Welding & Repair Technology Center (WRTC)

Industry / NRC Materials Programs Technical Information Exchange Public Meeting

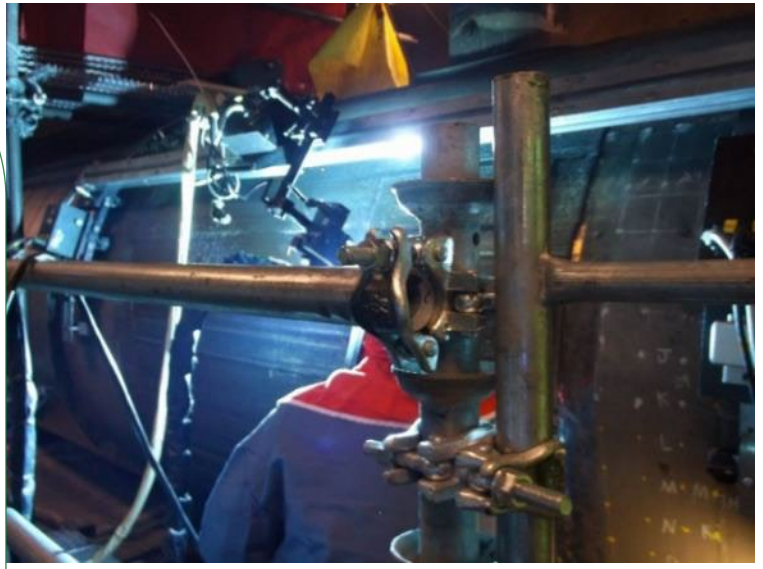
Steve McCracken, Senior Technical Executive

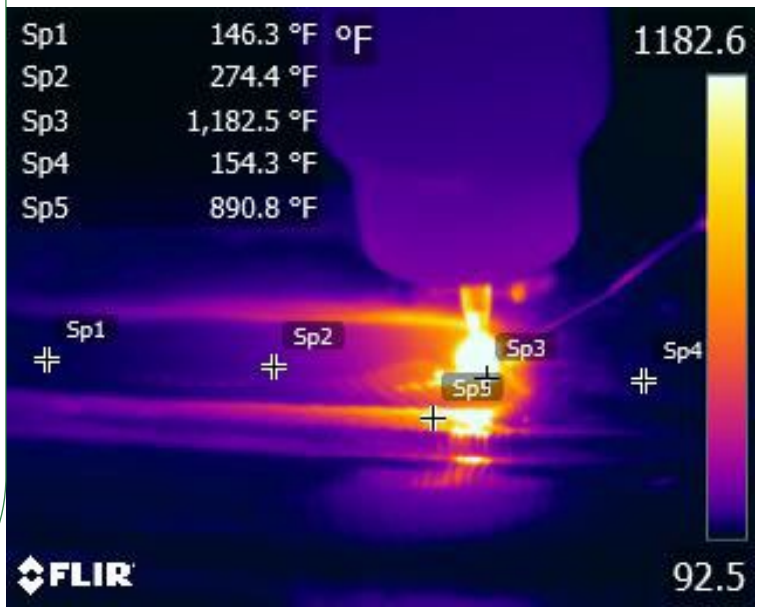
June 25, 2024

WRTC's Areas of Interest

Overview and significant Program updates since the last meeting

- No reports submitted to NRC
- No expected report submittals
- Areas of interest since last meeting will be highlighted
- Technical discussions with NRC are being planned for key topics and will also be highlighted





WRTC/ASME/Industry Meeting with NRC (March 7, 2023) – Summary (Refresher)

- Session 1: Nuclear Regulatory Commission (NRC) staff held a public meeting with the Electric Power Research Institute's Welding and Repair Technology Center (EPRI-WRTC).
  - Purpose of meeting was to have a technical exchange focusing on several ASME code cases with goal to gain a better understanding of the NRC's basis for the conditions and to help in future to reduce some conditions. (Examples)
    - Code Case N-847-1, "Partial Excavation and Deposition of Weld Metal for Mitigation of Class 1 Items…"
    - Code Case N-894, a new code case for repair of piping with thermal fatigue cracking
    - Code Case N-818-1, "Use of NDE and Fracture Mechanics for acceptance of Full Penetration Butt Welds in Lieu of Weld Repair, Class 1 and 2…."
    - Code Case N-853-1, "PWR Class 1 Primary Piping Alloy 600 Full Penetration Branch Connection Weld Metal Buildup for Material Susceptible to Primary Water Stress Corrosion Cracking, Section XI.."
- Session 2: Key Projects for Collaboration areas were discussed
  - Weldability Threshold for Irradiated materials
  - Effective Heat Input
  - Spent Fuel Canister Repair and Cold Spray Repair
  - Hardness Protocol for Temper Bead Welding

WRTC/ASME/Industry Meeting – Future Meetings

- Continue discussion/technical exchange focused on ASME code cases
  - Conditionally approved, Disapproved, Area of optimization or clarification
  - Include Code Case 752 – Risk Informed R&R **(continues to be an important case for the industry)**
- Continue discussions on Key Projects for Collaboration
  - Status of Additive Manufacturing Code Cases, and evaluations
  - Goal to establish collaboration with Irradiated material weldability studies
  - Continue discussion (as needed)
    - Effective Heat Input
    - Spent Fuel Canister Repair and Cold Spray Repair
    - Hardness Protocol for Temper Bead Welding

Date for future meeting is still being determined

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 **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

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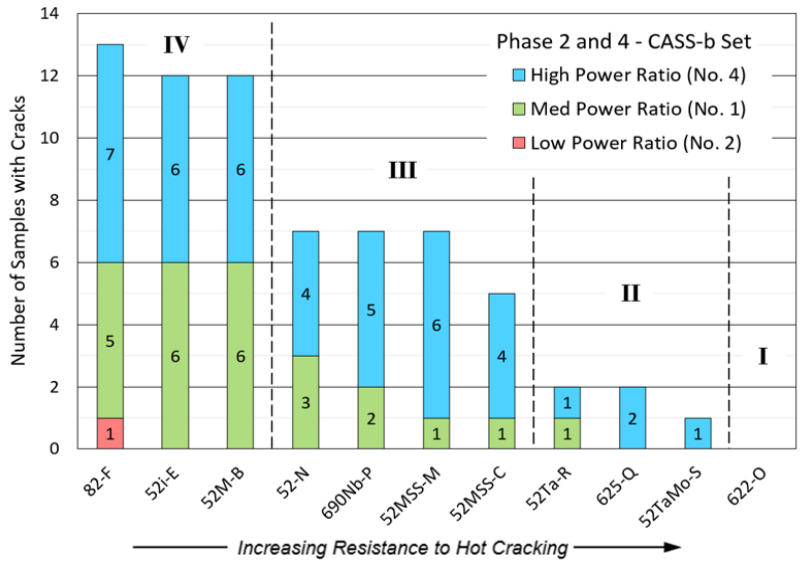
- **NRC liaison, Jim Cirilli, Sr. Technical Executive**
- **Advance Manufacturing liaison, David Gandy, Sr. Technical Executive**

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

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

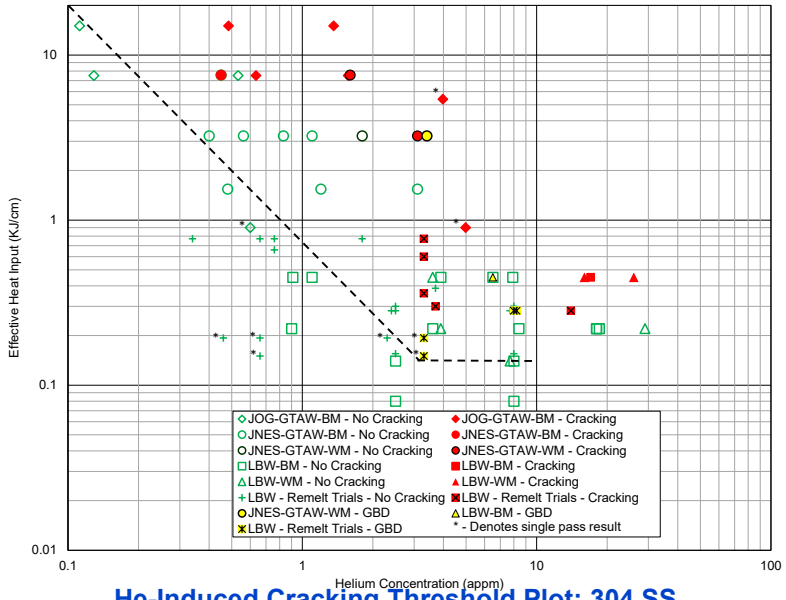
- Research and understand weldability of materials and filler materials
- Representative Demonstrations
- Develop solutions for improved weldability, implementation guidance and lessons learned
  - Current focus on high Cr Nickle alloys (Alloy 52 variants), duplex stainless steel and martensitic SS filler 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: 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

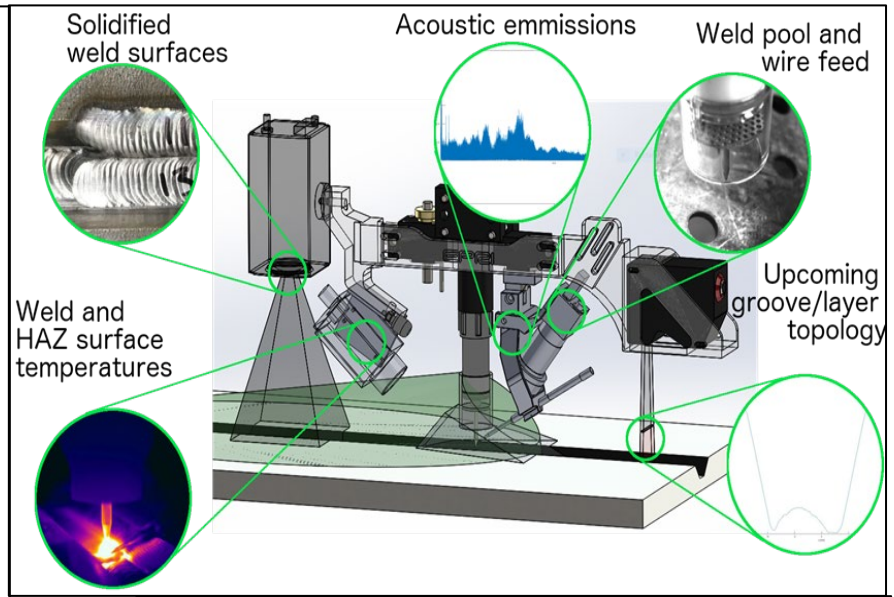


He-Induced Cracking Threshold Plot: 304 SS

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

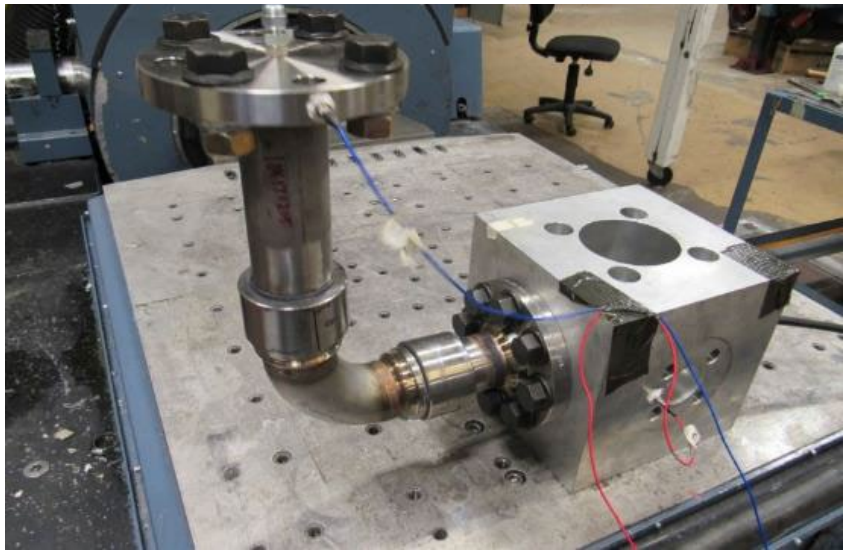
- Development of repair solutions for critical nuclear structures - current focus on containment, spent fuel pool (SFP), and dry cask storage system (DCSS) structures
- Interface with EPRI Extended Storage Collaboration Program (ESCP)
- New case for Repair & Replacement of canisters is planned for future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

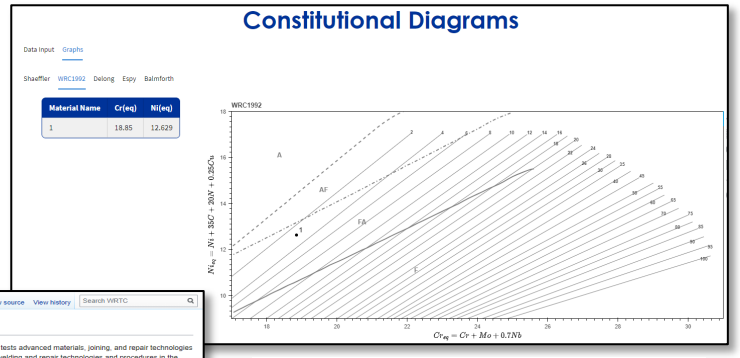


WRTC's RFA 6: Codes and Standards

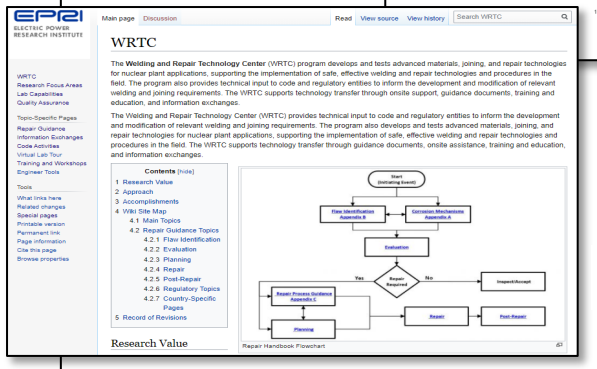
- Promote and progressing Codes and Regulatory adoption of Code Cases, Code Revisions via technical basis research, industry papers (e.g. PVP), etc.
- Reduce burden in requirements based on industry practices and promote utilization of repair processes.
- Publishes an Annual Report on status of Code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

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

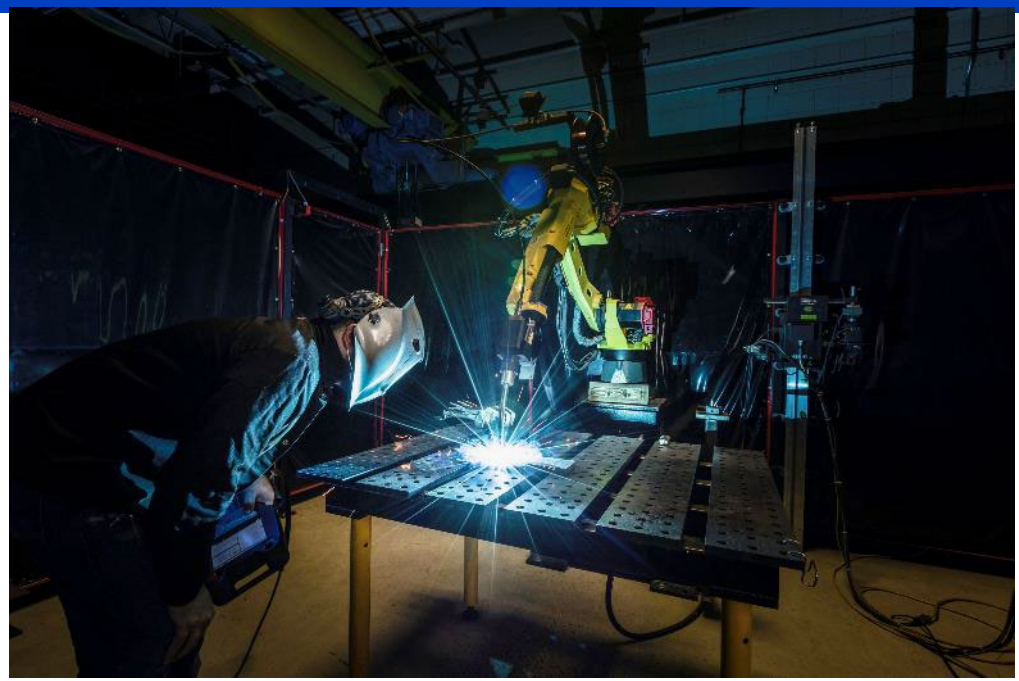
WRTC Lab Capabilities

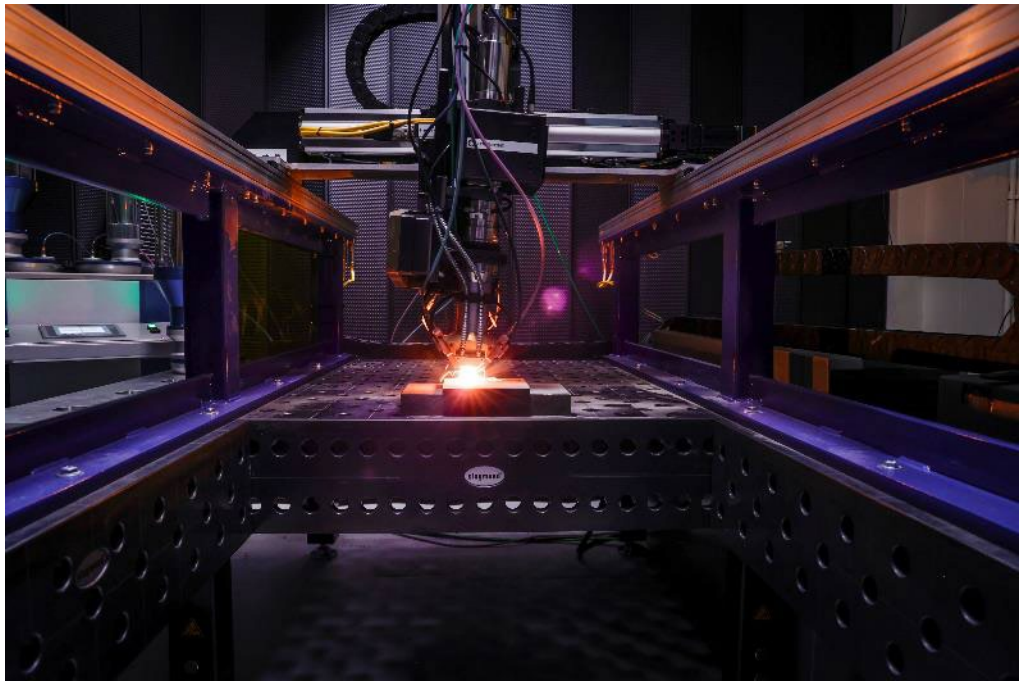
WRTC combines extensive laboratory capabilities and detailed familiarity with industry and regulatory issues to investigate and evaluate fabrication and repair/replacement techniques.

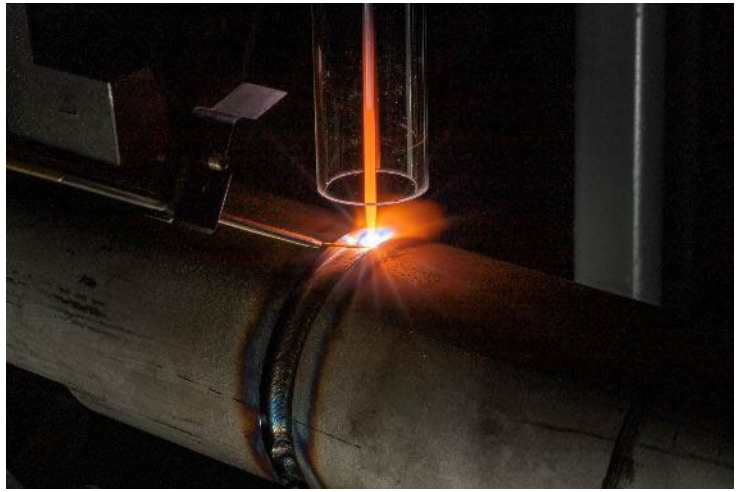
- Facilities and Lab Capabilities includes:
  - Material testing
  - Welding and Joining technology
  - Metallurgical support
  - Mockup/demonstration support
- EPRI can replicate field welding conditions such as techniques, materials, joining processes, and equipment to create realistic welding environments in the laboratory.
- The laboratory and staff expertise gives WRTC the ability to research a wide range of research such as advanced materials, weldability evaluations, and repair solutions

For a virtual tour of the WRTC labs with additional information pertaining to the equipment and ongoing research in these labs please visit the WRTC virtual lab tour website: [WRTC Welding Virtual Lab Tour]

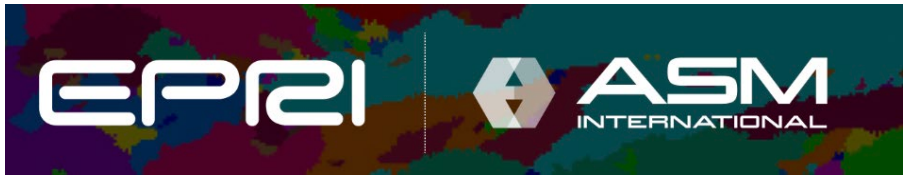
Overview of EPRI nuclear laboratories website: [Nuclear Laboratories]







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



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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