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Material Reliability Program (MRP)
Ni-Base Alloys Research

Al Ahluwalia
Materials Reliability Program
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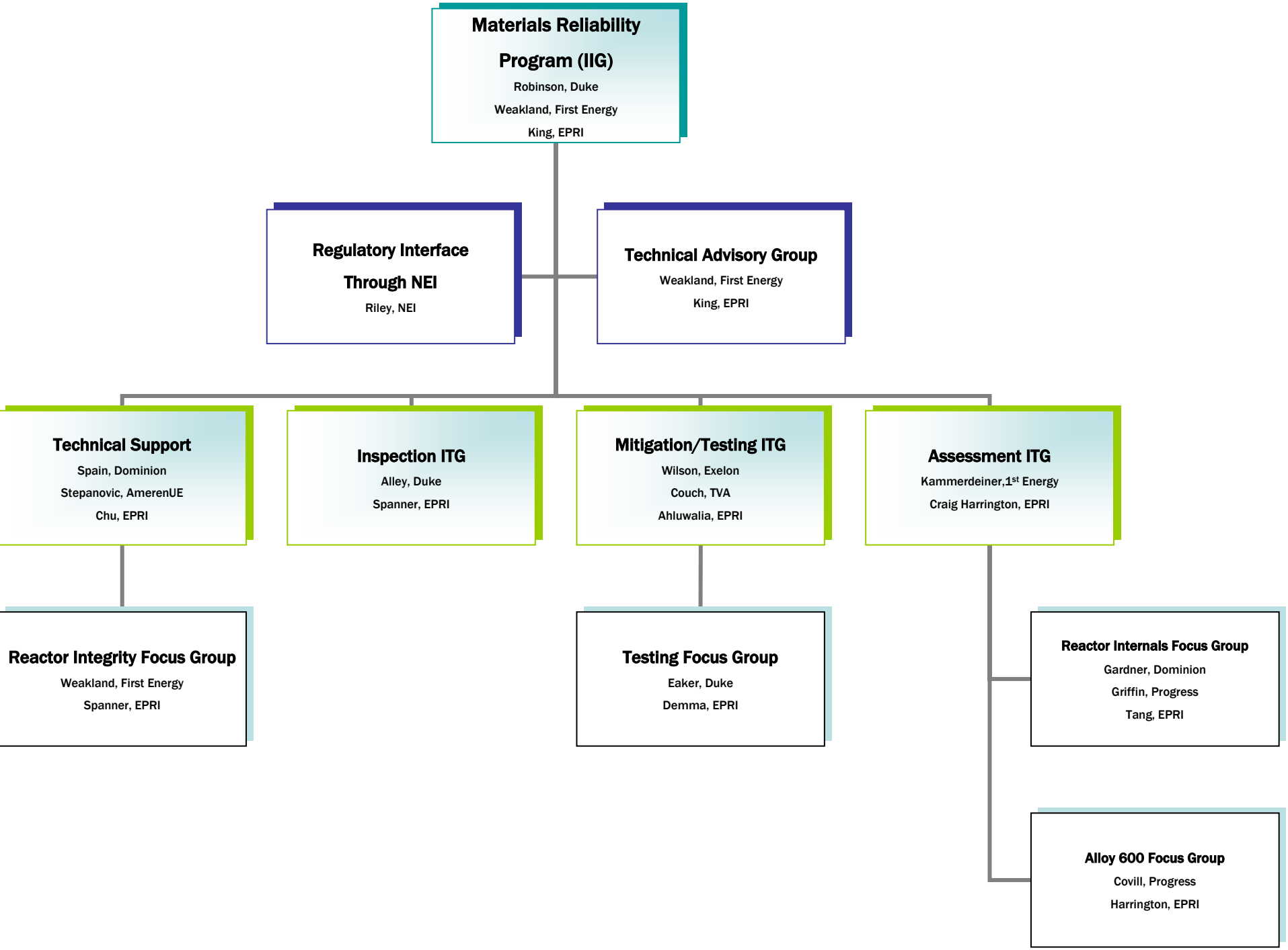
Charlotte, NC


Materials Reliability Program (IIG)
Robinson, Duke
Weakland, First Energy
King, EPRI
Regulatory Interface Through NEI
Riley, NEI
Technical Advisory Group
Weakland, First Energy
King, EPRI
Technical Support
Spain, Dominion
Stepanovic, AmerenUE
Chu, EPRI
Inspection ITG
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Spanner, EPRI
Mitigation/Testing ITG
Wilson, Exelon
Couch, TVA
Ahluwalia, EPRI
Assessment ITG
Kammerdeiner,1st Energy
Craig Harrington, EPRI
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Testing Focus Group
Eaker, Duke
Demma, EPRI
Reactor Internals Focus Group
Gardner, Dominion
Griffin, Progress
Tang, EPRI
Alloy 600 Focus Group
Covill, Progress
Harrington, EPRI

Assessment ITG IMT Gaps

- AS-13: Thermal & Irradiation Embrittlement: Synergistic Effects on CASS & SS Welds - Internals
- AS-14: Fluence Impact on SCC of Stainless Steels
- AS-15: Assess Void Swelling & Stress Relaxation Significance: PWR Reactor Internals
- AS-16: Fatigue Environmental Effects: Reactor Internals
- AS-18: Baffle Bolting Assessment
- AS-19: PWSCC Management: Ni-Alloy Reactor Internals
- I&E-01: NDE Technology: Dissimilar Metal (DM) Butt Welds
- I&E 04: I&E Guidelines: Bottom Mounted Nozzles
- I&E-05: I&E Guidelines: Alloy 600 “Orphan” Locations
- I&E-06: I&E Guidelines: Reactor Internals
- I&E-07: UT Demonstration: Baffle Bolting
- I&E-08: NDE Capability: Baffle Former Assembly IASCC
- I&E-09: NDE Capability: Void Swelling (Identification & Characterization)
- I&E-10: NDE Capability: CRGT Support Pins
- I&E-11: NDE Accessibility: Reactor Internals

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Inspection ITG IMT Gaps

- MT-03: PWSCC Mitigation: Stress Improvement (SI) of Butt Welds
- I&E-01: NDE Technology: Dissimilar Metal (DM) Butt Welds
- I&E-02: NDE Qualification Program: Ni-Alloy Penetrations
- I&E 04: I&E Guidelines: Bottom Mounted Nozzles
- I&E-07: UT Demonstration: Baffle Bolting
- I&E-08: NDE Capability: Baffle Former Assembly IASCC
- I&E-09: NDE Capability: Void Swelling (Identification & Characterization)
- I&E-12: NDE Capability: CASS Piping

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TSC IMT Projects

- AS-02: Environmental Fatigue Issues: Press. Bdry. Components
- AS-04: Irradiation Embrittlement: Clad LAS
- AS-06: Pressurized Thermal Shock (PTS) Re-Evaluation
- AS-07: Vibration Fatigue: Small Bore Piping
- AS-08 Capability: Baffle Former Assembly IASCC
- AS-27 Develop Alternative ASME Section XI Appendix G Methodology
- AS-29 Assess High Cycle Fatigue Potential for RPV Safety Injection and Core Flood Line Locations
- RG-01 Small Bore Piping (SBP): License Renewal Assessment

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Mitigation & Testing ITG IMT Gaps

- I&E-02: NDE Qualification Program: Ni-Alloy Penetrations
- MT-01: PWSCC Mitigation: Environmental Controls
- MT-02: PWSCC Mitigation: Stress Improvement (SI) of Alloy 600 Penetrations
- MT-03: PWSCC Mitigation: Stress Improvement (SI) of Butt Welds
- AS-01: Boric Acid Corrosion: C&LAS
- AS-09: PWSCC: Stainless Steels (Exposed to Primary Water)
- AS-11: Assess PWSCC CGRs for Alloys 82, 182, 132, 52, and 152
- AS-12: PWSCC Factors of Improvement: “Resistant” Ni-Alloys
- AS-14: Fluence Impact on SCC of Stainless Steels
- AS-17: High Cycle Fatigue - Internals
- DM-02: Low Temperature Crack Propagation
- DM-04: Irradiation Effects: Nickel Alloys (Reactor Internals)

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Mitigation and Testing ITG: Strategic Objectives

- Develop chemical and mechanical PWSCC mitigation strategies to delay component repair/replacement and to obtain inspection relief for RCS components
- Prepare technical bases for mitigation methods; some have been prepared or are planned over the next few years:
  - Pre-emptive weld overlay (PWOL)- 2005
  - Elevated hydrogen and zinc addition-2008
  - Cavitation and fiber laser peening- 2008
- Conduct PWSCC testing on replacement materials to obtain inspection relief for RCS components- 2008
- Perform Irradiation Assisted PWSCC Testing to support RI I&E GL goals
- Support basic tactical research and development for materials issues including chemistry effects, etc
- Resolve IMT gaps (Stainless steel degradation/mitigation?)

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PWSCC in Stainless Steel

- Objective: Characterize stainless steel susceptibility to PWSCC (IMT Gap AS-09)
- Work Scope: Review existing lab data and field experience to identify issues (Phase 1).

  Evaluate base/weld metal initiation/growth and mitigation gaps (Phase 2).

  Prepare work plans and conduct testing (Phase 3).
- Schedule: Phase 1: 2007; Phase 2: 2007; Phase 3: 2009
- Status: New project; proposed to begin in 2007. No 2007 funding in current budget (MTAG proposal?).
- Deliverables: MRP reports on Phases 1, 2 and 3.

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Boric Acid Corrosion Management

- Objective: Generate boric acid corrosion data to support justification of technical basis for calculating the required inspection intervals for CRDMs (and BMNs).
- Work Scope: Tests to study individual BAC mechanisms (Tasks 1, 2 and 3); Full-scale CRDM mock-up integrated test to study combined effects (Task 4)
- Schedule: Tasks 1, 2 and 3 were completed in late 2005 and early 2006.

  Task 4 planning and design started in January; Task 4 testing will be completed in 2008.
- Status: Task 1, 2 and 3 completed.

  Task 4 planning and design (Phase 1) interim review meeting held in early June; project on schedule.
- Deliverables: Task 1, 2 and 3 MRP reports available (MRP-163: 1007843; MRP-164: 1010089; MRP-165: 1011807).

  Task 4, Phase 1 report planned for late 2006. BAC guideline revision in 2008/2009

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Destructive Examination of North Anna 2 CRDM

- Objective: Destructive examination of a degraded CRDM to study PWSCC and compare with field and lab NDE indications.
- Work Scope: Removal, decontamination & NDE of 4 NA2 CRDMs (Phase 1); destructive examination of CRDM 54 (Phase 2); comparison of DE and NDE findings (Phase 3).
- Schedule: Phase 1 (2004); Phase 2 and Phase 3 (2006)
- Status: Phase 1 completed in 2004; Phase 2 complete- report under preparation; Phase 3 will be completed by fall 06.
- Deliverables: MRP reports on Phases 1, 2 and 3. Phase 1 report is available (MRP-142: 1007840).

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PWSCC Expert Panel

- Objective: Obtain international expert advice (industry/regulatory/academic) on approach and scope of ITG projects
- Work Scope: CGR disposition curves, direction for new research, review ongoing research results
- Schedule: Hold two meetings per year
- Status: First 2006 meeting in April in La Jolla on chemical mitigation (28 attendees)

  Second meeting expected in October on A690/52/152 CGR testing issues; NR contractors and NRC RES presentations.
- Deliverables: Meeting notes and presentations - limited distribution (proprietary information)

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Low Temperature Crack Propagation (LTCP)

- Objective: Determine when it is possible in PWRs and provide guidance to avoid possibility of occurrence.
- Work Scope: Confirmation of phenomenon (discovered by Naval Reactors) under different scenarios including PWR shutdown chemistry (Phase 1). Phase 1 partially funded by MTAG.

  Examine applicability to PWR shutdown conditions (Phase 2):loading effect testing & stress analysis.
- Schedule: Phase 1 (2006); Phase 2 (2007)
- Status: Phase 1 (several tasks) near completion

  Phase 2 initiated: contract in place and WM fabricated
- Deliverables: Two MRP reports on Phase 1 tasks available (MRP-108: 1009400; MRP-145: 1011810); last Phase 1 MTAG report due early 2007; Phase 2 report due early 2008.

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A690/52/152 CGR Testing

- Objective: Establish CGRs for replacement materials and seek inspection relief for replacement components.
- Work Scope: Conduct proof-of-principle A690 CGR testing (Phase 1); Conduct CGR testing on A690/52/152 mat'ls (Phase 2); Develop disposition CGR curves and design basis for inspection relief (Phase 3).
- Schedule: Phase 1 (2004); Phase 2 (2007); Phase 3 (2008).
- Status: Phase 1 completed.

  Phase 2 underway at two labs: Westinghouse testing nearly complete; GE testing to continue until late 2007.
- Deliverables: MRP report on Phase 1 available (MRP-123: 1010269); Phase 2 Westinghouse report in early 2007; GE interim report in 2006 and final report in late 2007 or early 2008.

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A600/690 HAZ CGR Testing

- Objective: Determine CGRs in HAZ of A600 and A690 and determine possible impact on MRP-55 disposition CGR curves.
- Work Scope: Fabricate HAZ specimens and select lab for CGR testing (Phase 1- MTAG funded); conduct CGR tests (Phase 2); determine impact on disposition CGR curves (Phase 3).
- Schedule: Phase 1 (2006); Phase 2 (2008); Phase 3 (2009).
- Status: Phase 1 completed. Phase 2 underway.
- Deliverables: MRP report on Phase 1 available (MRP-161: 1011805); Phase 2 MRP report in 2008.

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Surface Chemistry Mechanism in A82/182

- Objective: Understand what leads to the long incubation times in the field for crack initiation and investigate the feasibility of mitigating PWSCC by removing a thin surface layer of aged material prior to actual crack formation
- Work Scope: Part I: review of operating and laboratory experience of PWSCC in Alloy 182 weld metal; Part II: assess applicability of surface remediation techniques to delay PWSCC initiation in Alloy 600 base metal; Part III: exchange data with existing FROG test program to assess effects of surface finish on PWSCC of Alloy 182
- Schedule: 2006/2007
- Status: Parts I and II ongoing; complete in early 2007; Part III complete in 2006
- Deliverables: MRP reports in 2007

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“Low-K” CGR Testing for A600/82/182

- Objective: To fill a void in CGR data for Alloy 600 base metal and Alloy 182/82 weld metals at low values of stress intensity (in the 5 – 20 MPa$\sqrt{m}$ range).
- Work Scope: Conduct low-K CGR testing for A600/82/182 (Phase1); update appropriate disposition CGR curves (Phase 2).
- Schedule: Phase 1: 2008; Phase 2: 2009
- Status: Initiated review of labs with capability and interest. Expect work to begin in early 2007.
- Deliverables: MRP lab testing report in 2008. Updated disposition curves for A600/82/182 in 2009.

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PWSCC Mitigation in Ni-based Alloys by Elevated Hydrogen and Zinc Addition

- Objective: Qualify elevated hydrogen and zinc addition for PWSCC mitigation in Ni-based alloys; Develop technical basis for inspection relief for Ni-based RCS components.
- Work Scope: Conduct PWSCC CGR testing forA600/82/182 (Phase1); Develop design basis for inspection relief (Phase 2).
- Schedule: Phase 1: 2007; Phase 2: 2008
- Status: Significant CGR testing on A600 has been completed; Additional testing including with A182 is underway.

  In addition, PWROG is conducting certain tests to supplement MRP program to show PWSCC mitigation by zinc injection.
- Deliverables: MRP lab testing report in early 2008. Technical basis for inspection relief in 2008.

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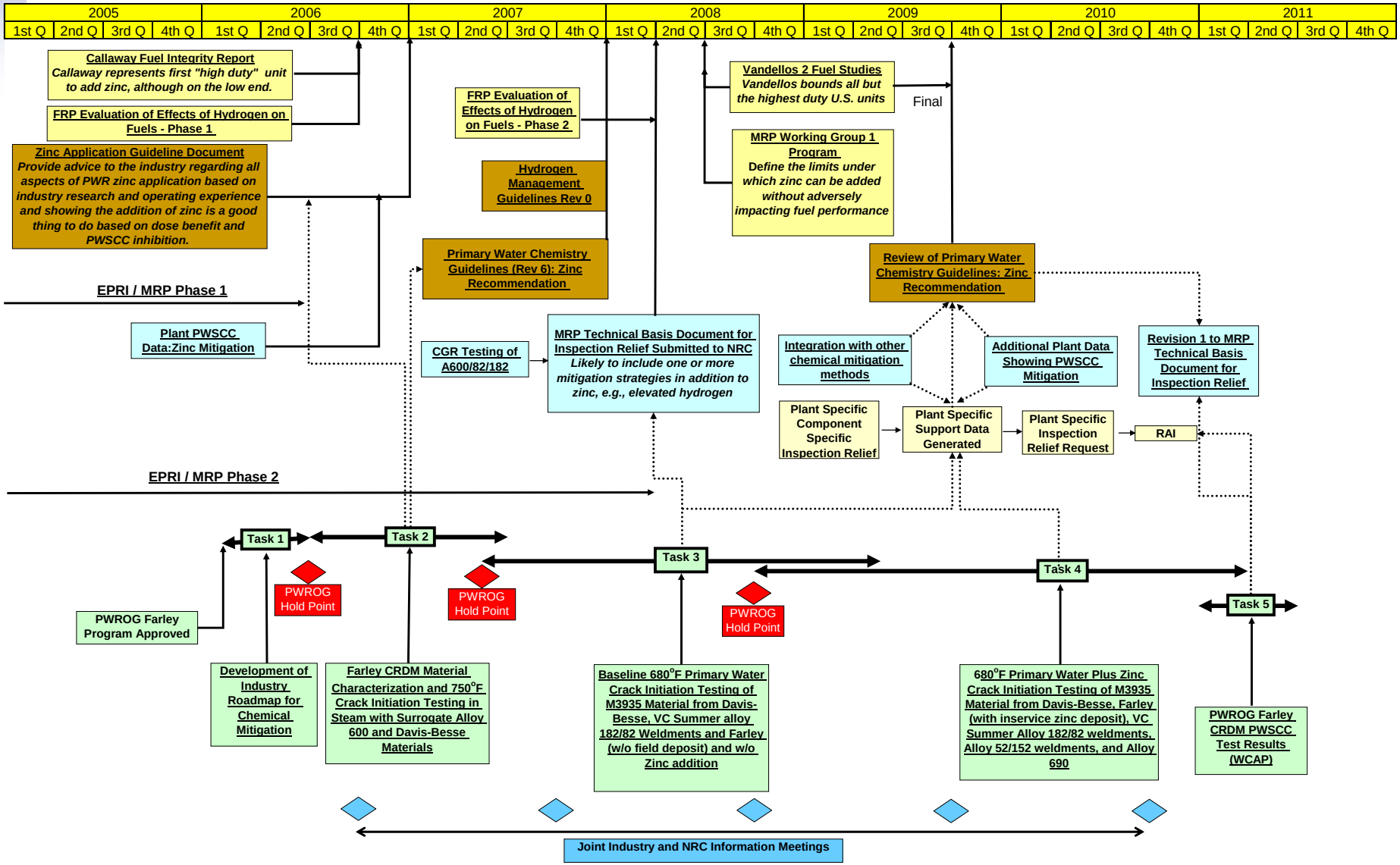
High Level Timeline Showing Industry Activities Associated With Chemical Mitigation



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PWSCC Mitigation by Surface Stress Improvement Technologies

- Objective: Qualify cavitation and fiber laser peening surface treatments for PWSCC mitigation in Ni-based alloys; Develop design basis for inspection relief for Ni-based RCS components.
- Work Scope: Qualify stress improvement with peening technologies (Phase 1- MTAG funded); conduct SCC tests on peened simple samples and BMI mock-ups (Phase 2); plant demonstration (Phase 3); develop design basis for inspection relief (Phase 4)
- Schedule: Phase 1: 2006; Phase 2: 2008; Phase 3 ?,Phase 4: 2008
- Status: Phase 1 completed. Phase 2 testing vendor selected by RFP process and work scope under review. Phase 3 will begin in 2007.
- Deliverables: MRP report on Phase 1 available (MRP-162: 1011806). Reports for Phases 2 and 4 planned for 2008.

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PWSCC Mitigation by Pre-emptive Weld Overlay (PWOL)

- Objective: Qualify PWOL for PWSCC mitigation in Ni-based alloys; Develop design basis for PWOL qualification for RCS components.
- Work Scope: Prepare PWOL pipe samples and measure stresses at ID; conduct stress analysis confirming compressive stresses at ID (Phase 1- MTAG funded); develop NDE methods for field application (Phase 2); plant demonstration (Phase 3).
- Schedule: Phase 1: 2005; Phase 2: 2007; Phase 3: 2008
- Status: Phase 1 qualification completed; topical report submitted to NRC-Received RAIs. Phase 2 NDE methods development initiated.
- Deliverables: MRP report on Phase 1 available (MRP-169: 1012843). Report for Phase 2 planned for 2008.

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RPV Internals Degradation

- Internals Guidelines are under development to support license renewal commitments
- By monitoring the internals, US PWR fleet can avoid costly internals replacement
- MRP will work with CR-3 in 2008 to harvest failed bolt and examine.