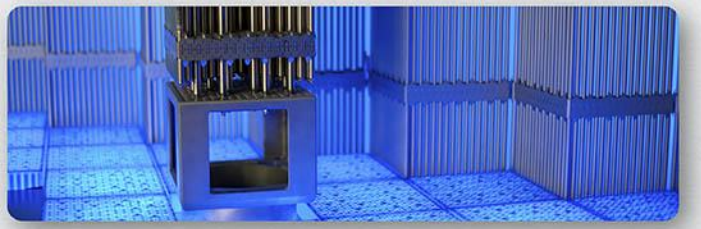

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Welding and Repair Technology Center – Overview

Greg Frederick, EPRI

WRTC Program Manager

Dan Patten, FENOC

Program Chair

Outline - Summary

- Welding & Repair Technology Center (WRTC)
  - WRTC Mission/Strategic Plan
  - Advisory Structure
  - Technology Roadmaps
  - Key Projects 2010/2011
  - Advisory meetings/conferences

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WRTC Strategic Plan

- WRTC balances fundamental research (long-term) with tactical projects (short-term)
  - WRTC focus on tactical support and short-term, utility-requested R&D.
    - *emergent repair needs*
    - *code cases*
    - *repair and welding process optimization*
    - *information exchange*
  - Apply resources toward proactive resolution of major industry gaps & development of advanced solutions
    - Collaborations to develop and deploy materials joining and repair fundamental solutions
    - Align WRTC resources, program objectives, and projects for long term research

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WRTC Strategic Plan

- WRTC Strategic Plan (Roadmaps)
  - Technology gaps were identified in the area of welding and repair
  - Six areas were highlighted for further development
  - Three roadmaps address fundamental R&D
    1. Develop new welding technology and guidance for the repair of highly irradiated material (PWR and BWR Internals)
    2. Alloy 52M Nickel-base filler metal weldability solution
    3. Develop a new SCC resistant nickel based or alternative alloy with high weldability for dissimilar metal weld applications

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WRTC Strategic Plan

- Three roadmaps address tactical applications
  4. Development & Implementation of Advanced Welding Technologies
     - Residual Stress Assessment Solutions
     - Welding Impact on Inspectability
     - Production Rates
  5. Small Bore Pipe Asset Management
  6. ASME Code Issues and Support – White papers and technical bases

- Other Key R&D Areas
  - Operating Experience Review
  - Root Cause Analyses
  - Best Practices and Guidelines - Benchmarking
  - Information exchange

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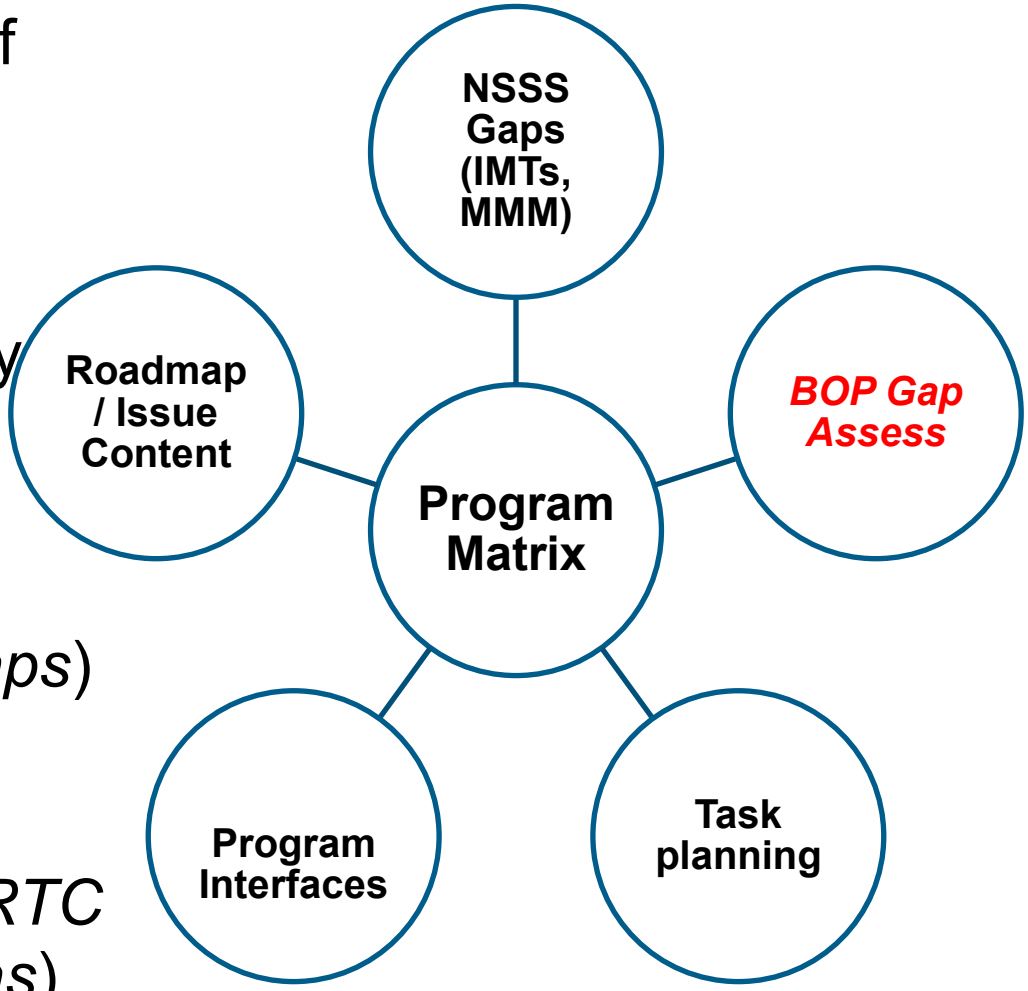
Program Matrix - Greybook

- Provide a high-level view of the WRTC program
- Identify program interfaces and WRTC projects & capabilities that provide key support to other issue programs
- Integrates with existing processes (*IMT & MMM gaps*)
- Additional elements to address WRTC needs (*BOP gap assessment, WRTC program maintenance areas*)



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WRTC Advisory Structure

- *25 of 26 US Utility Organizations (operating BWR and PWRs) participate in WRTC*
- *5 International members*
  - *EDF - France*
  - *KNHP – Korea (New 2011)*
  - *COG - Canada*
  - *CEZ NPP (New 2011)*
  - *British Energy Generation Ltd.*

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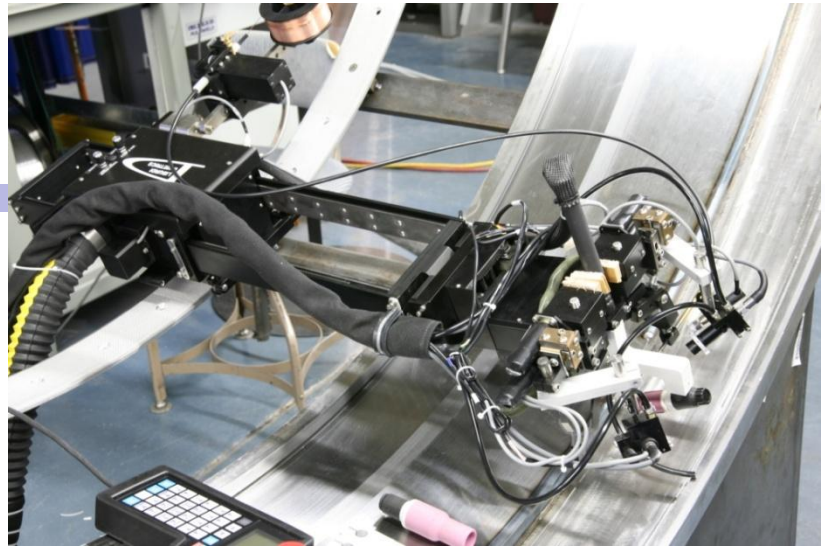
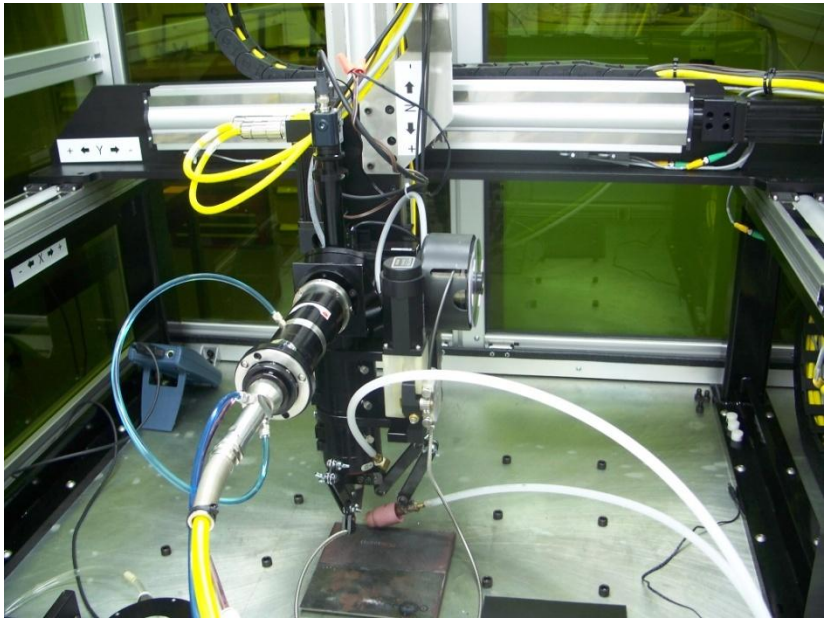
WRTC Capabilities

- *Weld Shop*
  - *Orbital Welding capabilities*
  - *GTAW, GMAW, SMAW, laser, friction stir*
  - *Weld monitoring and Data acquisitions*
  - *Hydrogen analyses*
  - *Stress evaluation*





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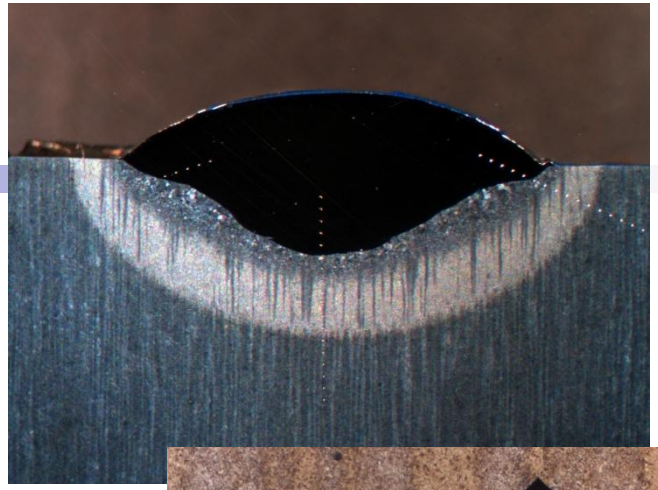
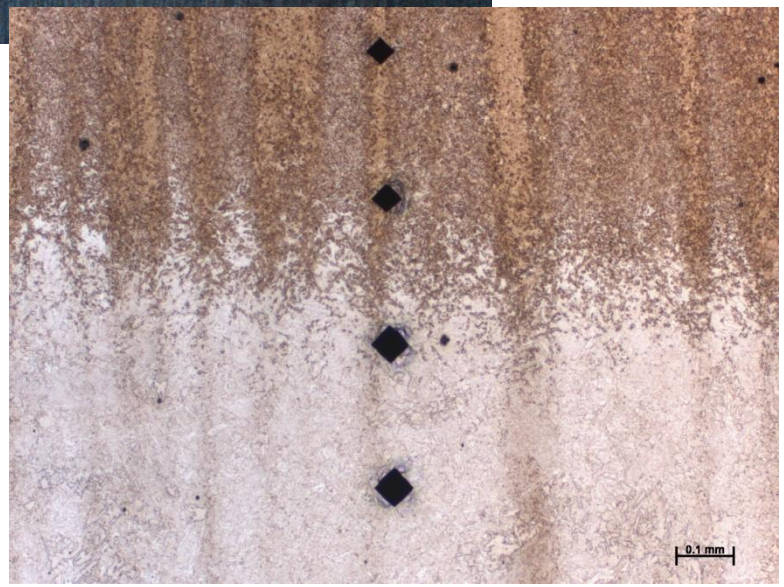
WRTC Capabilities





- *Metallurgical Lab*
  - *Scanning Electron Microscope*
  - *Hardness evaluation*
  - *Corrosion evaluation*
- *Machine Shop*
- *Material Archive*
  - *Alloy 690, 600*
  - *CASS*
  - *Vessel material*
- *Welding Filler Material Archive*
  - *Alloy 52 type*

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Current Supplemental Project listing (2010/2011)

- Small bore piping issues (including socket welds)
  - Automatic socket welds
  - Autogenouse butt weld – equipment verifcation/qualifications
  - Socket weld ratio 2:1 verification and guidance
  - Socket Weld test PQT- determine value.
- Guidelines for GTAW/GMAW Temper Bead repairs of Nuclear Components
  - Scenarios and technical guidance
- Code Rules for Waveform controlled GMAW
  - optimization for typical materials in power industry
  - GMAW Joint PQR (P4, P5, SS, CS)
  - GMAW guidance for welding on thinned wall
- Issues related to Alloy 52 welding
  - Screening/Grading of IN 52 weld metal (DDC improvement, hot cracking)
  - Evaluation of Welding Parameters on CASS (TASK 3)
  - UW Laser Welding Base material issues
  - Welding for PT-White
- Data Acquisition for real-time defect mapping, repair options, root cause
- Welding Best Practices/Benchmarking (INPO ER
- Training for new Repair & Replacement Engineers
- Relaxation of requirements for Preheat, Post Bake, and NDE hold times
  - GTAW/SMAW/GMAW

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RRAC – WRTC Team

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- Welding/Repair & Replacement Activities/New Plant Build
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June - WRTC Advisory Meetings

June WRTC Advisory and Technical Program

- *Day 1- Topical sessions*
  - *Utility discussions on operating experience, emerging issues and Code activities*
- *Day 2 - Review of Key Projects*
  - *Status and results of Projects*
  - *Introduction/Discussion of new project topics to address technical gaps*

- *Advisory Meeting scheduled in conjunction with Welding Technology Conference*

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December - WRTC Advisory Meetings

- December WRTC Advisory and Code Issue Meeting
  - *Day 1 - Code issues meeting (invited speakers)*
  - *Day 2 - Process Demonstrations*
    - *Welding and Joining equipment demo*
    - *Joint Welding Procedure Qualification*
      - *(5) GMAW PQRs performed successfully in 2010*
      - *Supported by Duke Energy, PSEG and Lincoln Electric*
    - *2010 December Advisory Meeting*
      - *54 attendees (Utilities and Code Experts)*
      - *21 Utility advisors present*

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December WRTC Advisory Meeting

- *Day 3 - Project Selection*
  - *Discussion of Roadmaps and Technology Gaps*
  - *Introduction of new projects*
    - *New items introduced by Utility representative (open discussion)*
    - *Information exchange topics from prior year*
    - *SRA activities*
    - *Code activities*
    - *Topics from other Issues Groups*
  - *Advisory structure or Coordinators assigned for each project*
  - *Leading to a Greybook format for project descriptions, deliverables*
    - *Establishing connection to technology gaps and roadmaps*

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Welding Technology Conferences

- Established conference series for Welding and Repair Technology
  - *Welding and Repair Technology for Power Plants, 9th International Conference (2010)*
    - *214 Attendees with 15 Countries Represented*
    - *32 Exhibitors*
    - *Sponsors (WEC, Euroweld, and Structural Integrity)*
  - *Welding and Fabrication Technology for New Power Plants and Components (June21-24, 2011, Omni Champions Gate, Orlando)*
    - Sponsored by WRTC and Fossil Materials Repair (Program 87), Boiler Life and Availability (Program 63), HRSG Dependability (Program 88)

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Workshops Planned for 2011 Conference

B31.1 Materials, Fabrication, & Examination - Doing It Right

- Discuss the bases for the B31.1 Power Piping Code rules for materials, fabrication, and inspection/examination. Special emphasis will be placed on rules that are different from other ASME Codes
- Course conductor: *Philip D. Flenner, PE*

Basics of Conducting a Failure Investigation

- Intended to educate the power plant engineer on the proper steps to take when conducting a failure analysis
- Course conductor: *Dr. Jude Foulds, P.E., Principal, Clarus Consulting, LLC*

Heat Treating Practices for Energy Construction: Quality and Consequences

- Discuss the basics of heat treatment and its growing significance in power construction. Emphasis on material quality and illustration of potential failures in base and weld material
- Course conductor: *Gary Lewis and Joe Borror, Superheat FGH*

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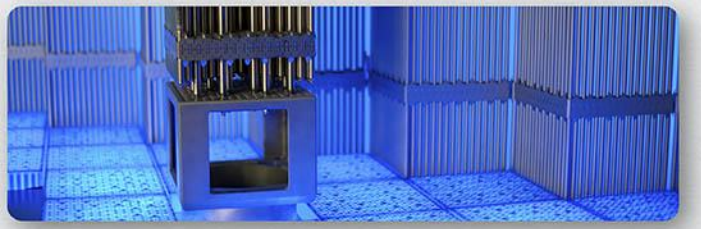

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WRTC – Key Activities Roadmaps

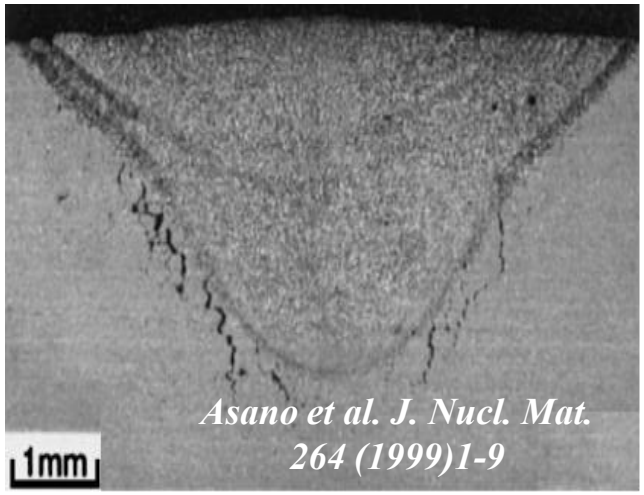
Roadmap – Weldability of Irradiated Material

Roadmap – Weldability of Irradiated Material

ISSUE STATEMENT

- *Continued operation of light water reactors will require repairs or replacement of reactor internal components as degradation occurs (Welding will play an important role)*

- *Weldability of the materials is altered by the formation of helium (helium-induced cracking)*



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Roadmap – Weldability of Irradiated Material

Project Objectives and Scope

- Develop advanced welding technology required for reactor repairs
- Collaborate with industry experts (integrated approach between Industry/EPRI and the DOE/LWRS/ORNL to support reactor life extension beyond 60 years
- Development Modeling Simulation to Guide Process Development and Predictive Application on Irradiated Materials
- Validate Processes
  - Hot Lab Welding and Testing
  - Neutron Irradiated Sample Set

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Industry Collaboration with DOE

Development of neutron irradiated sample set for testing advanced welding processes

- Material Type - 304 SS, 316SS and Alloy 182
- Tightly controlled Boron Content
- Produces a variety of Helium contents to simulate different fluences in the reactor

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Industry Collaboration with DOE (New Welding Hot Cell at ORNL)

EPRI is participating in the design and development of a New Welding Hot Cell (ORNL)

- Welding Capabilities:
  - Laser - conventional and hybrid
  - Friction stir
  - Material Testing and Metallography

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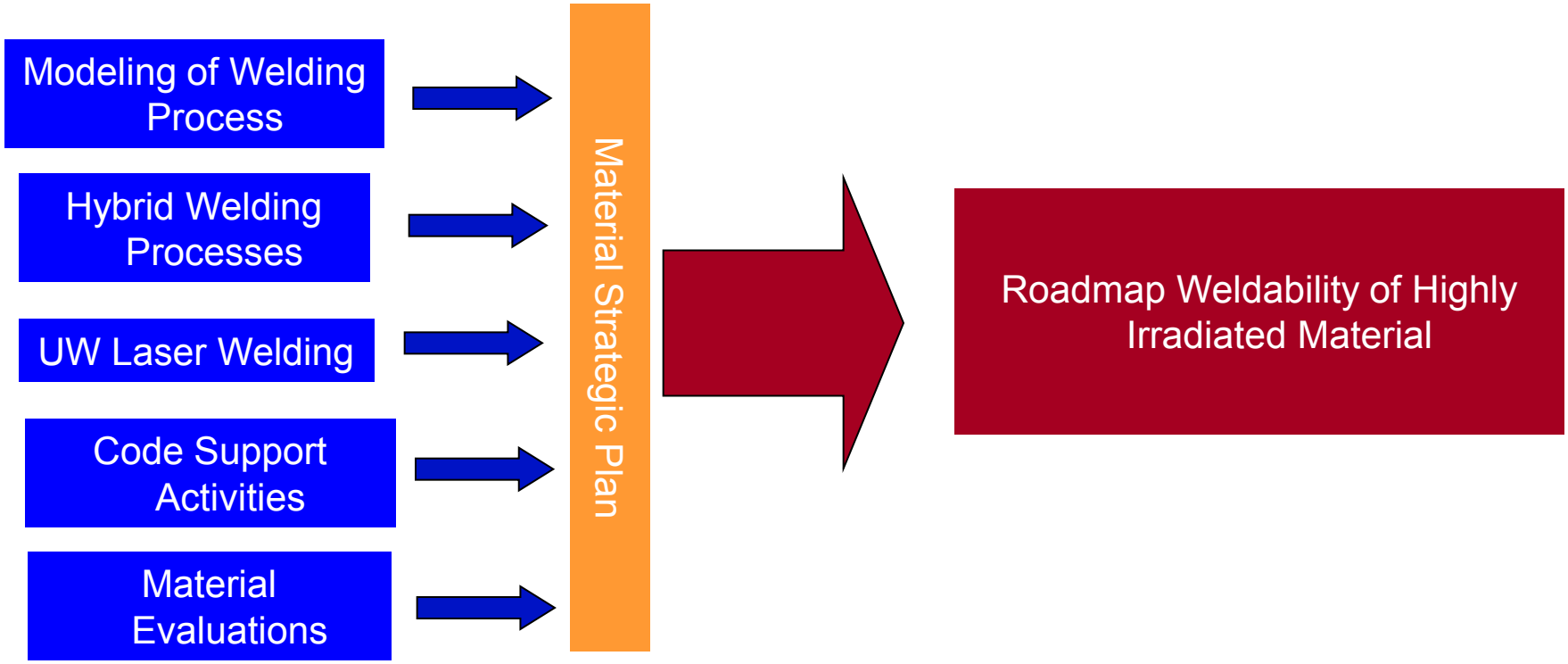
Roadmap – Weldability of Irradiated Material

Develop welding technology and guidance for irradiated material (PWR and BWR Internals)



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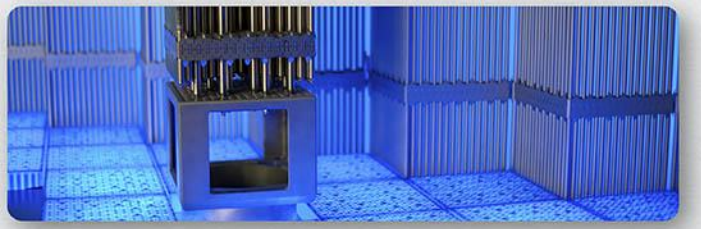

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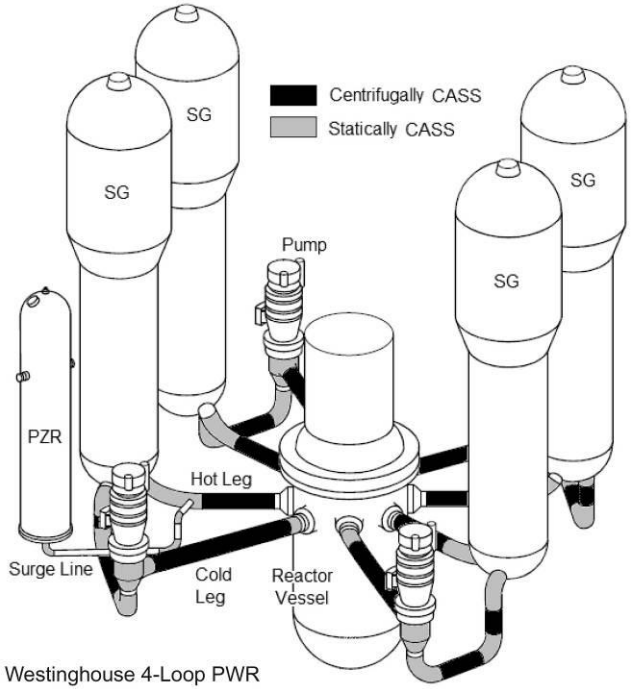
WRTC – Key Activities Roadmaps

Alloy 52M Nickel-Base Filler Metal Weldability Solutions

Alloy 52M Nickel-Base Filler Metal Weldability Solutions

ISSUE

- INCONEL 182 (ENiCrFe-3) filler metal extensively used in dissimilar metal welds for critical reactor coolant system components
  - Over time 182 is degraded by primary water stress corrosion cracking (PWSCC)
- Filler metal 52M (ERNiCrFe-7A) with ~30wt% Cr has high resistant to PWSCC and is currently filler metal required for;
  - Mitigation
  - Repair
  - New fabrication



Westinghouse 4-Loop PWR

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Alloy 52M Nickel-Base Filler Metal Weldability Solutions

Issue

- Weldability and crack susceptibility of 52 and 52M are complex and will continue to plaque the industry (outage schedule extensions and the associated lost plant availability and lost revenue).
- Adequate composition limits, narrow process controls and ranges, special requirements for isolating susceptible base materials and experience are required

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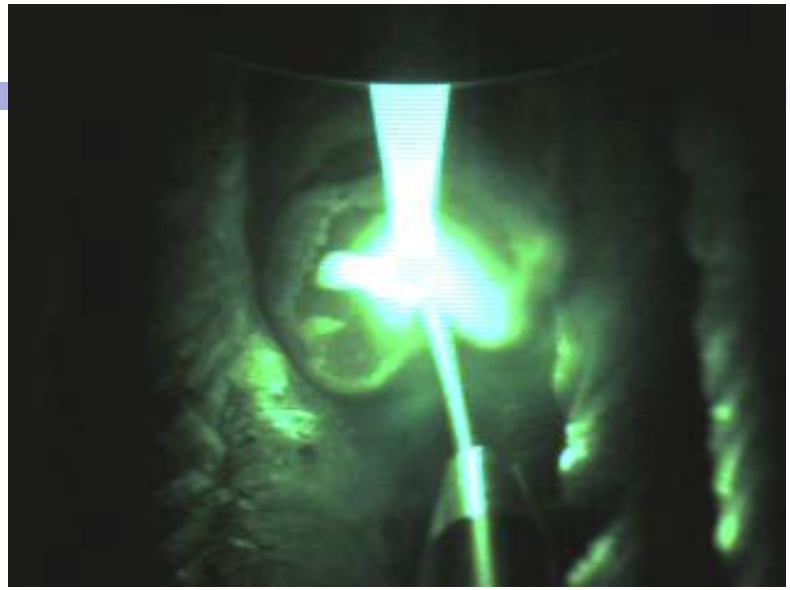
Alloy 52M Nickel-Base Filler Metal Weldability Solutions

- General Weldability Issues
  - Sluggish weld puddle
  - oxide build up
  - Lack of Fusion (LOF)



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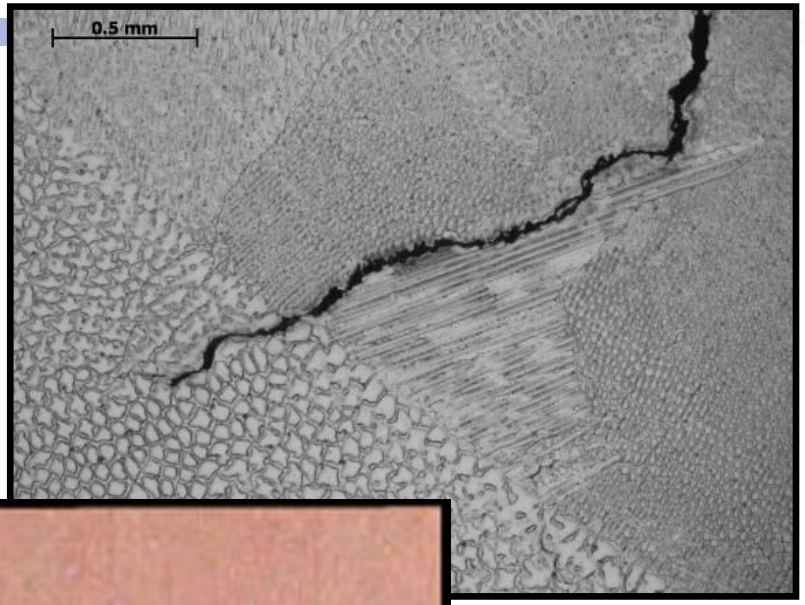
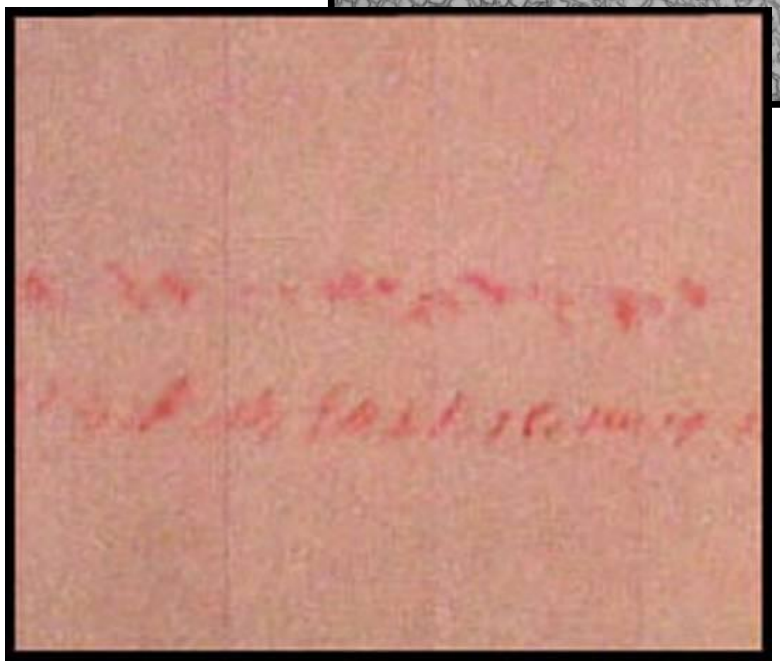
Alloy 52M Nickel-Base Filler Metal Weldability Solutions

- Material issues:
  - Ductility-Dip Cracking (DDC)
  - Liquation Cracking
  - Hot Cracking





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Alloy 52M Filler material evaluations

Objectives – Database of Alloy 52 heats of various chemistries graded for crack susceptibility

- Index number based on resistance to:
  - Solidification (hot) cracking
  - Reheat cracking (ductility-dip cracking)
- Standardize method for evaluating / measuring crack susceptibility of nickel weld filler metals (Alloy 52M and new alloys)
  - Varestraint
  - Strain-to-fracture
  - Cast-pin-tear
  - Thermal simulation (JMatPro/ ThermoCalc)
  - SS DTA (single sensor differential thermal analysis)
  - General Weldability

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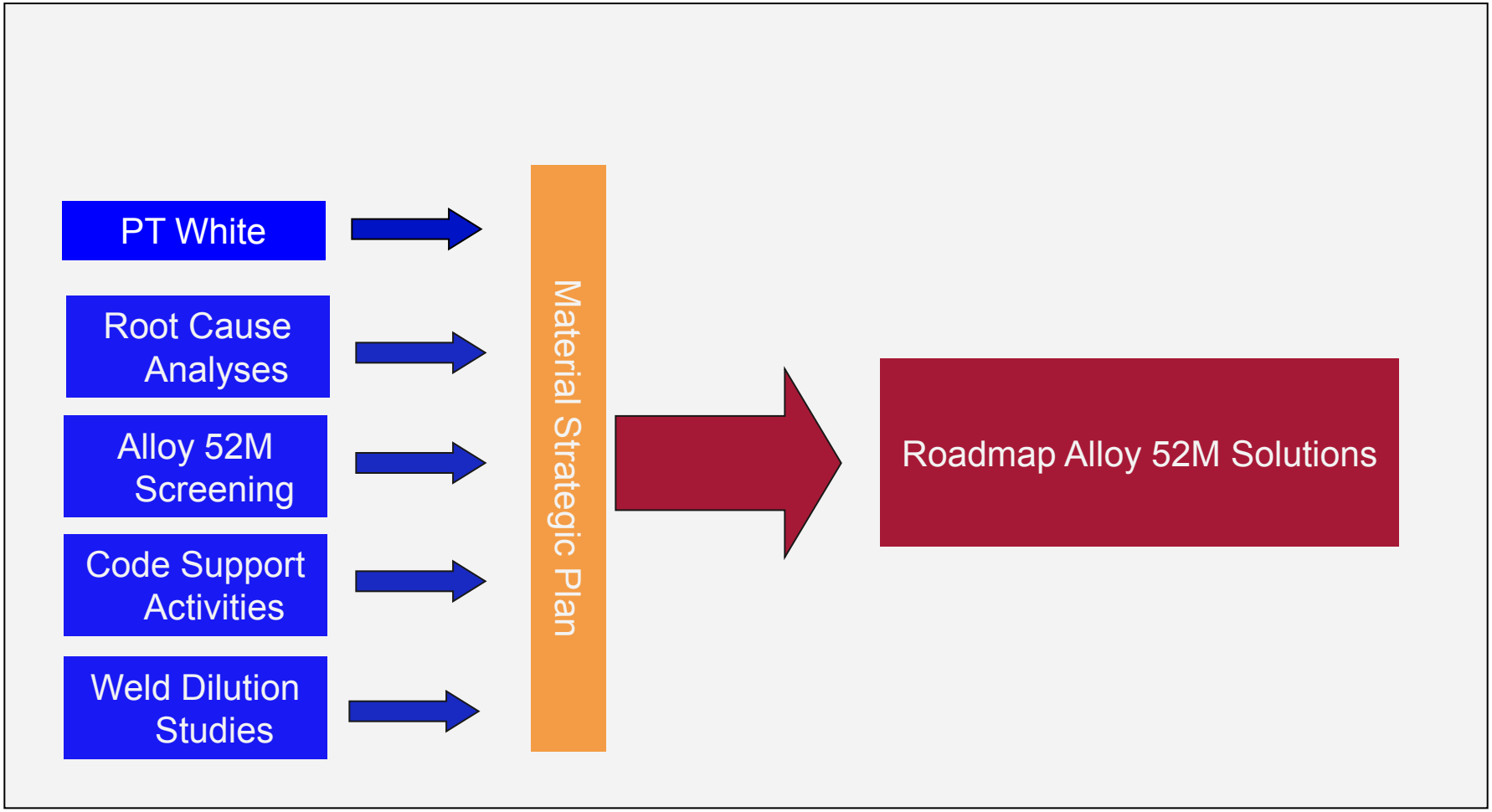
Alloy 52M Nickel-Base Filler Metal Weldability Solutions



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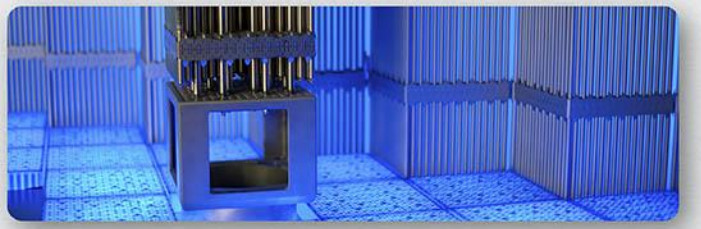

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WRTC – Key Activities Roadmaps

Development of New SCC Resistant Nickel Based or Alternative alloy

Development of New SCC Resistant Nickel Based or Alternative alloy

ISSUE STATEMENT

- *Alloys 52 and 52M currently required for DMW repairs*
  - *High-chromium, nickel-based weld metals developed specifically for their superior resistance to SCC*
  - *Alloys are susceptible to weld cracking and have less than optimum weldability.*
- *A new high-chromium welding alloy is needed*
  - *With desired mechanical properties and corrosion resistance*
  - *With significantly improvement in weldability and superior resistance to weld cracking.*

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Development of New SCC Resistant Nickel Based or Alternative alloy

SCOPE

- Fundamental research performed to understand cracking mechanisms and weldability problems
- Development of alloy composition
  - Model welding behavior and mechanical properties of target compositions
  - Validate modeled behavior with experimental weld wire heats
  - Perform mechanical, corrosion, and crack growth rate testing
- Assess welding and nondestructive evaluation of alloy composition
  - Assess process parameters for gas tungsten arc and gas metal arc welding
  - Large scale mockups and assessment of nondestructive evaluation
  - Assess feasibility of alternative advanced welding processes (laser welding, magnetic stir, hybrid, etc.)

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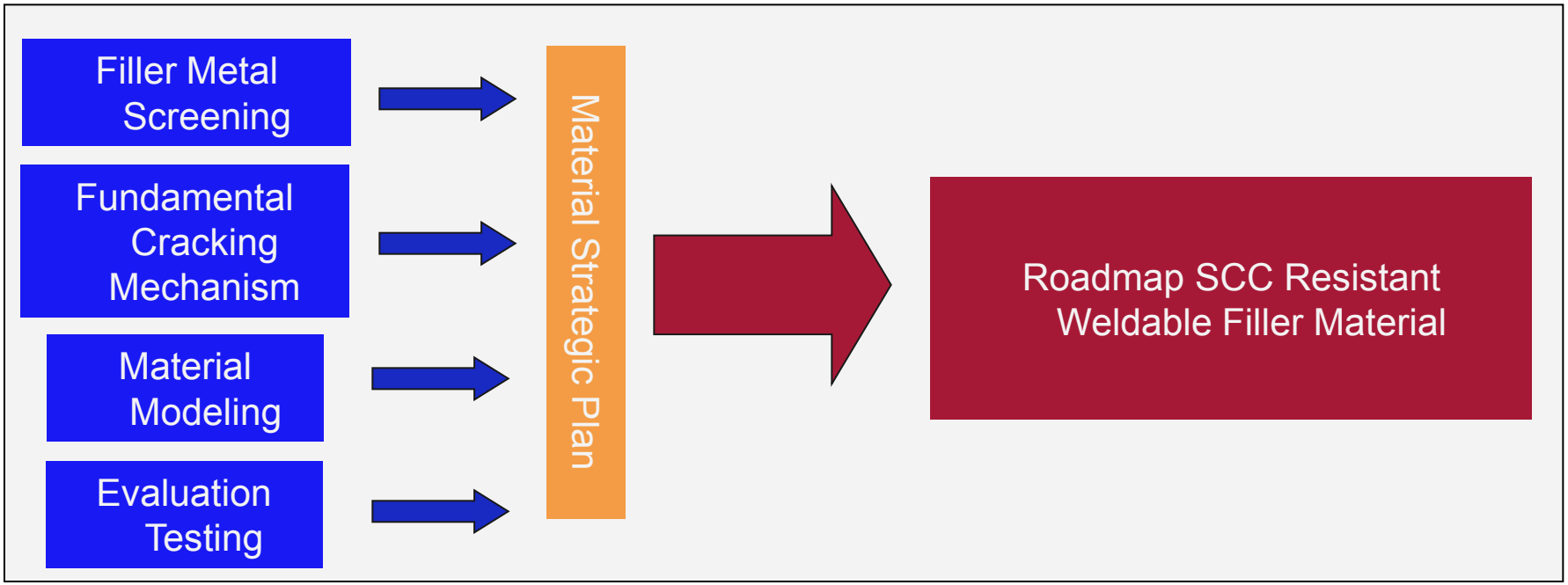
SCC Resistant Alloys with High weldability



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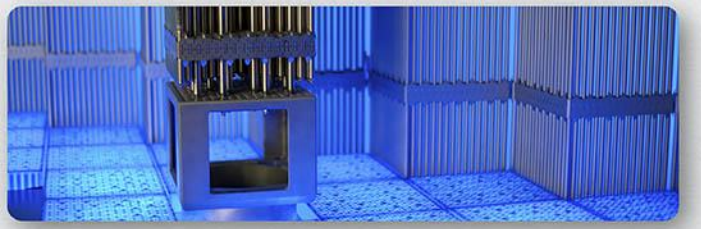

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WRTC – Key Activities Roadmaps

Development & Implementation of Advanced Welding Technologies

Development & Implementation of Advanced Welding Technologies

Objectives

- Roadmap for advance welding development
- residual stress improvements
- welding impact on inspectability
- increase production rates

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Development of Advanced Welding Processes

- Welding Process Studies
  - Redistribution of heat input and auxiliary heat sources
  - Controlled dilution and material interactions
  - Evaluate processes that do not create a molten weld pool
  - Evaluation of weld filler materials interactions
- Advantages compared to traditional welding processes
  - Creation of a wider repair welding window for non-repairable materials
  - Capable of effectively changing the local stress/strain field around the weld pool to a compressive state
  - Reduced heat affected zone (HAZ)
  - Improve inspectablity

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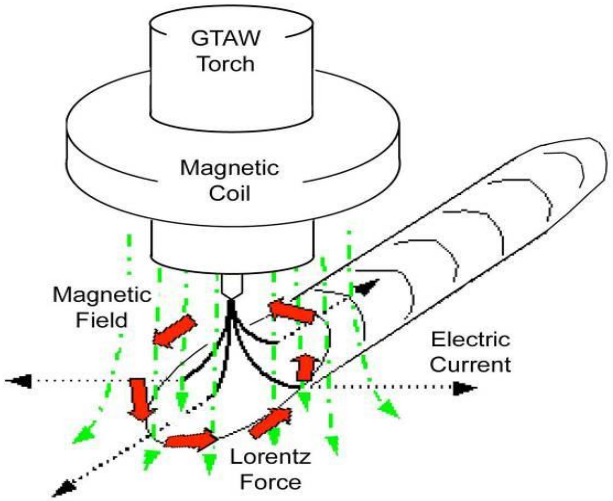
Development & Implementation of Advanced Welding Technologies

Magnetic Stir Welding Process Evaluations

- Initial results with overlay configuration with Alloy 52M
  - Show reduction in weld metal grain size
  - Significantly improved NDE (UT) examination capability by reducing ultrasound attenuation
- Work in 2011 will evaluate
  - Potential for reduction in hot cracking
  - Capabilities to address groove welding application for new construction and repair (single sided applications)



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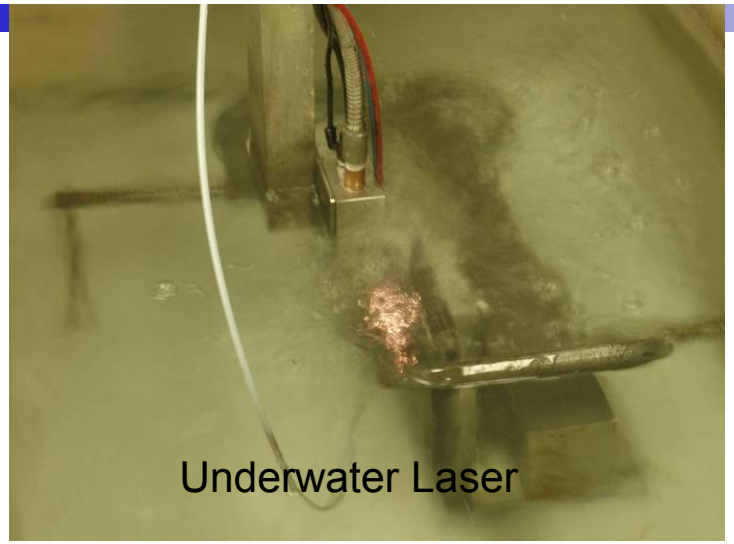
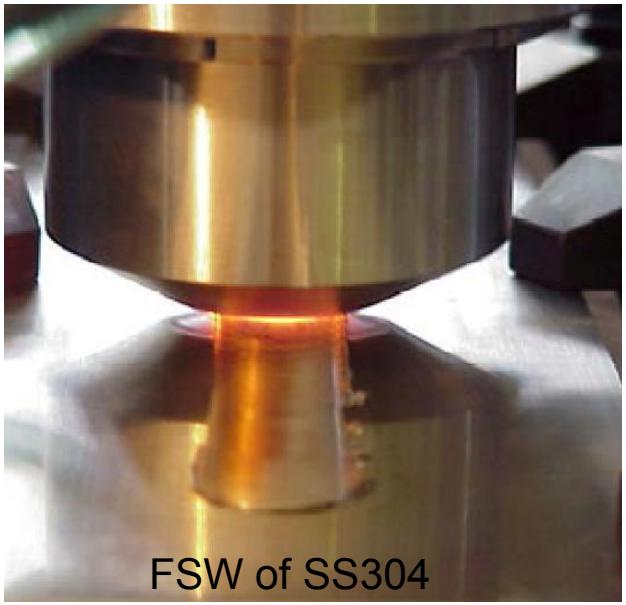
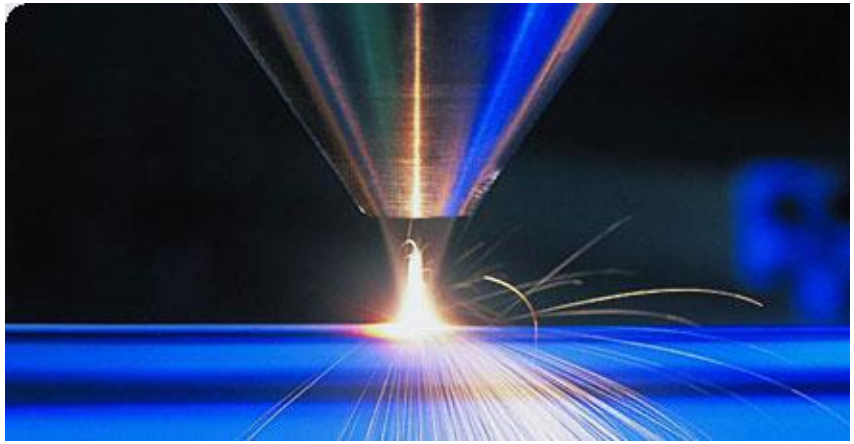
Develop welding technology and guidance for irradiated material (PWR and BWR Internals)



- Hybrid Laser Welding
- Friction stir welding (FWS)
- Ultrasonic welding (UW)
- Underwater Laser Welding (ULB)





Laser Welding

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Key Issue – Strategy for real-time monitoring of welding processes

ISSUE

- *Welding issues, defects and equipment problems arise during repair and mitigation activities such as;*
  - *Overlay applications, component replacement*
- *Currently the supporting data is limited*
  - *Post-weld indication (NDE) and surface indication*
- *Benefits of Real-time data logging and inspection*
  - *Identifying contributing welding parameters or malfunctions – root cause*
  - *Support corrective actions (minimize delay) prior to completion of weld*
  - *Eliminate concern of reproducing weld defects in subsequent welds or repair*

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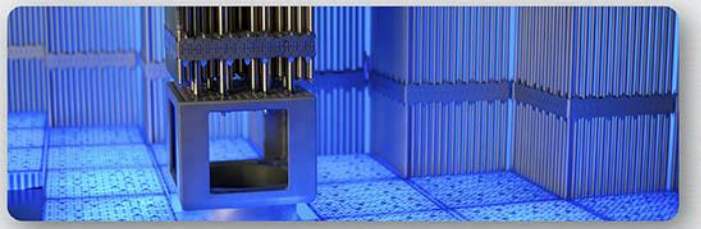

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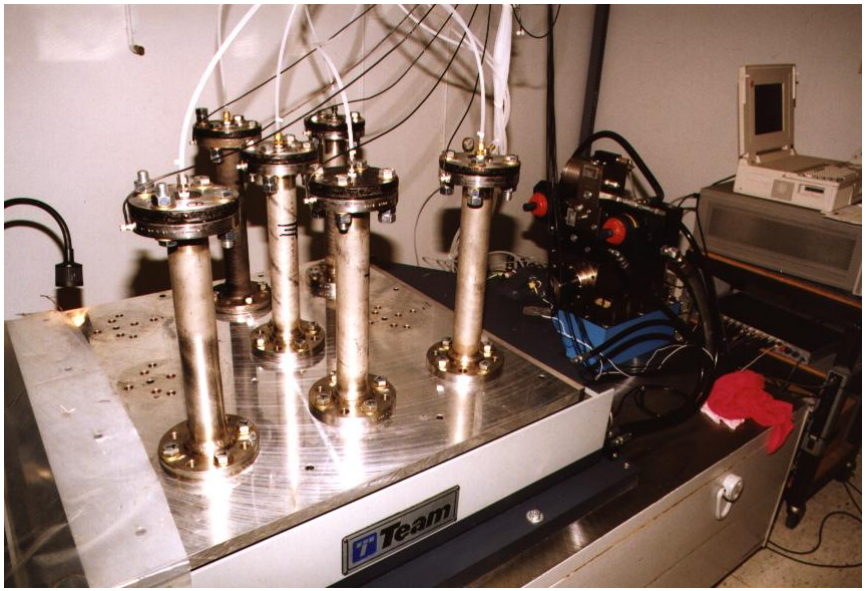
WRTC – Key Activities Roadmaps

Small Bore Pipe Asset Management

Small Bore Pipe Asset Management

- Leaks of small bore socket welds due to vibration continue to be a source for unscheduled outages, resulting in significant cost impact.
- Projects to evaluate and test improvements in socket weld design and alternative joining processes



- 2:1 leg size
- Weld Process limitations
- Importance of root quality
- In-situ Overlay Repair Capabilities

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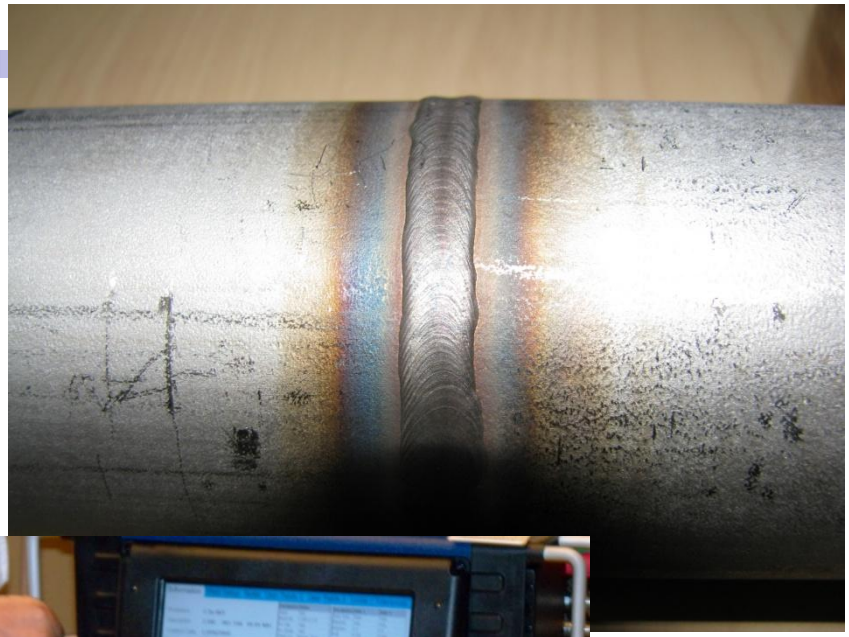
Small Bore Pipe Asset Management

- Alternative Welding Process
  - Examining the use of autogenous welding process in lieu of a welds with filler material manually applied
    - Machine (automated) process
    - Autogenous welding typically is used for:
      - Small diameter components
      - Thinner schedules
  - Successful welds have been applied to 2-inch schedule 80 weld (.218-in. wall)



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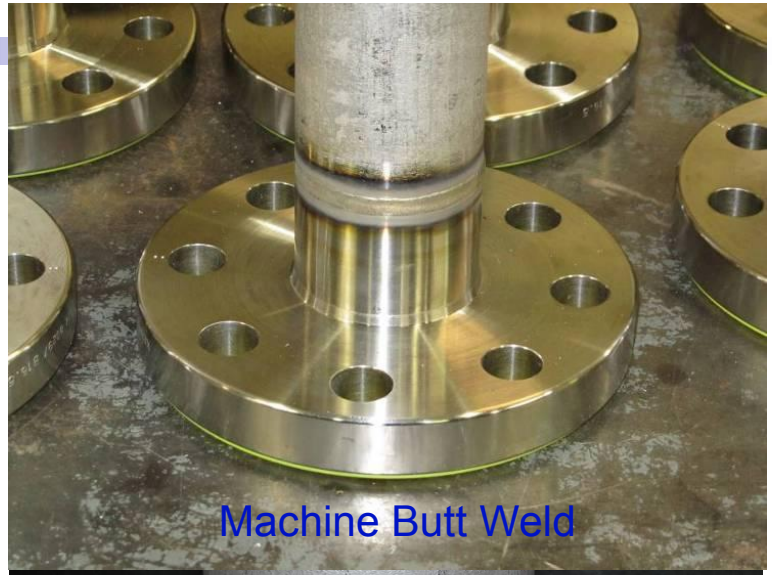
Small Bore Pipe Asset Management

- Two alternative to socket welds are being evaluated
  - Butt welded configurations
  - Socket welded configurations with alternative geometry (compression ring)
- Current studies (2011)
  - High cycle fatigue resistance compared to standard socket welded configurations
  - Material interactions
  - Fit up requirements
  - Assembly practices
  - Process controls and parameters
  - Wall thickness limitations
  - Base material sensitization tests
  - Purging requirements



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Small Bore Pipe Asset Management

- Benefits of the 2x1 weld size for high cycle fatigue resistance
  - How much benefit is obtained from a weld that is larger than Code minimum but less than 2 x 1?
  - Verify that any increase in leg length on the pipe side is a benefit for resistance to high cycle fatigue
  - Distinguish between the taper angle and the benefits of an increase in throat thickness
- Goal is to establish a fatigue strength reduction factor to give credit for 2 x 1 welds vs. 1 x 1 welds in NB-3600

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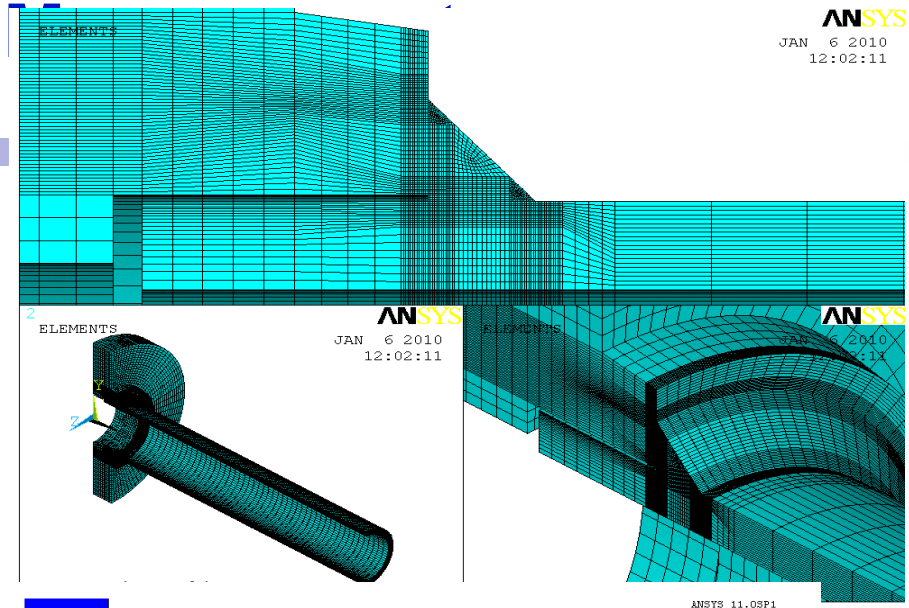
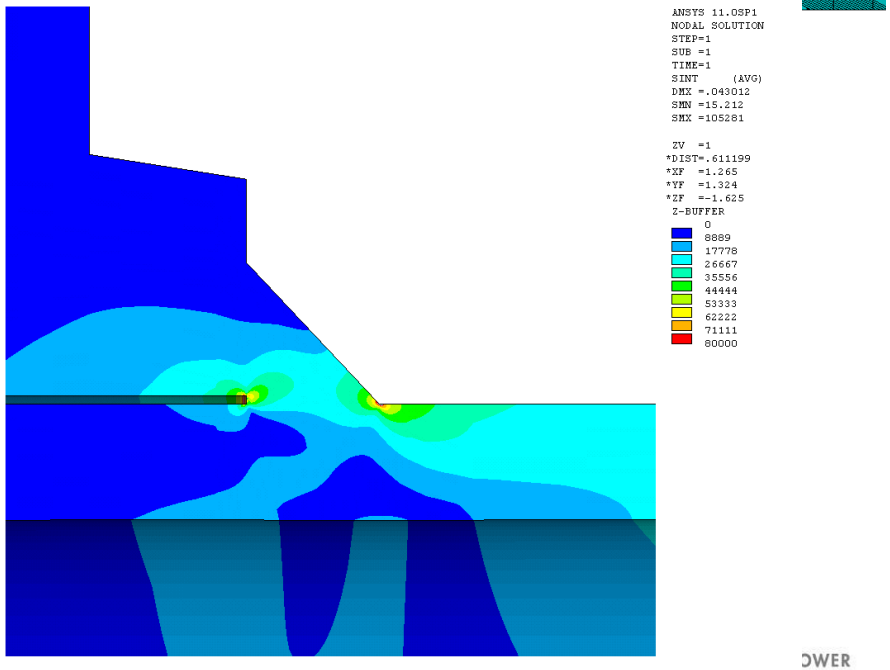
Small Bore Pipe Asset

- Approach
  - Perform finite element analysis of socket weld geometries between 1 x 1 and 2 x 1, and 1 x 1.4
  - Validate results with a limited high cycle fatigue testing of variable geometries





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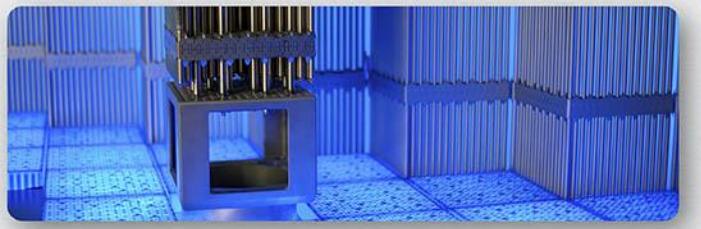

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WRTC – Key Activities Roadmaps

ASME Code Support

WRTC Code Involvement

- WRTC Team and Utility representative
  - ASME B31.1
  - ASME Section III
  - ASME Section IX
  - ASME Section XI
    - Post Construction Committee (PCC)
    - Code Cases
  - AWS Weld Process Committees and Certification Committee

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