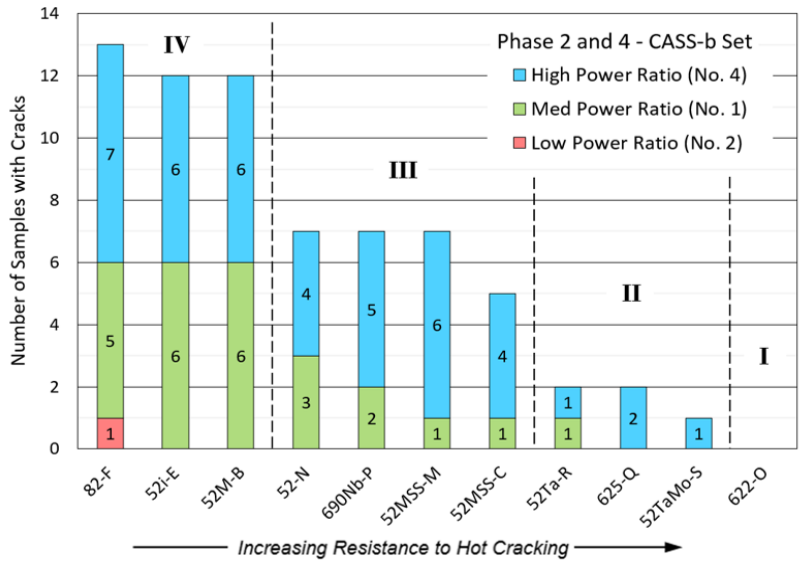
Guidance documents, training, and technical information exchange

8 **Advance Manufacturing**

Supporting advance manufacturing methods, material testing and Code Acceptance

WRTC's RFA 1: Material Weldability and Welding Alloy Development

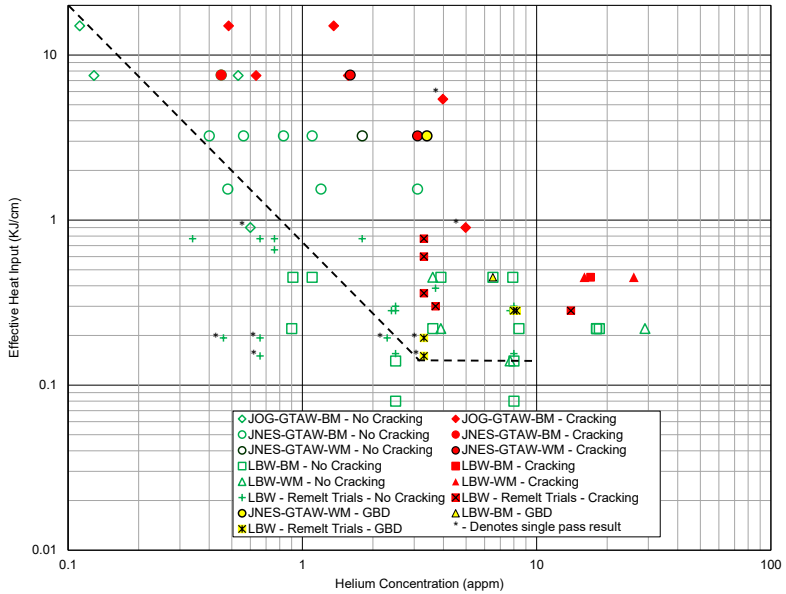
- Research and understand weldability of materials and filler materials
- Representative Demonstrations
- Develop solutions for improved weldability, implementation guidance and lessons learned
  - Current focus on high Cr Nickle alloys (Alloy 52 variants), duplex stainless steel and martensitic SS filler materials
  - Evaluation of alloys for new nuclear and small modular reactors
  - Goal to improved weldability and selection criteria for welding alloys for all applications (overlay, cavity, repair, fabrication)



Performance Comparisons Between NiCrFe Variants

WRTC's RFA 2: Degraded and Irradiated Materials Repair Solutions

- Welding challenges are being evaluated related to the high helium content generated in aged reactor internals
- Conventional and advance welding process under review on representative materials
- Weldability thresholds are being expanded based on effective heat input, helium content and welding process
- Identified as area of collaboration and further discussion with NRC

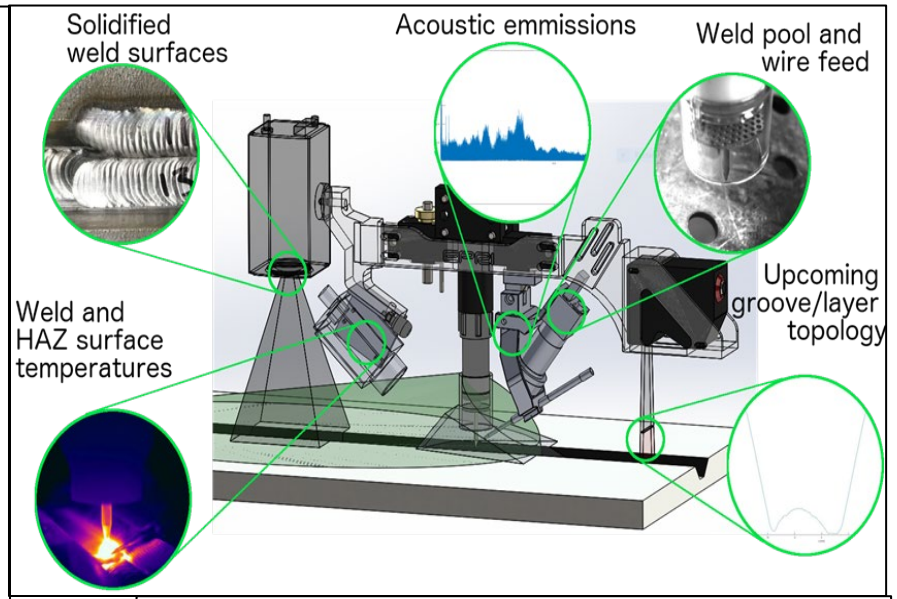


He-Induced Cracking Threshold Plot: 304 SS

WRTC's RFA 3: Optimize Joining, Fabrication, and Repair Processes

- Technology transfer for innovative technologies, techniques, and processes, either to support joining processes, code acceptance, or data collection

- Some key activities
  - Cold Spray process and other repair processes are being evaluated for Spent Fuel Canisters
  - Alternative methods for measuring heat input (Effective Heat Input). Supporting Hardness drop criterion for temper bead and Effective Heat input for temper bead
  - Adaptive Feedback welding being researched to control welding conditions through AI, and machine learning control



Adaptive Feedback Welding Technology

WRTC's RFA 4: Repair Solutions for Structures

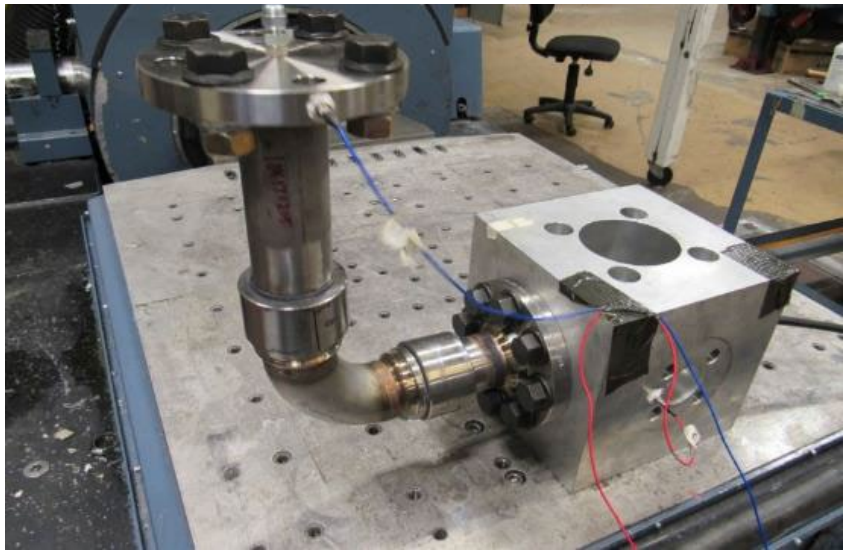
- Development of repair solutions for critical nuclear structures - current focus on containment, spent fuel pool (SFP), and dry cask storage system (DCSS) structures
- Interface with EPRI Extended Storage Collaboration Program (ESCP)
- New case for Repair & Replacement of canisters is planned for future discussion with NRC.

Dry Cask Storage (NRC, ML062200058)

WRTC's RFA 5; Small Bore Piping Issues

- Training material for understanding small bore piping issues, high cycle fatigue, and leak sealing.
- Implementation guidance for Mechanical joints and fittings (Lokring)
- Understanding small bore piping issues and eliminating small bore piping failures
- Socket welds and overlay leak repairs

High cycle fatigue testing of elbow mechanical fitting

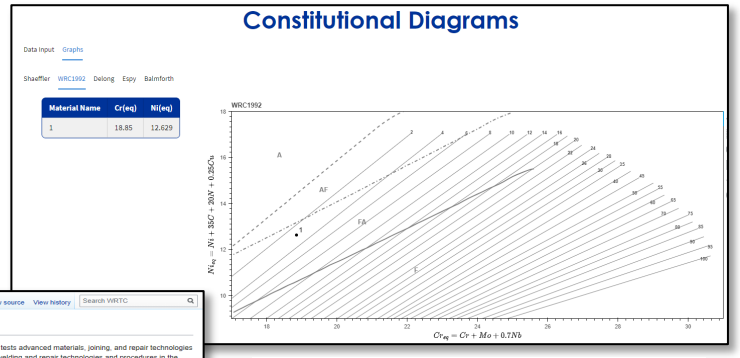


WRTC's RFA 6: Codes and Standards

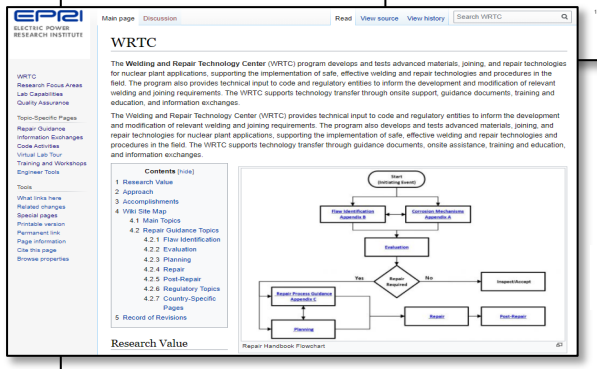
- Promote and progressing Codes and Regulatory adoption of Code Cases, Code Revisions via technical basis research, industry papers (e.g. PVP), etc.
- Reduce burden in requirements based on industry practices and promote utilization of repair processes.
- Publishes an Annual Report on status of Code changes, Code Cases, and Technical Issues

WRTC's RFA: 7 – Tactical Implementation of Repair Methods and Training;

- Development and implementation of specific repair solutions such as guidance for implementing new and innovative repairs and mitigation methods.
- Innovative tools developed for helping members find relevant information quickly
- Trending and tracking of industry performance and development / maintenance of guideline documents.
- OE, training, workshops, information exchanges, training, and assessment/ benchmarking activities **(Knowledge Transfer)**



Metallurgical Calculators



WRTC Wiki

WRTC's RFA 8; Advance Manufacturing - Development and Evaluation

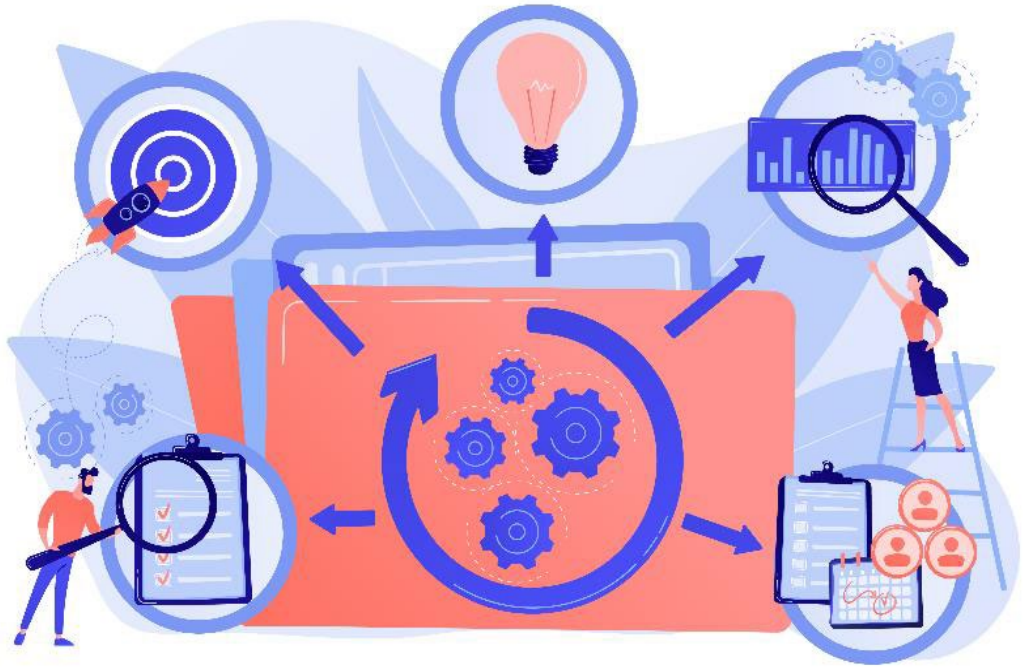
- Explore potential advanced manufacturing, materials and applications, reduce barriers to implementation
- Provide technical bases documents
- Progressing code and regulatory adoption
- Powder Metallurgy, Additive, Hardfacing and Coatings Applications for new and operating fleets

Direct Energy Deposition Valve Body

PM-HIP Scaled SMR Head and Valve body

Project Status Updates – One Slide per Project

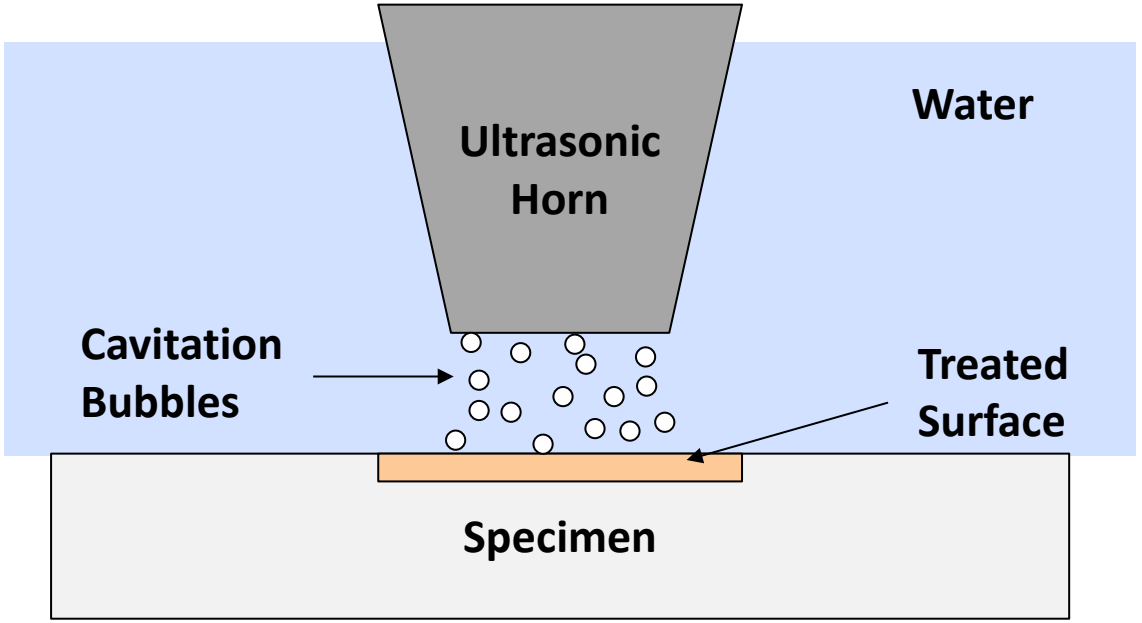
- List all current Research Focus Areas (RFAs) – High level overview of RFA's found in backup slides
- List all WRTC Program Projects, by RFA
  - Project's Title
  - Project Manager's Name
  - Project's Expected Completion
- Project Titles are hyperlinked to:
  - Objective & Scope Information
  - Planned Deliverables
  - Schedule and Milestones
  - Additional information
- Found on WRTC home page for Members



KHNP Ultrasonic Cavitation Peening Validation

Project Objective & Scope

- Project Objective
  - Evaluate novel surface stress improvement technique Ultrasonic Cavitation Peening (UCP) providing another technique for mitigation and repair (e.g., Bottom Mounted Nozzles)
- Project Scope & Approach
  - Perform similar surface stress improvement tests found in EPRI report 3002018458 such as residual stress depth/ magnitude characterization, stress relaxation, SCC initiation testing, mockup demonstration, etc.



Deliverable and Collaboration

- Final deliverable will be an EPRI report documenting the results from all tests performed during this research project.
- Support / Collaboration
  - Korea Hydro & Nuclear Power Company (KHNP)
  - KEPCO Plant Services & Engineering (KPS)

Schedule & Upcoming Work

- Project kickoff late 2024
- Specimen preparations, UCP of specimens, testing of specimens – 2025 – 2026
- Mockup demonstration of UCP – 2026 – 2027
- Final Report – Late 2027

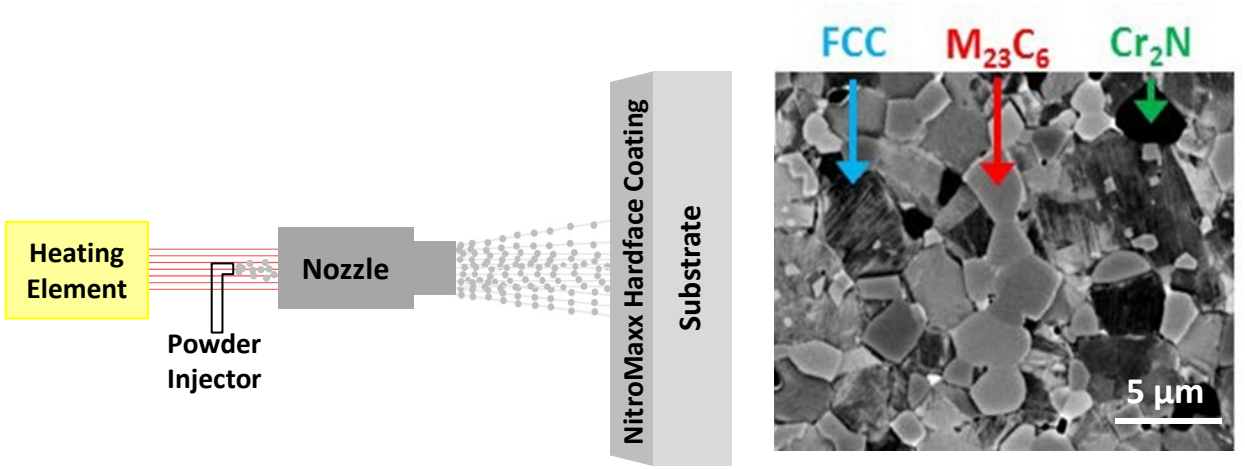
Assessing the Wear Performance and Repair Capabilities of NitroMaxx Deposited via Cold-Spray

Project Objective & Scope

- Project Objective
  - Evaluate the feasibility of depositing NitroMaxx via cold-spray, in addition to assessing the wear resistance of the NitroMaxx deposit and the influence of common post-deposition treatments such as solution annealing and lapping
- Project Scope
  - Cold-spray NitroMaxx alongside historical hardfacing alloy, then benchmark via standardized wear testing

Deliverable and Collaboration

- Present out on initial research at December 2024 Technical Advisory Committee (TAC) meeting
- Report detailing research expected late 2025
- Collaborations for project:
  - Materials and Repair (M&R) Program
  - Technology Innovation (TI)



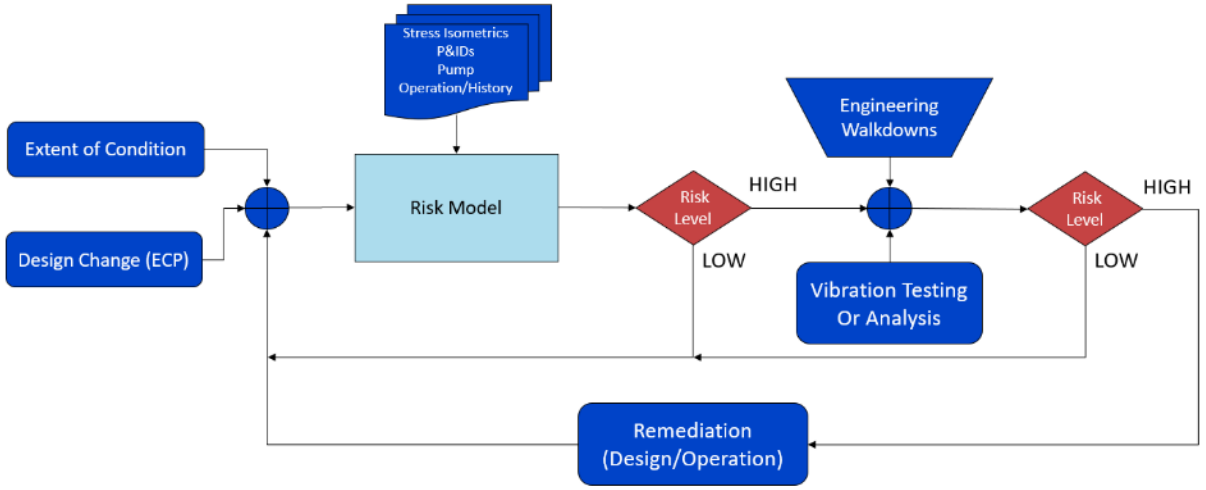
Schedule & Upcoming Work

- Project Schedule (2024/2025)
  - NitroMaxx powder procurement
  - Parameter development and sample creation of cold-spray deposited NitroMaxx
  - Subject cold-spray deposited NitroMaxx samples to solution annealing and lapping
  - Perform standardized wear testing
  - Status reports at TAC meetings
  - Final reporting end of 2025

Quick Guide to Small Bore Vibration Risk

Project Objective & Scope

- Project Objective
  - To provide members a set of focused guidelines and instructions to develop a risk ranking for small bore piping vibration failures.
- Project Scope & Approach
  - Risk ranking methodology and example application
  - Allows utilities to focus their limited resources on the highest risk lines



Deliverable and Collaboration

- Technical report
- Training webcast (Potential in-person at TAC)
- Structural Integrity contractor
- Utility example to be completed on their system/lines

Schedule & Upcoming Work

- Project Schedule
  - Methodology developed
  - Survey to drive utility input complete
  - 2025 Tech Report and Recorded Training

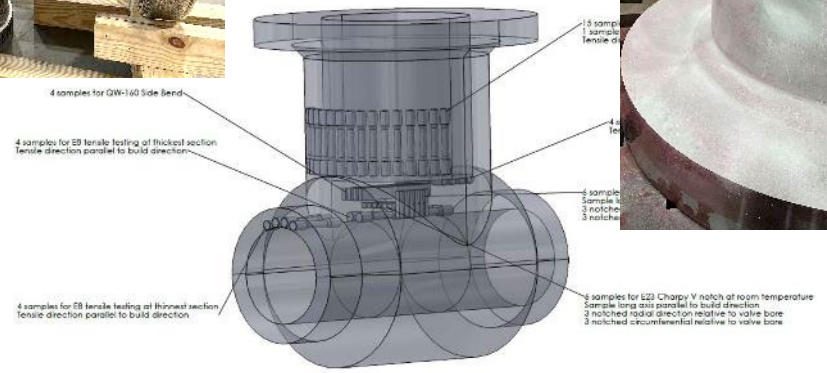
Directed Energy Deposition Development: 316L

Project Objective & Scope

- Project Objective
  - Reduce barriers to implementation of advanced manufacturing, specifically ASME
- Project Scope & Approach
  - Mechanical testing and microstructure evaluation to generate data package for ASME Code implementation of 316L

Deliverable and Collaboration

- ASME data package, EPRI-ASM conference paper 2024
- Material Science and Engineering A Journal Paper
- Potential tech transfer with utility installations
- Support / Collaboration
  - Collaboration with AM3, ANT, P229
  - Lincoln Electric, Flowserve, Colorado School of Mines
  - BEES Inc.



Schedule & Upcoming Work

- Project Schedule
  - Microstructure work and reporting in 2024
  - ASME Code changes initiated, need balloted by Nov. 2024 to get in 2025 edition

Crack Growth Rate and Fatigue Testing of DED 316L

Project Objective & Scope

- Project Objective
  - Reduce barriers to implementation of advanced manufacturing, specifically regulatory
- Project Scope & Approach
  - Stress corrosion crack growth rate testing in BWR and PWR environments: base material and HAZ samples
  - Fatigue testing to look at surface finish variable

Deliverable and Collaboration

- Technical report, 2025
- Environmental Degradation Conference presentation
- Support / Collaboration
  - Collaboration with IMR and ANT
  - Lucideon testing contractor

Schedule & Upcoming Work

- Project Schedule
  - 2023 SGF, 2024 MAI funding
  - Sample welding and machining planned completion May 2023
  - Autoclave testing 2023 and 2024
  - Fatigue testing initiated in 2024

Directed Energy Deposition Development: Alloy 690

Project Objective & Scope

- Project Objective
  - Reduce barriers to implementation of advanced manufacturing, specifically ASME
- Project Scope & Approach
  - Mechanical testing and microstructure evaluation to generate data package for ASME Code implementation of Alloy 690

Deliverable and Collaboration

- Technical Report, 2025
- ASME engagement
- Support / Collaboration
  - Collaboration with ANT, AM3
  - KHNP collaboration
  - BEES contractor for wire arc DED

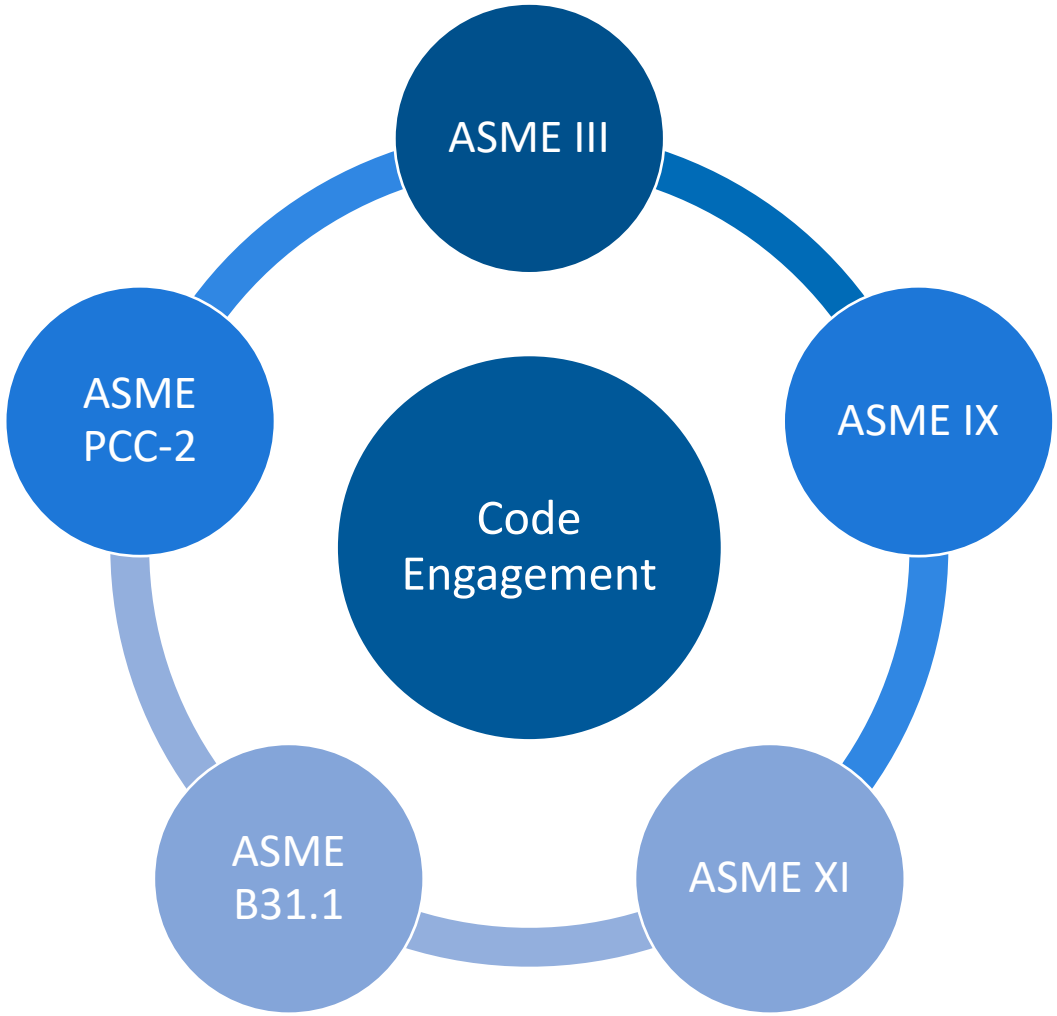
KHNP

BEES
Best Engineering in Energy Solutions

Schedule & Upcoming Work

- Project Schedule
  - Initiated October 2022
    - Difficulty sourcing filler wire required use of 52M instead of 52MSS-Ta
  - Interim report Q4 2024

WRTC Code Engagement



- WRTC leadership/actions/research resulted in, but not limited to, the following code cases which included continued actions to gain NRC approval in Regulatory Guide 1.147 (i.e., Accepted without Conditions (A), Conditionally Accepted (CA)):
  - N-638 (GTAW Ambient Temperature Temper Bead) – A
  - N-661 (Pad Reinforcement for Carbon Steel Piping) – A
  - N-666 (Socket Weld Overlay) – CA
  - N-740 (Full Structural Weld Overlay)
  - N-752 (Risk Informed Repair and Replacement)
  - N-754 (Optimized Full Structural Weld Overlay) – CA
  - N-766 (Weld Inlay and Onlay Repair) – CA
  - N-786 (Sleeve Reinforcement for Carbon Steel Raw Water Piping) – A
  - N-789 (Pad Reinforcement for Carbon Steel Raw Water Piping) – A
  - N-839 (SMAW Ambient Temperature Temper Bead) – A
  - N-847 (Partial Excavation and Deposition of Weld Metal for Repair) – CA
  - N-853 (Branch Connection Weld Metal Buildup) – A
  - N-865 (Pad Reinforcement of Class 2/3 Atmospheric Storage Tanks) – A
  - N-871 (Repair of Using Carbon Fiber Reinforced Polymer Composites)
  - N-874 (Acceptance of Leaking Brazed Joints) – A
  - N-882 (Pin Brazing for Non-Structural Attachments) – A
  - N-888 (Ambient Temperature TB- GTAW/SMAW) – A
  - N-931 (Surface Stress Improvement for Section III Applications)
  - 2866 (Pin Brazing Qualification- Section IX)

Engagement – Technical Bases, Management, Support (Questions, Implementation)

WRTC Supplemental Membership

- Access to all WRTC Technical Advisory Committee (TAC) meetings (June and December)
  - Research, Workshops, Webinars, Training
  - Global welding community
- All current and past WRTC research
- Training – E-Learning Modules (14), past and current webinars
- Ability to conduct member specific projects / work scopes (access to EPRI labs)
- Code engagement across various codes
- Benchmarking, assessments, lessons learned, operating experience, and welding industry surveys

What is Included

WRTC TAC – Upcoming Meetings – SAVE THE DATE(s)

June and December TAC Meetings are for members and invited guests

December WRTC TAC Meeting – 2024

Register Now: https://cvent.me/RwAD8l

Date: December 9-12, 2024

Location: Hilton Cabana Miami Beach, 6261 Collins Avenue, Miami Beach, FL 33140

Workshop Topic for TAC Meeting (In Planning) – Repair to Leaking ASME piping/components and Operational Leakage

Technical Advisory Committee (TAC)

June WRTC TAC Meeting – 2025

Date: June 23-26, 2025

Location: Hilton Scottsdale Resort, Scottsdale, AZ

December WRTC TAC Meeting – 2025

Date: Dec 8 -11, 2025

Location: Marriott Sanibel Harbor, Fort Meyers, FL

June WRTC TAC Meeting – 2026

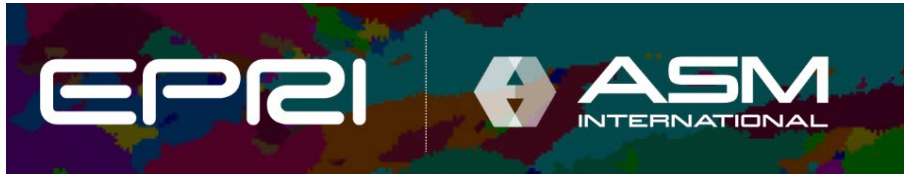
(in conjunction with NDE)

Date: June 22-26, 2026

Location: Marriott Sawgrass, Ponte Vedra Beach, FL

EPRI 10th International Conference on Advances in Materials, Manufacturing, and Repair for Power Plants

Tuesday October 15th – Friday October 18th, 2024



[Registration is Open]

Thermal power generation:

- Steam Power (HRSG, boilers, steam turbines
- Gas turbines
- CSP & geothermal

Advanced Energy Systems:

- Small modular reactors
- Advanced nuclear technologies
- Bulk energy storage
- sCO2 power cycles
- Next gen CSP
- A-USC steam
- Hydrogen, energy production, & more

- **High-Temperature Materials**: *superalloys, CSEF steels, stainless steels, intermetallics, non-metallics, coatings, claddings*
- **Damage Mechanisms & Properties**: *Creep, creep-fatigue, oxidation and corrosion, weld performance, wear/erosion*
- **Component Manufacturing**: *castings, forgings, blades, rotors, valves, shop & field fabrication processes, etc*
- **Advanced Manufacturing**: *additive (PBF, DED, etc.), Powder Metallurgy Hot Isostatic Pressing (PM-HIP), advanced welding and cladding processes*
- **Qualification**: *Design, design rules, codes & standards,*
- **Performance**: *Field experience, Life management, Fitness-for-Service (FFS), feature testing, modeling & validation*
- **Repair**: *weld repair, rejuvenation, advanced repair methods*
- Emerging High-Temperature Materials Technology*: refractories, new alloy developments, modeling developments*

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