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Chemistry, Radiation Management and Low Level Waste Program

EPRI Cobalt Sequestration Technology

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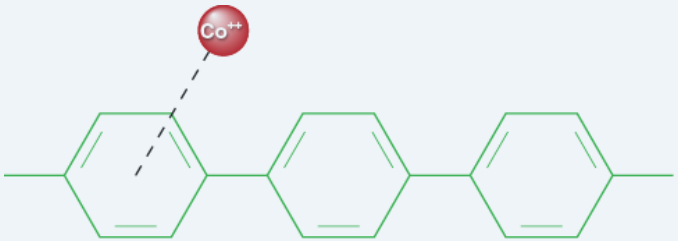
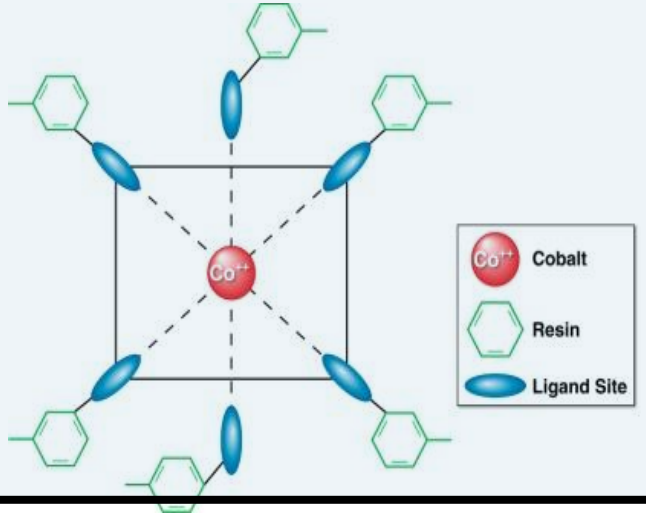
How it Works – Ion Exchange vs. Sequestration

ION EXCHANGE



- Ionic species are loosely “bonded”
- Easily replaced by other species

SEQUESTRATION



- Sequestration “captures” the species
- Species is irreversibly trapped under plant water conditions
- Species can be removed later via specific chemical processes if desired

Cobalt Sequestration
Research Objectives & Industry Value

Objectives

- **Reduce cobalt** concentration in nuclear plant water streams.
  - The current ion exchange resins are limited.
    - Exhausted by high concentrations of impurities
    - Competition limits cobalt uptake.
- The EPRI resin (CoSeq™) **captures cobalt preferentially** over other species and **irreversibly holds** the cobalt within the ligand structure.

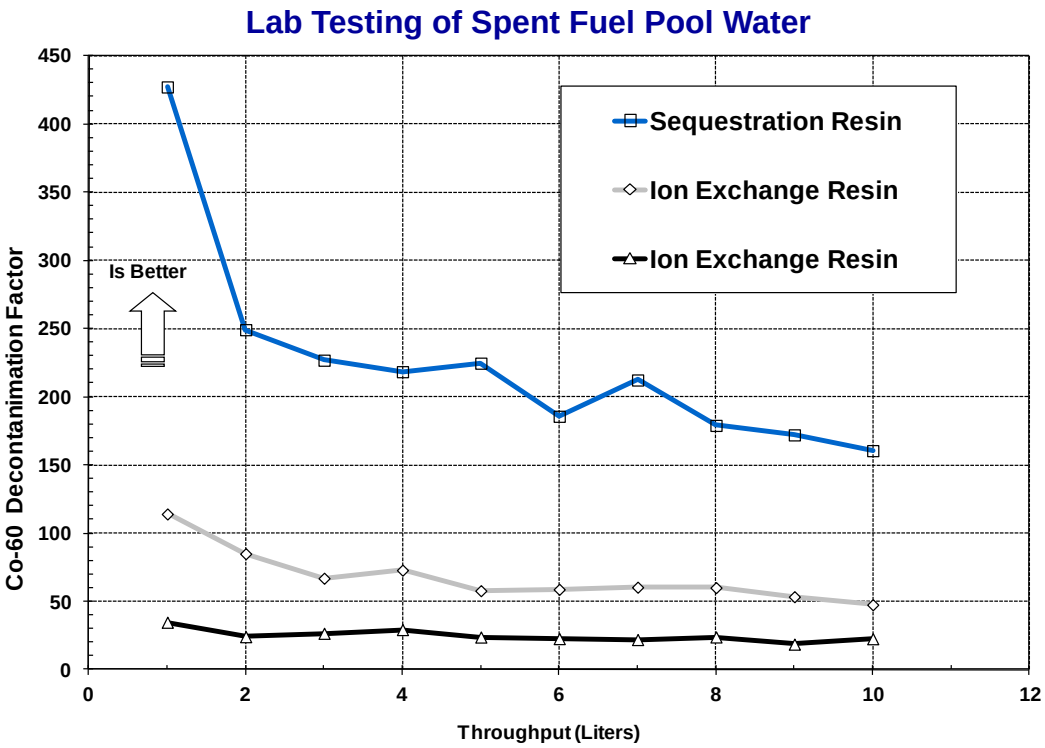
Value

- Reduced activity levels during both plant operation and shutdown.
- Higher efficiency could reduce outage cleanup time before outage activities can commence.
- Reduction in outage time can save a plant power replacement costs.
- Worker exposure reduction supports utility ALARA goals.
- Reduced effluents and better waste class control can reduce radwaste cost.

Cobalt Sequestration Resins for BWRs

Status

- Reactor water and fuel pool water tested
- Kilogram synthesis successful (powdered)
- Flocculation and scaled-up studies complete
- Demonstrations underway



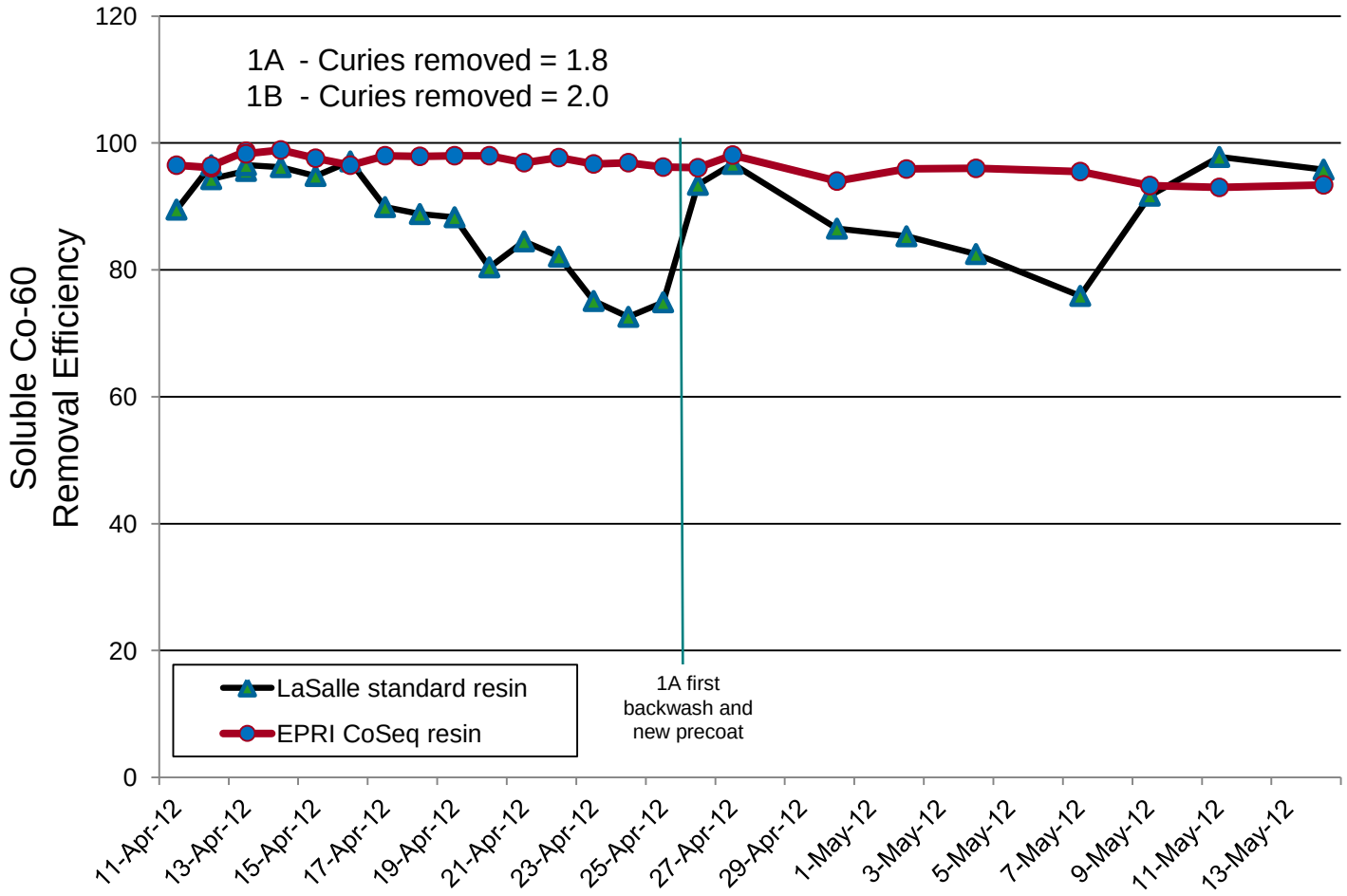
Backwash of Resin in Scale-up Test Skid

2012 Technical Scope & Tasks

- **Task 1: Large Scale Powdered Resin Synthesis** Work with a specialty chemical company to generate enough CoSeq™ powdered resins for plant-scale testing (kilogram quantities).
- **Task 2: Plant Demonstration Support – BWR** Perform necessary safety evaluations for plant demonstrations. Plant test plans/procedures.
- **Task 3 (ongoing): BWR Plant Operation Demonstration** Perform head-to-head demonstration in a BWR reactor water cleanup system during normal plant operation. Collect, analyze and report data.
- **Task 4 (ongoing) BWR Plant Shutdown Demonstration s** Perform demonstrations in BWR reactor water cleanup systems during plant shutdown when activity levels peak. Collect, analyze and report data.
- **Task 5: Submersible Filter/Demin Evaluation** Evaluate the use of resins in submersible systems to be used during plant outages to reduce activity levels.

EPRI Resin Loading into LaSalle Reactor Water Cleanup System for Demonstration Tests - April 2012

Preliminary Results of EPRI's CoSeq™ Resin Demonstration in LaSalle-1 RWCU System



1B continuous run with CoSeq™

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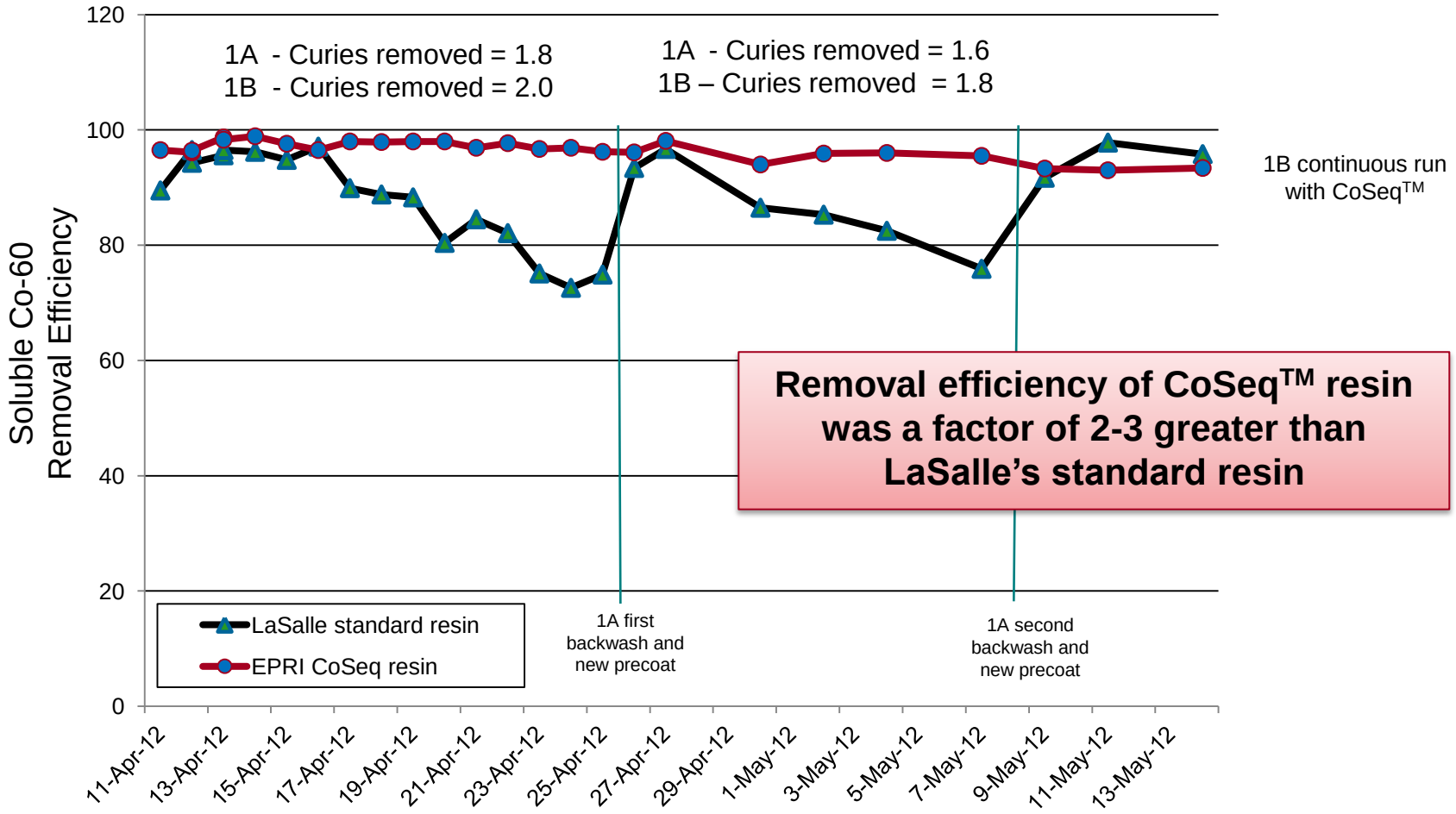
Preliminary Results of EPRI's CoSeq™ Resin Demonstration in LaSalle-1 RWCU System



Removal efficiency of CoSeq™ resin was a factor of 2-3 greater than LaSalle's standard resin

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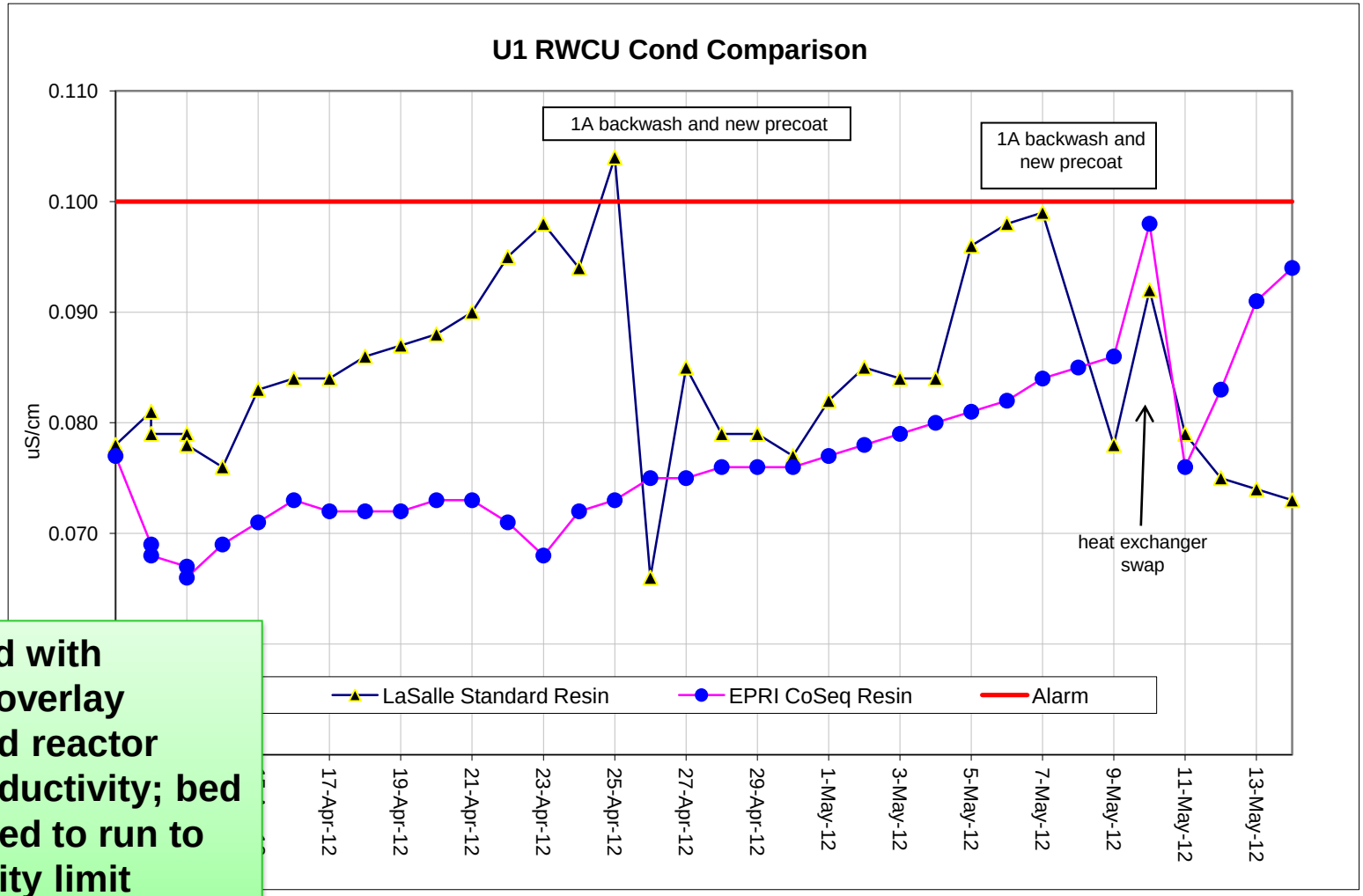
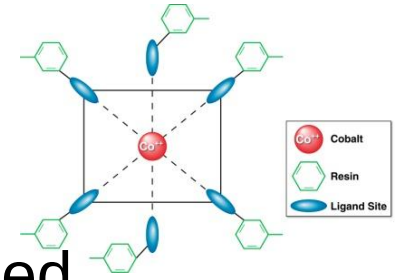
Preliminary Results of EPRI's CoSeq™ Resin Demonstration in BWR RWCU System



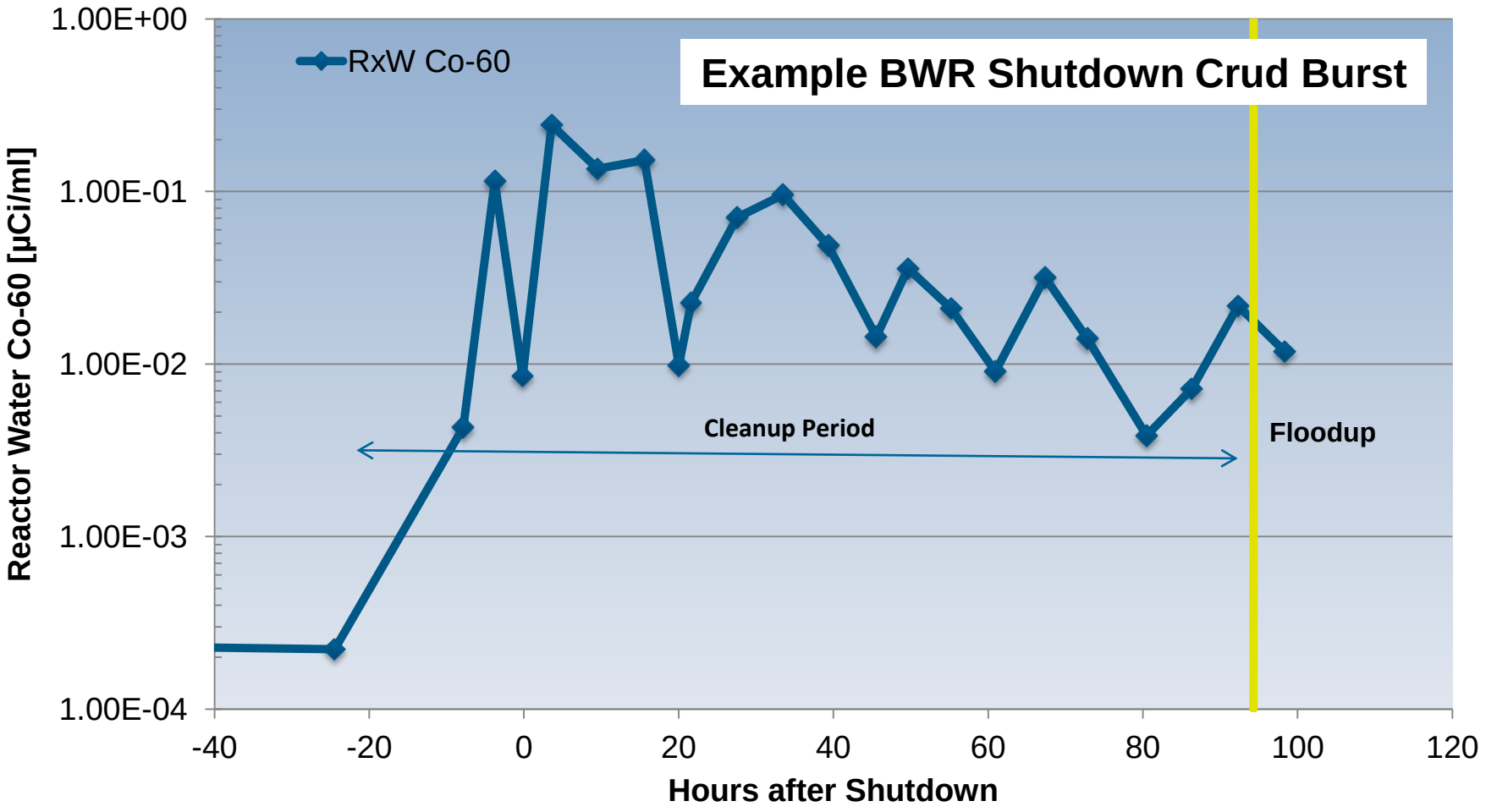
- **RWCU bed with CoSeq™ overlay maintained reactor water conductivity; bed was allowed to run to conductivity limit**

Key Results to Date & Next Steps



- CoSeq™ removal efficiency performance confirmed
- No negative impacts on plant water or operations
- Operating test results are being analyzed
- Similar testing protocol planned for PWRs and radwaste systems in 2013
- Head-to head testing at LaSalle 1 during OLNC – data being analyzed
- Shutdown demonstrations planed for multiple BWRs
  - Head-to-head testing with the plant's standard resin (Peach Bottom 2) – very good results
  - Head-to-head testing and/or full system testing (both beads overlayed with CoSeq™), 2013

BWR Shutdown Co-60 Cleanup Timeline Example



2012-2013 Technical Scope & Tasks (Bead Form)

- **Task 1: Large Scale Bead Resin Synthesis**
  Work with a specialty chemical company to generate enough CoSeq™ bead resin for plant-scale testing (gram-kg quantities of bead resin).
- **Task 2: Plant Demonstration Support**
  Perform necessary safety evaluations for plant demonstrations. Develop plant test plans and procedures.
- **Task 3: Radwaste Demonstration**
  Perform demonstration in a radwaste treatment system or mock-up system using plant water. Collect, analyze and report data.
- **Task 4: PWR Demonstration**
  Perform PWR demonstration. Collect, analyze and report data.
- **Task 5: Submersible Filter/Demin**
  Use of resins in submersible systems during plant outages to reduce activity levels.

Bead-type resins for PWR and Radwaste Applications

Next - Radwaste use of CoSeq™

- Two sets of tests underway
- **Seabrook**
  - 4 column testing of various resins
  - Optimization of bead-type CoSeq™
- **KHNP** (South Korea)
  - Also 4 column testing
  - Evaluation of colloidal cobalt removal
  - Evaluation of multiple waste streams

KHNP

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Next – CoSeq™ in Submersible Filters or Demins

- Commercially available equipment (multiple vendors)
- CoSeq™ could be used as bead resin material, possibly overlay
- CoSeq™ could be embedded in filters, possibly cation & anion mix
- Could be tailored for plant-specific needs
  - Cavity cleanup
  - Fuel pool
- Plant demonstrations should help quantify the value and use of submersible units

From Cobalt to Other Elements

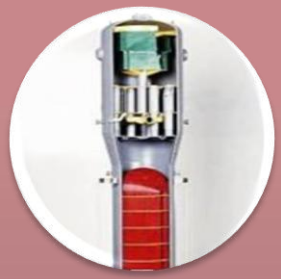
Cobalt Sequestration → Element Specific Media

RadWaste

- Processing and Disposal
- Volume Reduction
- Recycle waste for Source Production
- Example: ^{90}Sr (Fukushima) and $^{63}Ni/^{55}Fe$

Reactor Coolant

- Shutdown/Normal Operation and Local Purification
- Outage Dose Rates
- Example: $^{124/125}Sb$ and Improvements to CoSeq™ - ^{60}Co and ^{58}Co



Other Systems

- PWR Secondary (SCC)
- Fossil Generation
- Examples: Lead (Pb) and Arsenic

Cobalt Sequestration Summary

- Significant progress made to date
- Patent-pending technology
- Completion for CoSeq™ efforts in 2013 with licensing of vendors
- Investigating expansion to other nuclides
- Utility participation through demonstration programs is **valuable and appreciated**

Together…Shaping the Future of Electricity