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Mitigation Monitoring

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Introduction

- Criteria and guidance for monitoring to ensure IGSCC mitigation have evolved.
- BWRVIP programs continue to monitor the adequacy of OLNC.
- Water chemistry guidance has been updated with Interim Guidance for OLNC.
- Key criteria and guidance for mitigation monitoring are presented.

Topics

- Reactor Coolant Excess Dissolved Hydrogen (DH) and Molar Ratio
- Water Chemistry Criteria for Mitigation
- Interim Guidance for Mitigation Monitoring
- HWC Benchmarking with OLNC
- Secondary Parameters with OLNC
- Catalyst Monitoring around the BWR Circuit with OLNC.
- Summary

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Excess DH and Molar Ratio

Excess DH and Molar Ratio

- Excess DH and hydrogen to total oxidants Molar Ratio are related.
- Measured concentrations of H_2 and O_2 will be lower in the sample than in the reactor coolant because of recombination in sample lines containing noble metal deposits.
- When the in-reactor molar ratio is >2, the relative reduction in O_2 will be greater than for H_2, causing the measured molar ratio to be greater than the molar ratio in the bulk reactor coolant.
- Excess DH is the preferred parameter to monitor because the measured value is equal to the reactor coolant value, unaffected by oxygen depletion in the catalytic sample line.
- Interim Guidance has been implemented with specific requirements for Excess DH to ensure the water chemistry environment is adequate, with margin, to mitigate IGSCC with OLNC.

Total Oxidant, Molar Ratio and Excess DH

- Although the concentration of hydrogen peroxide in reactor water samples is normally below detectable limits, hydrogen peroxide is present in the reactor itself.
  - Hydrogen peroxide decays rapidly at high temperature and it also decays in sample lines
- On a molar basis, hydrogen peroxide requires half as much hydrogen to be reduced to water:

$$O_2 + 2H_2 \rightarrow 2H_2O$$

$$H_2O_2 + H_2 \rightarrow 2H_2O + \frac{1}{2}O_2$$

- The total oxidant (TOX), as O_2 equivalent, accounts for oxygen and hydrogen peroxide:

$$[TOX, ppb\ O_2] = [ppb\ O_2] + 0.47 \times [ppb\ H_2O_2]$$

- Molar Ratio of hydrogen to total oxidant is calculated as:

$$MR = \frac{[H_2, ppb]}{[TOX, ppb\ O_2]} \times 15.87$$

Species	Molar Mass
H_2	2.016
O_2	31.998
H_2O_2	34.014

- Excess dissolved hydrogen is computed as:

$$[Excess\ DH, ppb\ H_2] = [H_2, ppb] - 0.126 \times [TOX, ppb\ O_2]$$

Example of Catalytic Sample Line Effects

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Water Chemistry Criteria for Mitigation

Reactor Water Diagnostic Parameters- Power Operation > 10% Power (*BWRVIP-190 Rev 1*)

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BWRVIP-190 Revision 1: BWR Vessel and Internals Project, BWR Water Chemistry Guidelines—2014 Revision. EPRI, Palo Alto, CA: 2014. 3002002623

Reactor Feedwater Diagnostic Parameters – Power Operation > 10% Power (*BWRVIP-190 Rev 1*)

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Interim Guidance: Feedwater Control Parameters – Power Operation, >10% Power (*BWRVIP-190 Rev 1*)

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Basis for Excess DH Control

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Excess DH and BWRVIA Molar Ratio at Upper Downcomer

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MSLRM Ratio vs. Reactor Water Excess DH

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Interim Guidance for Mitigation Monitoring

BWR Water Chemistry Guidance Classifications

- BWR Water Chemistry Guidelines are classified as described in NEI 03-08 (*Guideline for the Management of Materials Issues*).
- **"Mandatory"** indicates a requirement is important to inhibit intergranular stress corrosion cracking (IGSCC) that the industry believes should not be deviated from by any utility.
  - The only "Mandatory" requirement is that each plant shall have a Strategic Water Chemistry Plan.
- **"Needed"** requirements are those that are considered important to long term operability. These may be deviated from with suitable technical justification, in accordance with *BWRVIP-94* (latest revision).
- **"Good Practice** or **Diagnostic"** guidance is considered in each plant's Strategic Water Chemistry Plan.

Interim Guidance Scope

- Interim Guidance supplements or revises guidance given in *BWRVIP-190 Revision 1.*
- The interim guidance includes:
  - Industry Initiatives: BWRVIP sponsored programs to collect and evaluate data and update BWRVIP documents to support the implementation of OLNC+HWC.
  - Technical Evaluation: **Needed** guidance for plants to have the required mitigation monitoring capabilities under OLNC+HWC.
  - Additional Guidance: **Needed**, **Good Practice** and **Diagnostic** guidance for mitigation monitoring under OLNC+HWC.

Industry Initiatives

- Ongoing program to collect and evaluate results from plants applying OLNC to support presence of catalytic material and activity on plant surfaces, artifacts, and specimens.
- Results include:
  - Brush and scrape results from core shroud and surveillance capsules.
  - Cumulative catalyst mass loading external sampling system specimens.
  - Field Emission Scanning Electron Microscopy on MMS cumulative coupons and artifacts.
- If ongoing and planned work reveals that plant modifications or procedural changes are required *to assure IGSCC mitigation*, **Needed** implementation guidance will be issued by the BWRVIP.
- If ongoing and planned work reveals plant modifications or procedural changes *to optimize OLNC*, **Good Practice** implementation guidance will be issued by the BWRVIP.

Plant Technical Evaluation

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Plant Technical Evaluation

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Additional Interim Guidance

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3.4 Additional Interim Guidance

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Reactor Water Chloride Action Level 1 Value Interim Guidance

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Mitigate cracking of LAS at low chloride concentration

HWC Benchmarking with OLNC

HWC Benchmark Testing with OLNC

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MMS and RRS ECP Responses during HWC Ramp Test

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Secondary Parameters with OLNC

BWRVIP-62-A Table 3-5: Primary and Secondary Parameters

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BWRVIP-62-A Table 3-8: Implementation Steps for Category 3a

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Secondary Parameters with OLNC

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Catalyst Monitoring around the BWR Circuit with OLNC

Mitigation Monitoring with OLNC

- BWRVIP ongoing programs to collect and evaluate data from plants applying OLNC to measure:
  - Presence of catalytic material and catalytic activity on plant surfaces, artifacts, and specimens.
  - Core shroud crack reinspection results.
  - ECP at internal and external locations.
- External sample system: MMS coupons continue to be exposed to multiple OLNC applications, although loading is low compared to reactor vessel structural and artifact surfaces.

Core Shroud/Downcomer Region: OLNC

- BWR5-A and BWR5-B core shroud OD scrapes (mass loading)
- BWR6-C surveillance capsule scrapes (mass loading)
- BWR2-A tie rod latch, Inconel X-750 (mass loading, particle analysis)
- BWR5-C jet pump auxiliary wedge, 316 SS and X-750 (mass loading, particle analysis)
- BWR4-G (first plant to apply OLNC) core shroud crack mitigation results
- Core shroud crack re-inspection results (*BWRVIP-174 R1*)

Reactor Recirculation System: OLNC

- BWR6-A RRS ECP (main and mini-injections)
- BWR2-A RRS ECP (annual OLNC injections)
- BWR5-C RRS ECP (annual OLNC injections)

Lower Plenum: OLNC

- BWR4-B BHDL ECP probe & 304 SS housing artifacts (mass loading, particle analysis)
- BWR4-A BHDL ECP (annual OLNC injections)
- BWR4-B BHDL ECP (annual OLNC injections)
- BWR4-I LPRM Lower Plenum ECP (annual OLNC injections)
- BWR4-J LPRM Lower Plenum ECP (annual OLNC injections)
- BWR2-A CRD stub tube leakage elimination (NMCA, OLNC)

Core Shroud ID: OLNC

- BWR4-G SCDM specimens (mass loading, Pt detection)
- BWR6-D dry tubes (mass loading)
- BWR6-A dry tubes (mass loading as expected, particle analysis)
- BWR4-A fuel channel fasteners inner core bypass exposure (mass loading, particle analysis)

OLNC Exposure: Total Pt Deposition (μg/cm^2)

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Summary

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- Results of catalyst monitoring around the BWR circuit show the presence of catalyst and catalytic activity with OLNC.
- BWRVIP programs continue to monitor OLNC effectiveness by collecting results on the presence of catalyst and the mitigation of cracks.

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