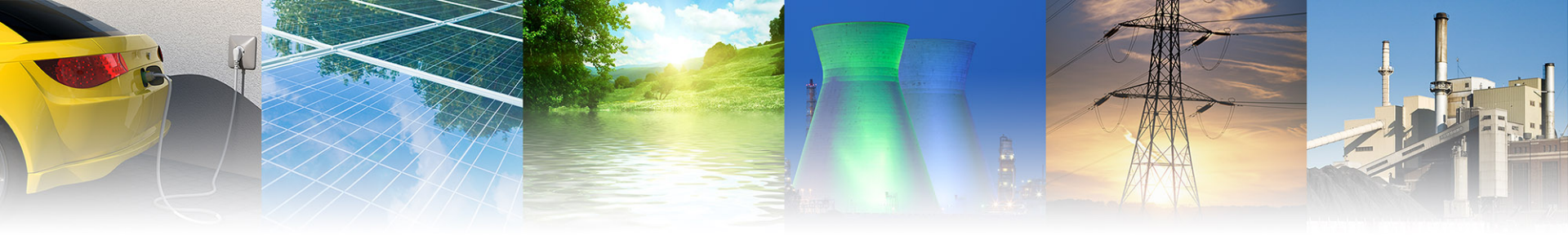

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EPRI BWR/PWR Water Chemistry Guidelines Update and Impact on RP

Daniel M. Wells, PhD – EPRI
Project Manager

2012 International ISOE ALARA Symposium
Ft. Lauderdale, FL, USA

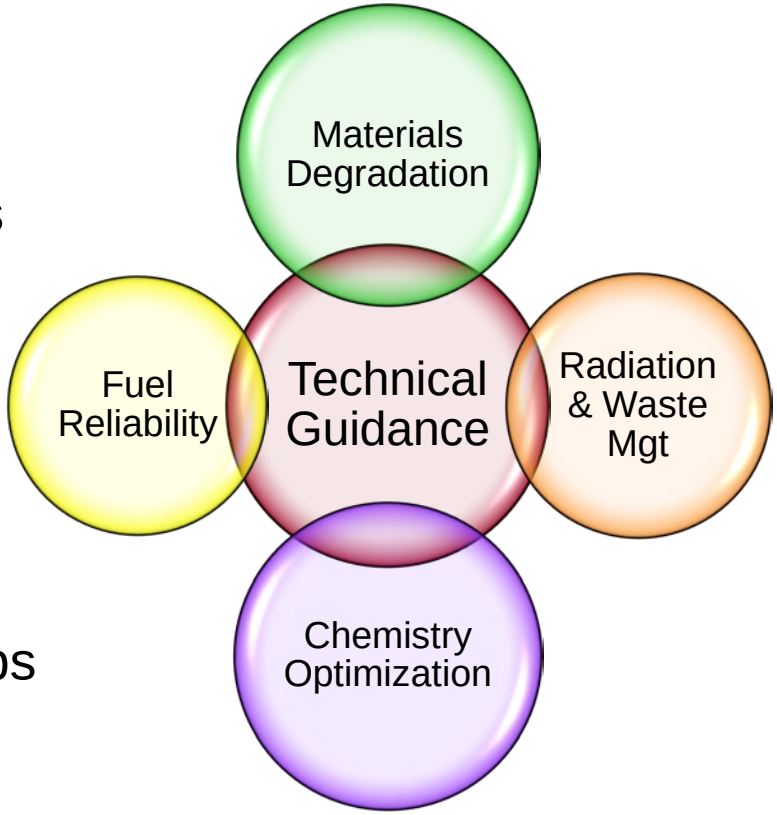
January 11, 2012

Overview

- EPRI Chemistry Program Introduction
- PWR Primary Water Chemistry Guidelines Revision 7
- BWR Water Chemistry Guidelines Revision, 2013
- EPRI Source Term Related Projects

EPRI Chemistry Program Roles

- Industry Strategic & Planning Roles
  - Lead cross-functional collaboration (internal and external)
  - Technical basis for regulatory change
- Industry Technology Development Role
  - Innovative R&D
  - Technology demonstrations/evaluations
- Leadership for Technical Guidance
  - Guidelines/guides and desk references
  - Application sourcebooks/decision trees
  - Benchmarking
- Unique Tech Transfer/Application Role
  - Software/application tools
  - Communications/conferences/workshops
  - Onsite presence/assessments
  - Users groups



EPRI Chemistry Program Newsletter –EPRI Document 1023604
Updated Bi-annually

EPRI Water Chemistry Guidelines
Background

- Review Required per BWRVIP and SGMP
  - Supporting NEI 97-06 and NEI 03-08
  - Review starting two years after a published revision, and then each year until next revision started
- Review Addresses:
  - Do the identified issues necessitate a GL revision starting in the next year?
  - Does any particular issue require development of interim guidance?
- Applicable to all plant designs

EPRI Water Chemistry Guidelines
Review Scope

- Review process addresses:
  - Industry Operating Experience
  - Technical work from EPRI Programs
  - Industry Comments
  - Input from NSSS and Owner's Groups
  - Active Interim Guidance
  - Active Deviations
  - Active Inquiries / Review Board Interpretations
  - Relevant SGMP/BWRVIP Information Letters

PWR Primary Water Chemistry Guidelines

Key Contact: Joel McElrath
jmcelrath@epri.com, 1-650-714-4557

PWR Primary Water Chemistry Guidelines 2011 Review Meeting

- Revision 6 issued December 2007
- Most recent Review meeting held on June 15, 2011
  - 55 Attendees
  - 25 Utilities, 11 countries
  - EPRI, EPRI consultants
  - BWC, Westinghouse, PWROG
- Results
  - There is a need to begin a revision starting in 2012
  - No additional interim guidance is needed at this time – considering that the revision is starting in 2012
- 2011 Deliverable
  - EPRI Technical Update (1022827, Dec. 2011)

PWR Primary Water Chemistry Guidelines Revision Needed

- Incorporation of research results related to Chemistry, Fuels, Materials and Radiation Management
- Incorporation of additional plant operating experience
- Coordination with other EPRI Guidelines, specifically the PWR Fuel Cladding Corrosion and Crud Guidelines (revision starting in 2012)
- Two interim guidance documents and a standing SGMP Review Board interpretation need to be incorporated.

PWR Primary Water Chemistry Guidelines

Revision 7 Committee

Preparation:

- **Oct 18, 2011: Notification to Industry**
- **Dec 01, 2011: Deadline for Identification of Voting, Attending and TRT Members**
- **Jan 31, 2012: Deadline for additional Technical issues**

Revision Committee Meetings:

- **March 27-29, 2012 (Crystal River 3)**
- **June 2012 (Europe)**
- **September 2012 (TBD, USA)**
- **March 2013 (TBD, USA)**

Point of Contact:

- Joel McElrath (650-714-4557)
- jmcelrath@epri.com

BWR Water Chemistry Guidelines

Key Contact: Susan Garcia
sgarcia@epri.com, 1-650-855-2239

BWR Water Chemistry Guidelines
Revision Needed

- Incorporation of research results related to Chemistry, Fuels, Materials and Radiation Management
- Incorporation of additional plant operating experience
  - On-Line Noble Metal (OLNC)
  - TiO_2 Experience
- Need for additional guidance identified
  - Sampling and monitoring
- Two interim guidance documents Issued
  - BWRVIP letter 2010-255
  - BWRVIP letter 2011-097

BWR Water Chemistry Guidelines
Review Committee

- EPRI Staff (Materials, Fuel, Chemistry, Radiation Management)
- Utility Staff – domestic and international (same groups as EPRI)
- INPO (non-voting participation)
- NSSS Vendors (GE-H, Toshiba, Hitachi)
- Fuel Vendors (GNF, AREVA, Westinghouse)
- Technical Experts & Consultants

BWR Water Chemistry Guidelines
2013 Revision

Preparation:

- **December 12, 2011: Notification to Industry**

Kickoff Webcast:

- **February/March 2012**
- **October/November 2012**
- **March 2013**

Revision Committee Meetings:

- **May 21-23, 2012 – Zurich, Switzerland**
- **June 12, 2012 – Santa Fe, New Mexico**
- **Dec. 4, 2012 – Naples, Florida**
- **June 2013 (TBD, USA)**

Point of Contact:

Susan Garcia (650-855-2239)

sgarcia@epri.com

Source Term Related Projects

Key Contact: Dan Wells
dwells@epri.com, 1-650-855-8630

Chemical Strategy for Reducing Radiation Fields
R&D Plan

Corrosion and Release	• Chemistry and Releases • Zinc injection • Interaction of Chemistry and Surface Modification • Hydrogen and ECP
Corrosion Product Transport	• Advanced resin/media development • Primary Side Resin Testing • Primary Side Cleanup Optimization • Startup and Shutdown Sourcebooks
In-Core Deposition, Activation, and Release	• Extended Activity Releases • Optimized Fuel Crud Characteristics • Crud Modeling • Fuel Cleaning
Out-of-Core Deposition and Incorporation	• Chemical Injections on Dose Rates • Decontamination/Flushing • Particulate Transport • Activity Transport and Gamma Scanning

Recent EPRI Source Term Related Projects

- **Cobalt Reduction Sourcebook (2010, 1021103)**
  - Provides generalized valuation strategies in tables and flowcharts.
  - Focuses on cross-discipline cobalt reduction program.
- **PWR Activity Transport and Source Term Assessment: Surface Activity Concentrations by Gamma Scanning (2011, 1023027)**
  - Compiles available gamma scan campaign data from PWRs.
  - Quantitatively evaluates the effect of zinc on Co-58 release and out-of-core incorporation rates.
- **PWR Standard Radiation Monitoring Program Summary (2011, 1023020)**
  - Provides updated plant benchmarking comparison for the most recent, available cycle radiation field data collected in the program.
- **Extended Releases during PWR Shutdowns (2011, 1023026)**
  - Suggest fuel crud deposit thickness is related to instances of extended releases.

PWR Activity Transport and Source Term Assessment (2011, 1023027)

Collect and evaluate surface activity data from PWR primary system components and improve understanding of the impact of source term reduction technologies on activity transport and radiation field generation.

Objective:

- Collect available PWR gamma spectroscopic data
- Collate data and compare to standard dose rates using plant operating life (EFPY), isotope half-lives, chemistry, and core design information

Description:

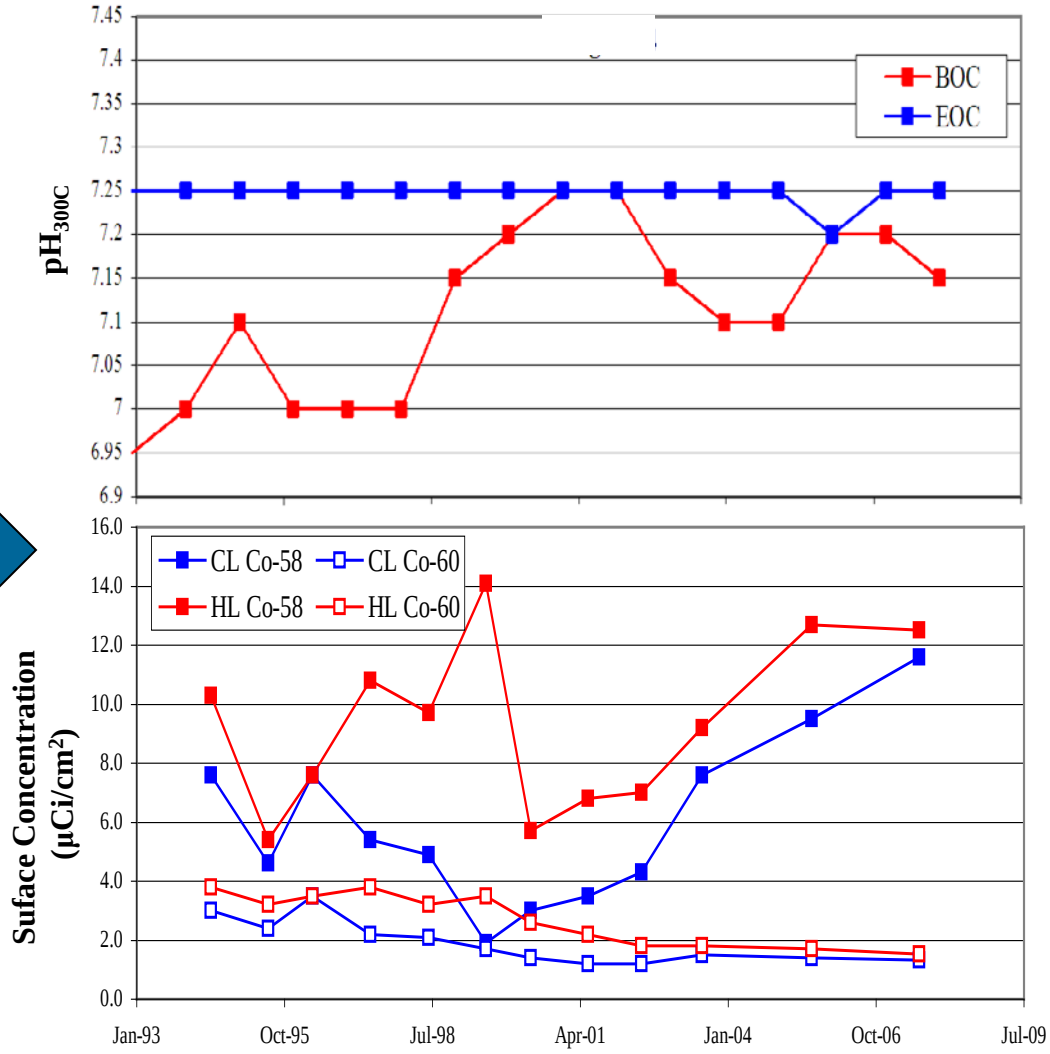
- Evaluate available PWR gamma spectroscopic data for availability and application in the plant
- Identify technical gaps in understanding of corrosion product generation and future research needs

Benefits:

- Establish applicability of isotopic radiation field information to source term reduction efforts
- Improve understanding of activity transport in the PWR primary system

PWR Surface Activity Concentration Data
General Results (1023027)

- Available PWR gamma spectroscopic data
  - 22 cycle, 6 collection methodologies
- Trends incredibly complex
  - Concentrations significantly impacted by minimal operating chemistry changes
- Co-58 and Co-60 are major isotopes
  - Generally Co-58 > Co-60
  - Co-60 major contributor to dose due to high energy gammas



Quantitative Activity Transport Balance
Activity Balance Using Gamma Scanning Data

- **Balance of radioisotopic elements developed**

Net release rate from fuel = Net incorporation rates into Stainless Steel and Inconel + Decay in coolant + Letdown removal

- **At steady state equilibrium, net incorporation rate into surface oxides equals decay rate in oxides**

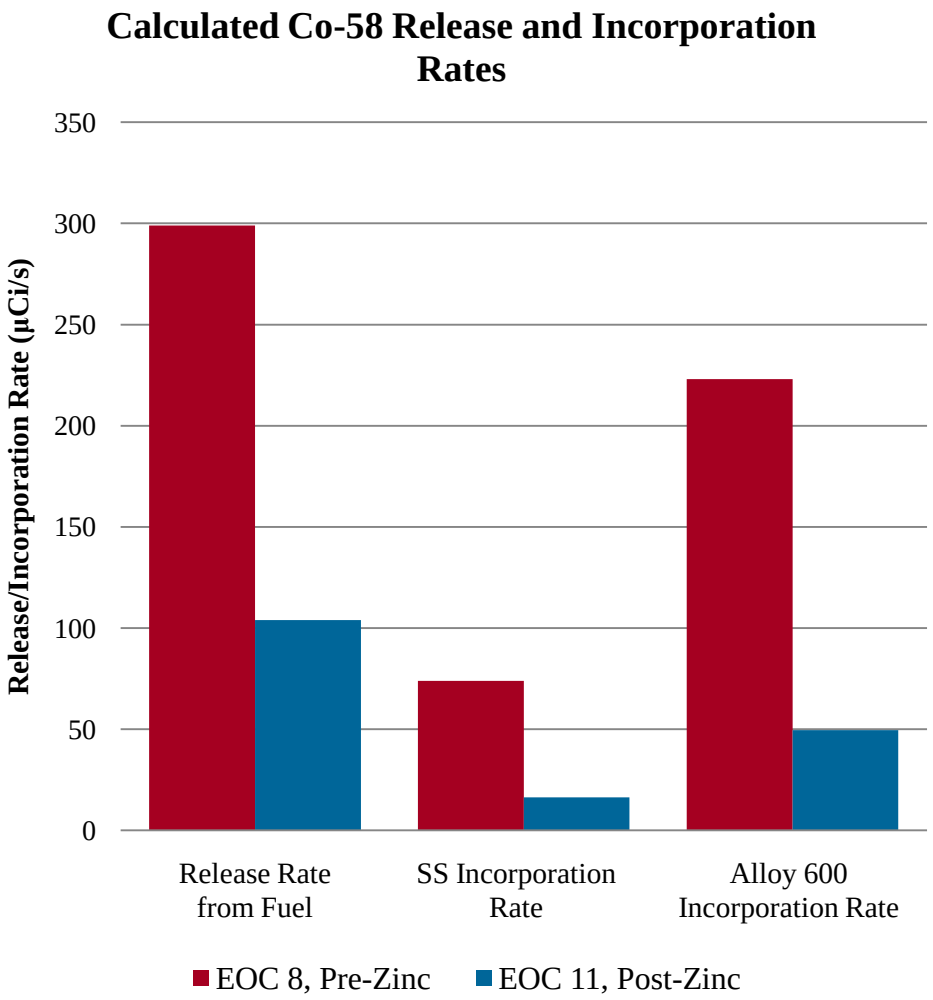
$$kAC = \lambda AC$$

- **Application to Co-58 with piping and tubing surface specific activity data (μCi/cm²) from gamma scans**

Pressurized Water Reactor Activity Transport and Source Term Assessment: Surface Activity Concentrations by Gamma Scanning. EPRI Palo Alto, CA: 2011. 1023027.

Effect of Zinc on Co-58 Transport
Release and Incorporation Rates

- Piping surface incorporation rate constant decreased ~100x
- 35% decrease in core release rate
  - Decrease also observed at BWRs
- 2012 application to BWR coupon samples and other chemistry changes



Pressurized Water Reactor Activity Transport and Source Term Assessment: Surface Activity Concentrations by Gamma Scanning. EPRI Palo Alto, CA: 2011. 1023027.

Optimization of Fuel Crud Characteristics for Reducing Radiation Fields (NEW PROJECT)

Provide utility members with clear guidance on fuel crud properties that can be targeted by chemistry control and fuel and core design parameters for reducing activated corrosion product and radiation field generation.

Objective:

- Improve understanding of interacting chemistry, fuel, and core design on source term generation and radiation field generation.

Description:

- Establish properties bands for optimized fuel crud that effect residence times for and activation of corrosion products
- Evaluate parameters of fuel and core design that could result in desirable radiation management performance

Benefits:

- Provide a route to effecting core residence time and generation of activated corrosion products
- Incorporate radiation field reduction drivers into core/plant optimization activities

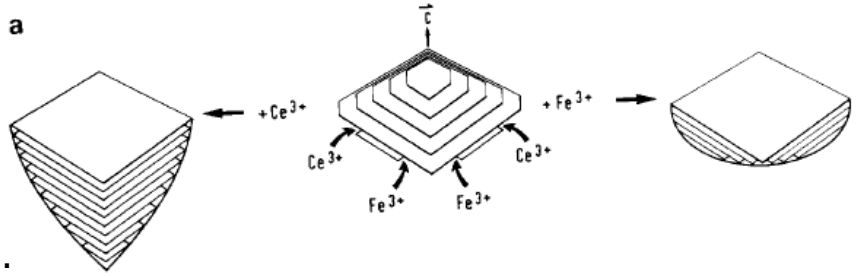
Reducing Source Term Residence Times
Background and Motivation

- Deposited activity on out-of-core surfaces results from activation in the core

  $^{59}Co(n,\gamma)^{60}Co$ produced by thermal neutrons

  $^{58}Ni(n,p)^{58}Co$ produced by fast neutrons

- Neutron cross-sections of Ni and Co require deposition and increased residence times (beyond time in water)
  - Consider all physical, mechanical, chemical properties of crud that effect residence times
  - Leverage previous work on crystal habit modification*



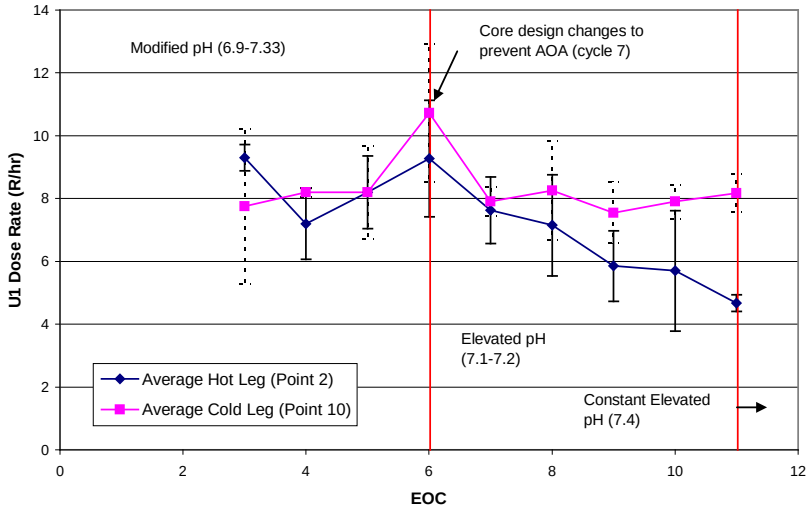
*EPRI Palo Alto, CA: Reports1016243 and 1021649.

Reduction of Parent Nuclide Activation
Background and Motivation

- Cladding surface characteristics effect deposition and release
- Thermal neutron flux (Co-60 activation) and water channel geometry
- Zoning to minimize local high boiling/temperature
  - Burnable absorbers and radial enrichment zoning
  - Flow zoning—higher power assemblies have increased flow
- Grid design can effect mixing, heat transfer, and pressure drop
- Rod geometry – diameter and length
- Fuel Cycle Length

Chemical, Fuel, Core Design Control Evaluation
Phase I Task

- Establish properties bands for optimized fuel crud that impact residence times for and activation of corrosion products
  - *What stays in the coolant or on the fuel does not cause worker dose*
- Evaluate parameters of fuel and core design that could result in desirable radiation management performance
  - Prioritize control parameters for cost, ease of implementation, and effectiveness



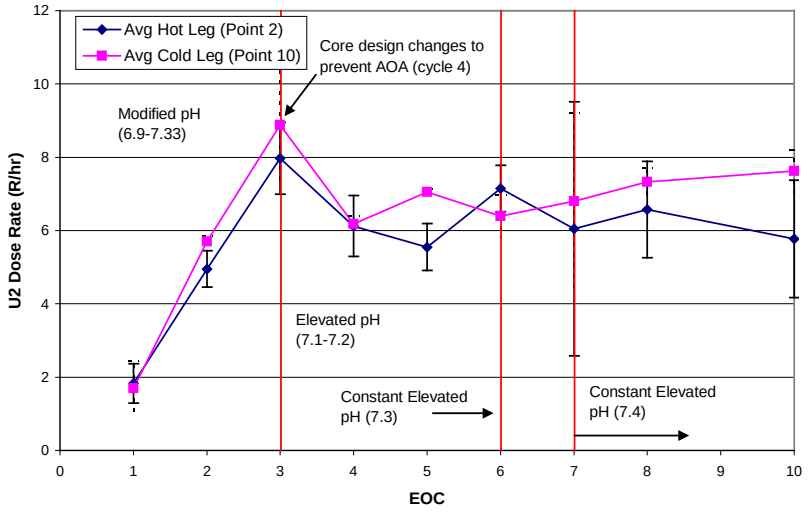


Figure from *Plant Specific Recommendations for PWR Radiation Source Term Reduction*, EPRI, Palo Alto, CA: 2009. 1019225.

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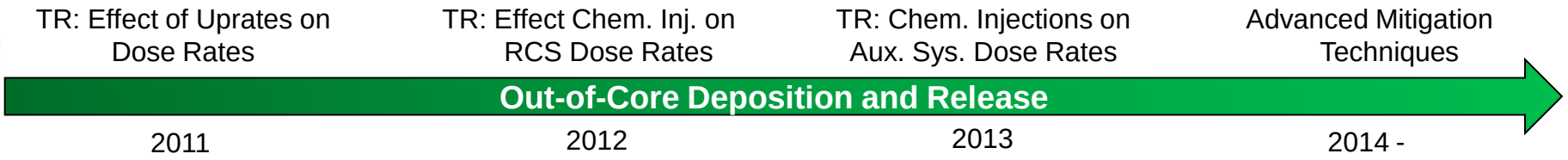
Impact of Chemical Injection on Dose Rates

New 2012-2013 Project



Provide a parameter to evaluate the effect of chemistry on dose rates and improved understanding of reactor water radiocobalt concentration's effect on radiation field generation.

Objective:

- Improve the understanding of the interaction of chemical regime and RCS radiocobalt concentration on shutdown dose rates in PWRs and BWRs.

Description:

- Evaluate the effect of BWR OLNC application and PWR chemistry regimes on radiocobalt RCS concentrations and shutdown dose rates
- Develop correlation for standard RCS dose rates and extend to auxiliary system dose rates

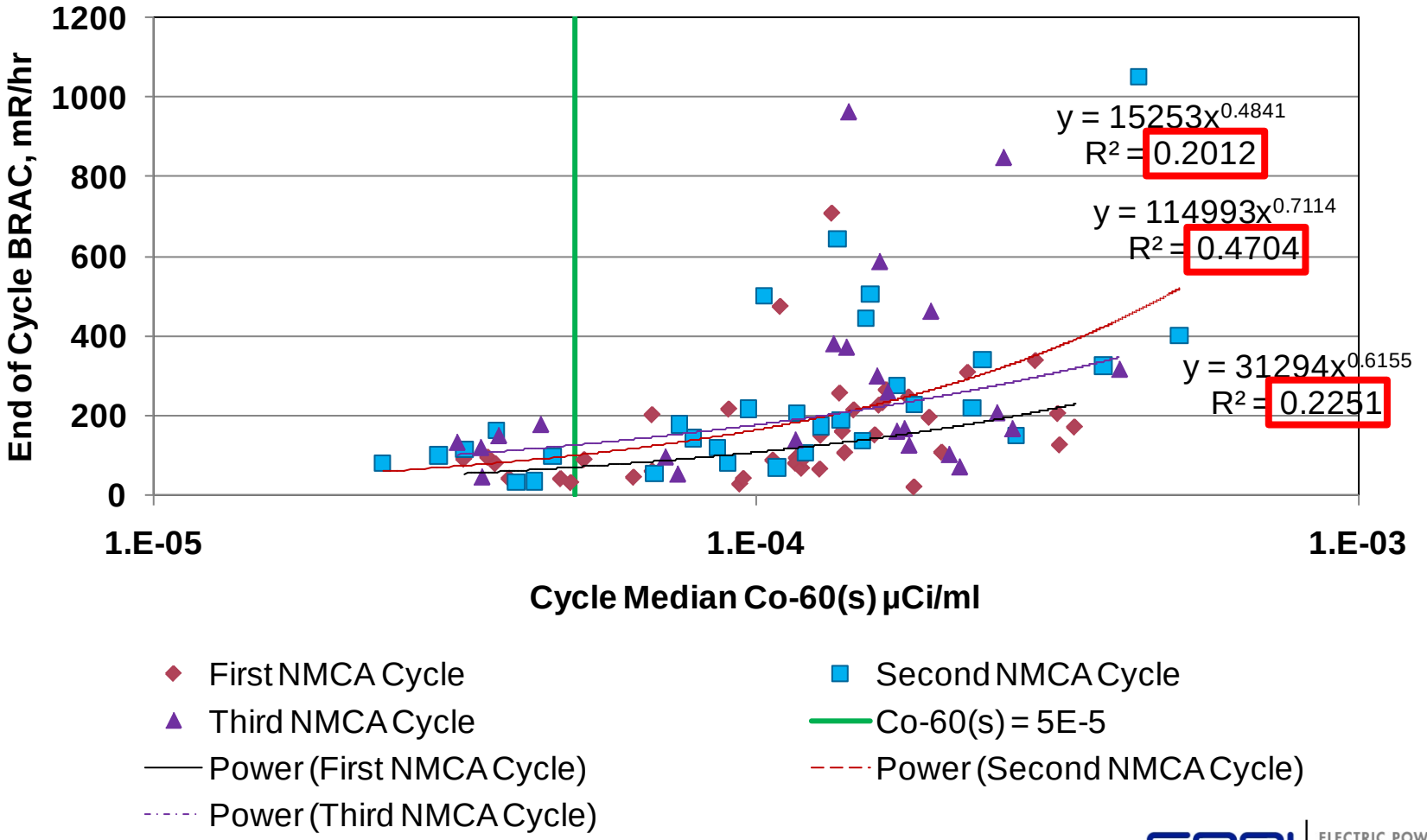
Benefits:

- Improve accuracy of shutdown dose rate estimations to support ALARA dose planning
- Provide valuable input to utility Strategic Water Chemistry and outage plans

Impact of Chemical Injection on Dose Rates

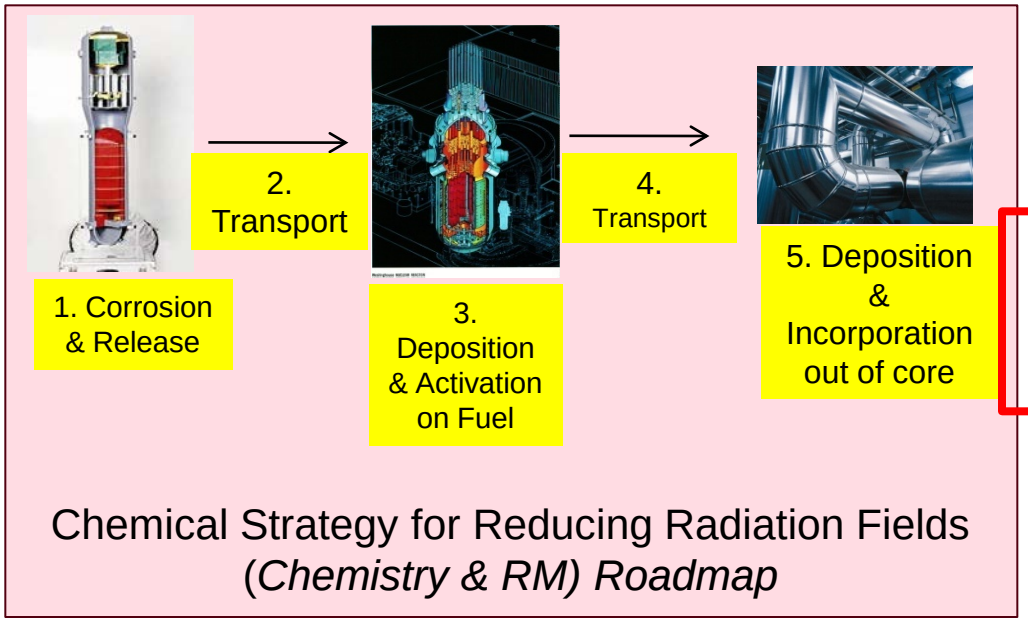
Background and Motivation

BRAC vs. Soluble Co-60 by Application Cycle

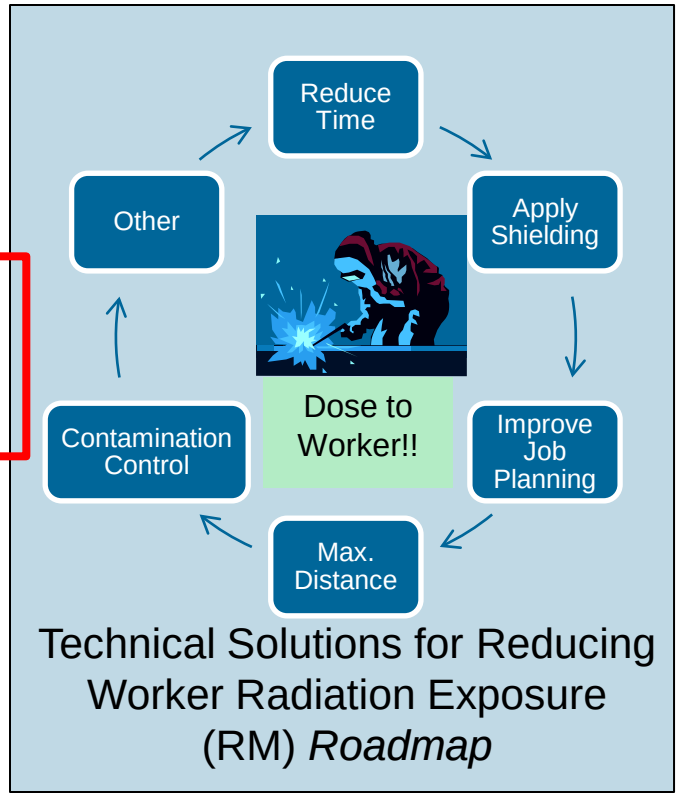


Predictive Tool for Radiation Fields
New Project Initiative

- Issue: Effectively manage worker dose to meet new industry goals
- **Identified Gap**: Ability to predict location, magnitude, and composition/isotopics, of radiation fields during both normal and off-normal operations



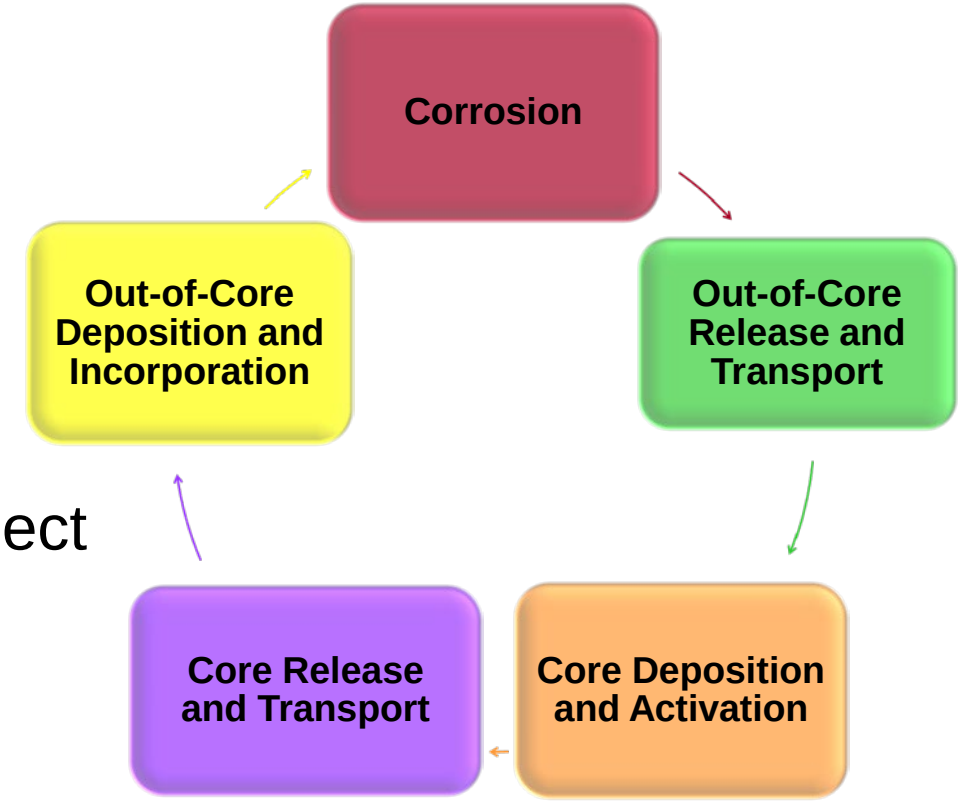
Chemical Strategy for Reducing Radiation Fields (*Chemistry & RM) Roadmap*



Technical Solutions for Reducing Worker Radiation Exposure (RM) *Roadmap*

Predictive Tool for Radiation Fields
Initial Project Tasks

- ID & incentivize stakeholders
- Evaluate available tools:
  - Understand what is calculated
  - Physical models
  - Input requirements
  - Outputs
  - Restrictions/limitations
- Identify how the pieces connect
- Analyze Gaps
  - Information requirements
  - Modeling requirements
- Define the tool to be developed



EPRI Water Chemistry Program Summary

- Water chemistry optimization (defined in guidance documents) supports crack mitigation, maintenance of fuel cladding integrity, and radiation field management objectives
  - Both BWR and PWR Primary Guidelines will begin revision in 2012
- Efforts are continuing in order to improve technical understanding of radiation field generation
  - These efforts are collaborative across the institute
  - Ultimate goal to effectively manage worker dose
- Plant data, *reliably and accurately collected* , remains the best source of information

Together…Shaping the Future of Electricity