

Cobalt Sequestration

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Manager**

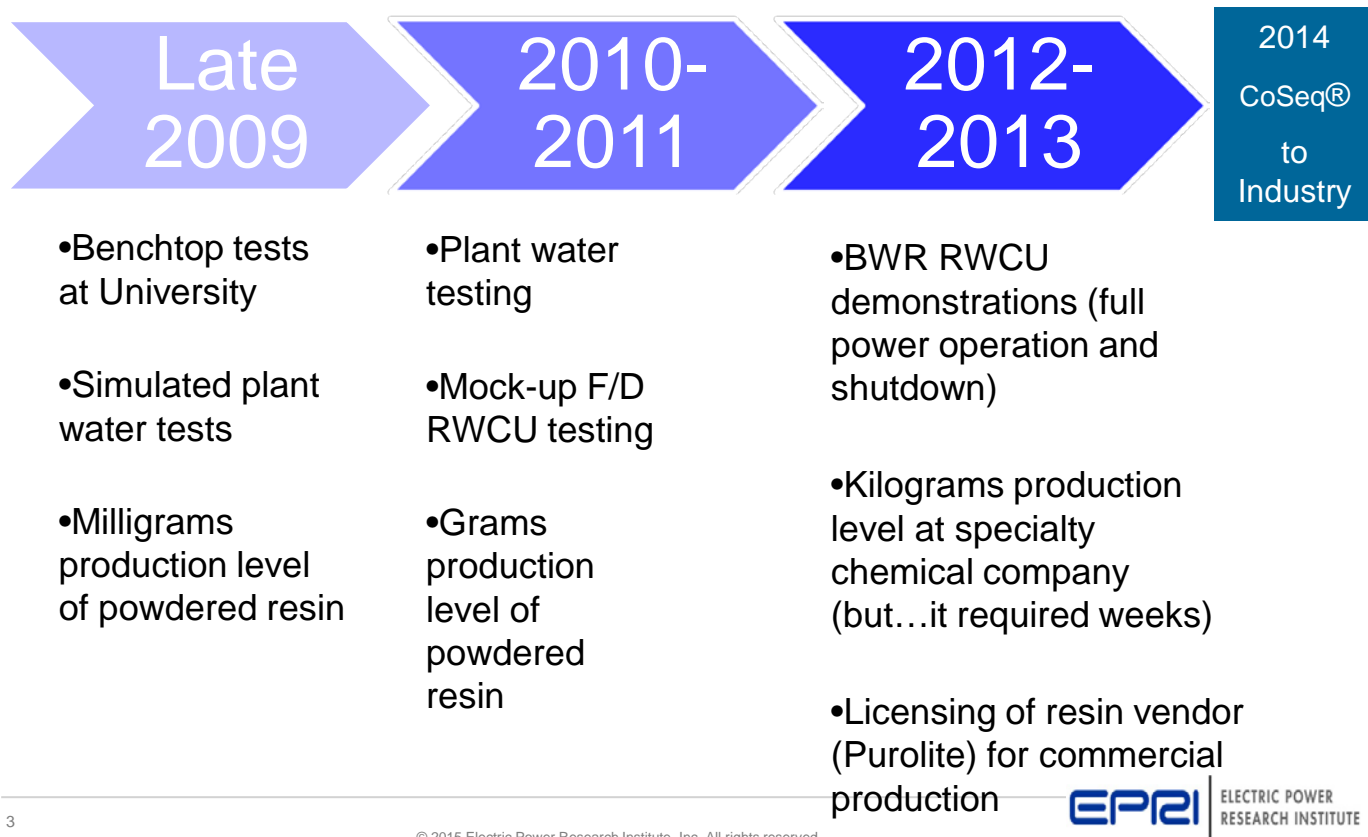
**2015 ISOE International
Symposium
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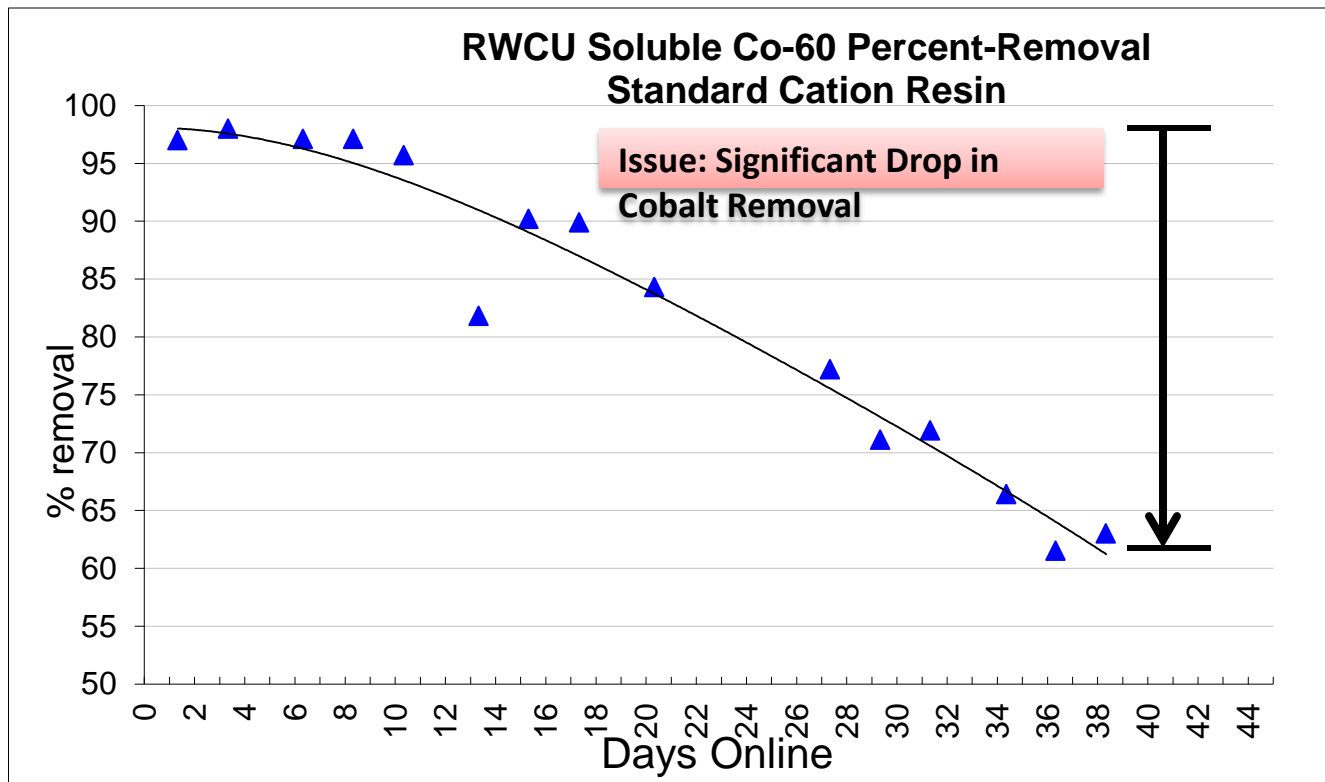
Introduction

- EPRI's new media, **CoSeq®**, has been shown in laboratory and plant testing to have a very high potential for selectively sequestering elemental and radioactive cobalt ions.
- **CoSeq®** is intended for use in full scale operation as an overlay with typical powdered ion exchange media.
- Several full scale BWR demonstrations have been conducted during shutdown and full power operation.
- **CoSeq®** was applied during these demonstrations as an overlay with a standard resin underlay in one RWCU F/D vessel while a control vessel operating in parallel was precoated with standard ion exchange resins.

Cobalt Sequestration – CoSeq®



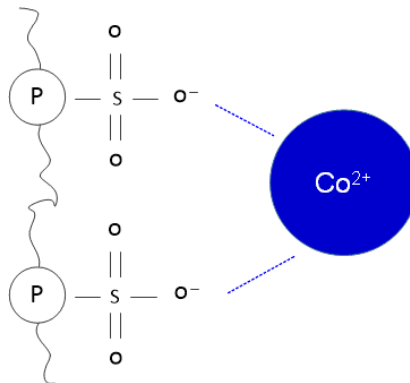
Typical BWR Reactor Water Cleanup Operation



Challenge and Current Technology

- Challenge for nuclear power plants to remove very low levels of an ion [ppt] from an aqueous solution containing competing ions of similar charge but at higher concentrations [ppb].
- Limitations of ion exchange process:
 - Ability to obtain an ionic bond.
 - Relative selectivity of exchange media.
 - Phase equilibrium limitations of mass action driving force.

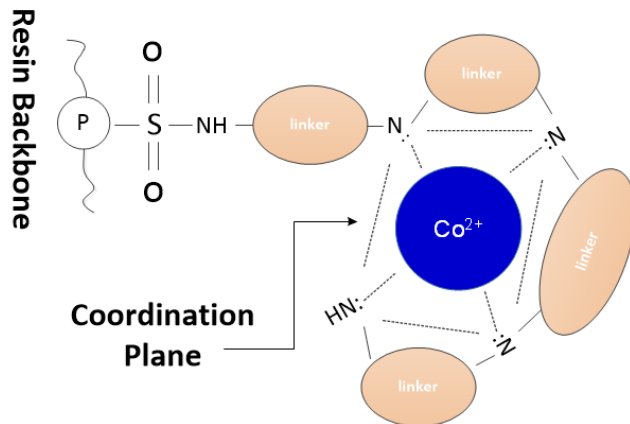
**Ion Exchange
(Reversible)**



Science of Sequestration

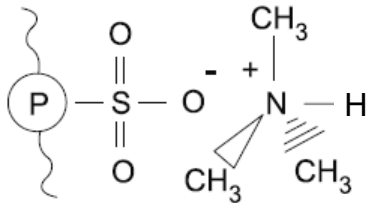
- The covalently attached sequestration ligand binds the cobalt with lone-pair or organometallic type bonding rather than ion exchange.

Ligand Capture (Irreversible)



- More about **CoSeq®** technology can be found in EPRI report: *Program on Technology Innovation: Cobalt Sequestration Media-CoSeq® Development and BWR Plant Demonstration Results*. EPRI, Palo Alto, CA: 2014. 3002003123.

Ion Exchange Versus Sequestration

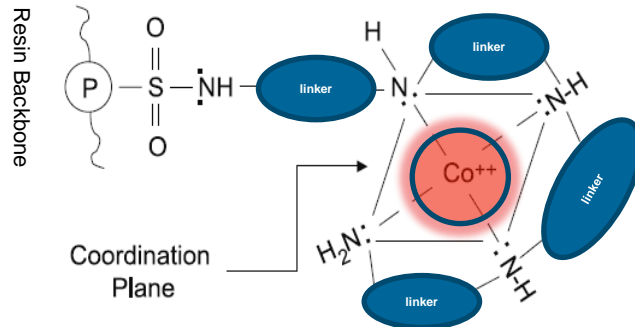


Ion Exchange Resin

- Ionic attraction
- Competition
- “Exchangeable”

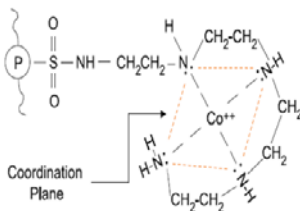
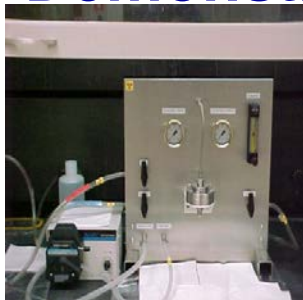
Sequestration is Superior

Single CoSeq® Ligand

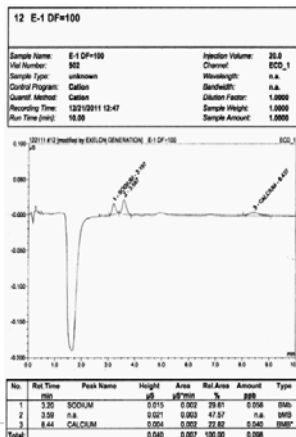


- Non-ionic attraction
- Irreversible uptake
- Higher capacity

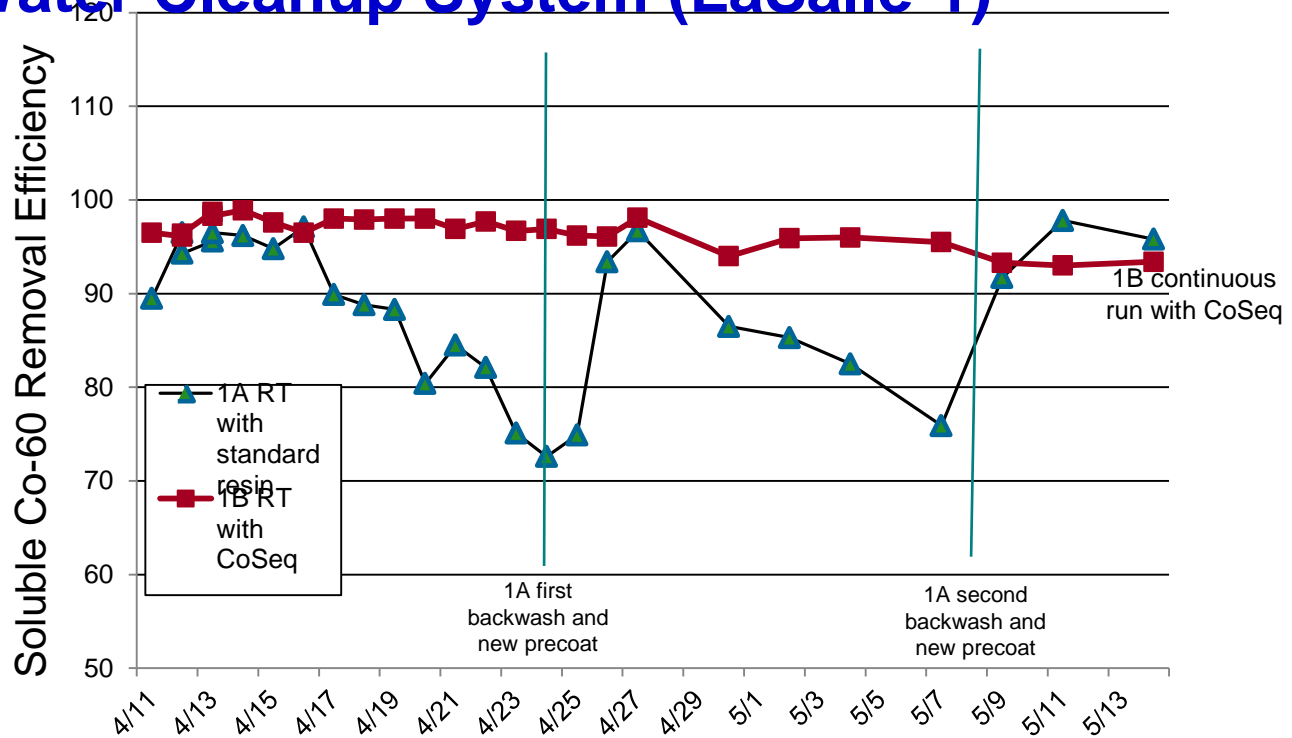
Cobalt Sequestration Development and Demonstrations



Plant	Refuel Outage Number or Cycle Number	Start of Demonstration (Month Year)
Demonstration during Shutdown		
Peach Bottom 2	RFO19	September 2012
LaSalle 2	RFO14	February 2013
Clinton	RFO14	October 2013
Demonstration during Power Operation		
LaSalle 1	Cycle 15	April 2012
Peach Bottom 2	Cycle 20	November 2013

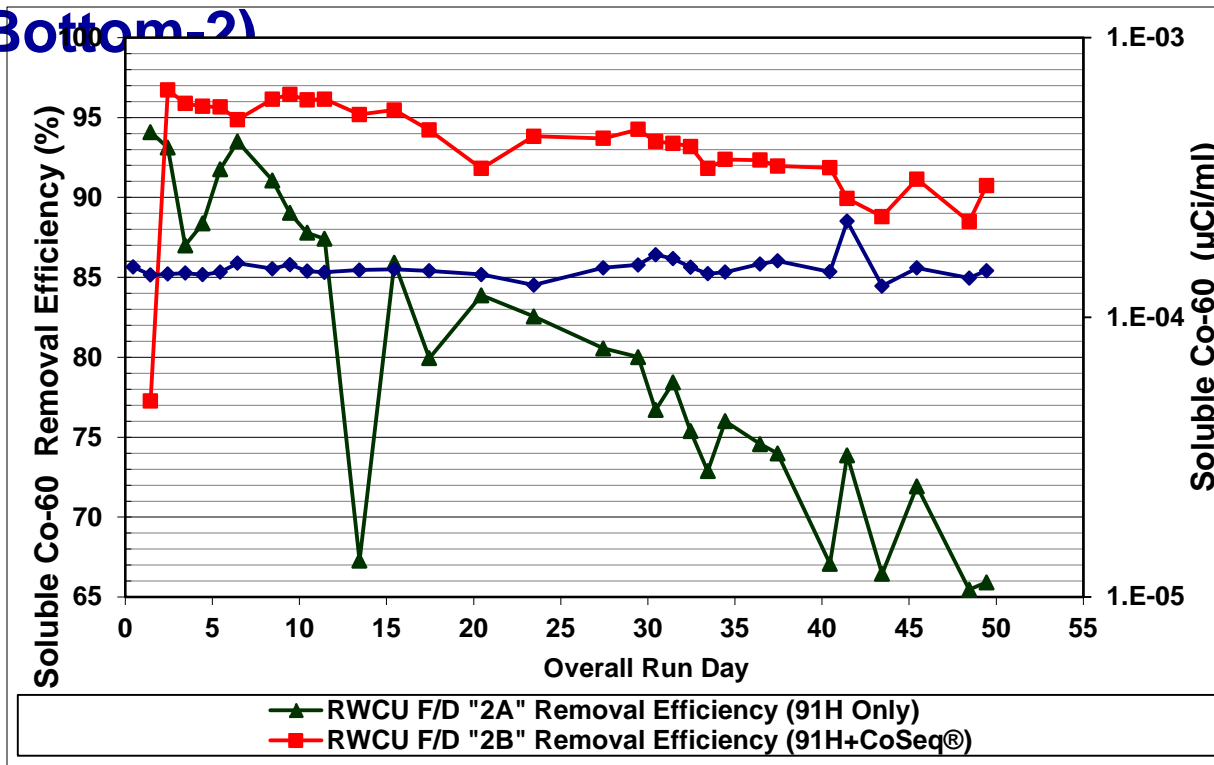


Full Power Demonstration in BWR Reactor Water Cleanup System (LaSalle-1)



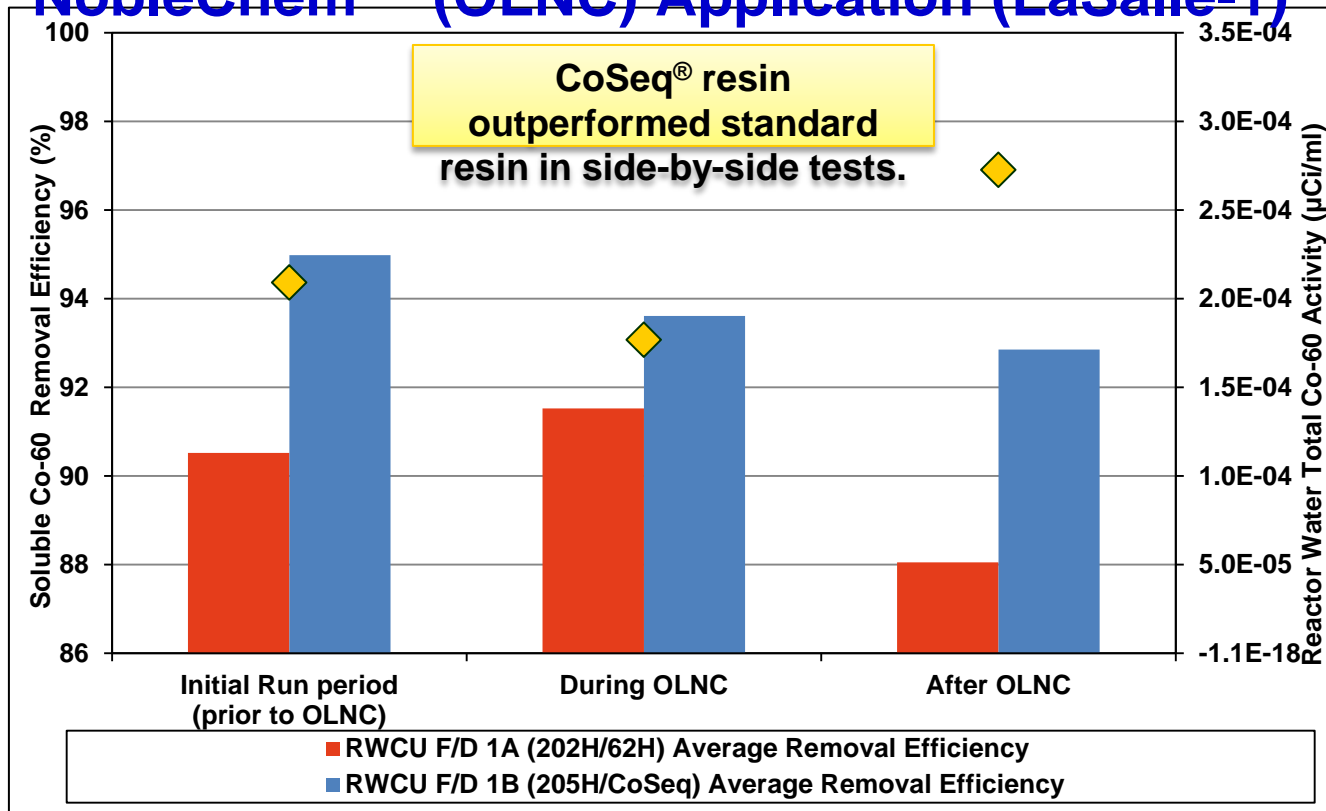
**CoSeq® resin outperformed standard resin in side-by-side test.
Standard resin replaced twice during CoSeq® 36-day run.**

Full Power BWR Demonstration (Peach Bottom-2)



Longest Demonstration to Date – 45 Days

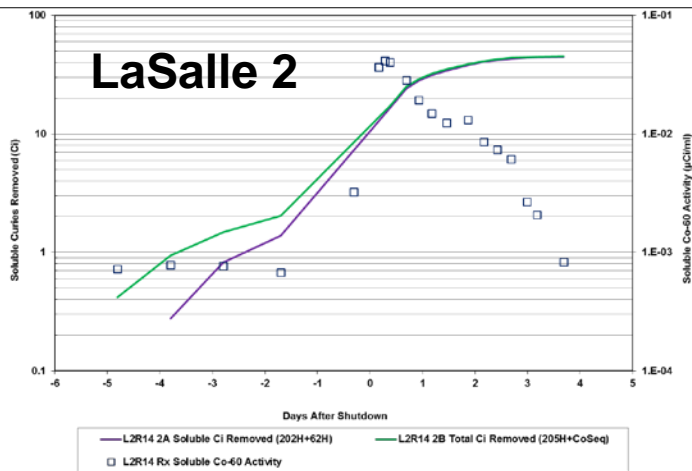
Full Power BWR Demonstration during On-line NobleChem™ (OLNC) Application (LaSalle-1)



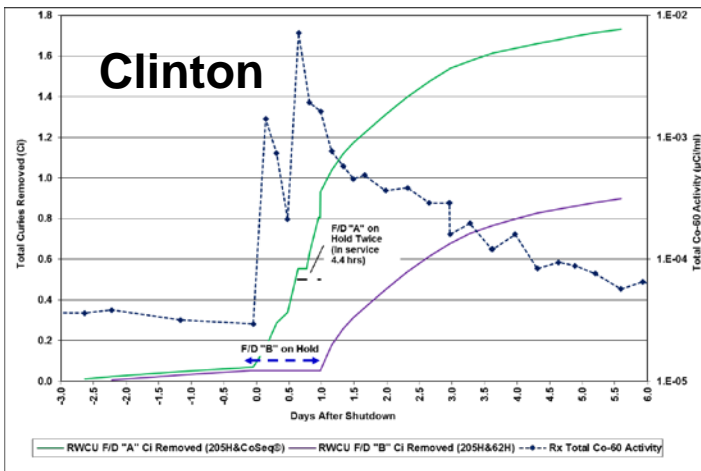
Refueling Outage Demonstration Results

LaSalle 2 and Clinton

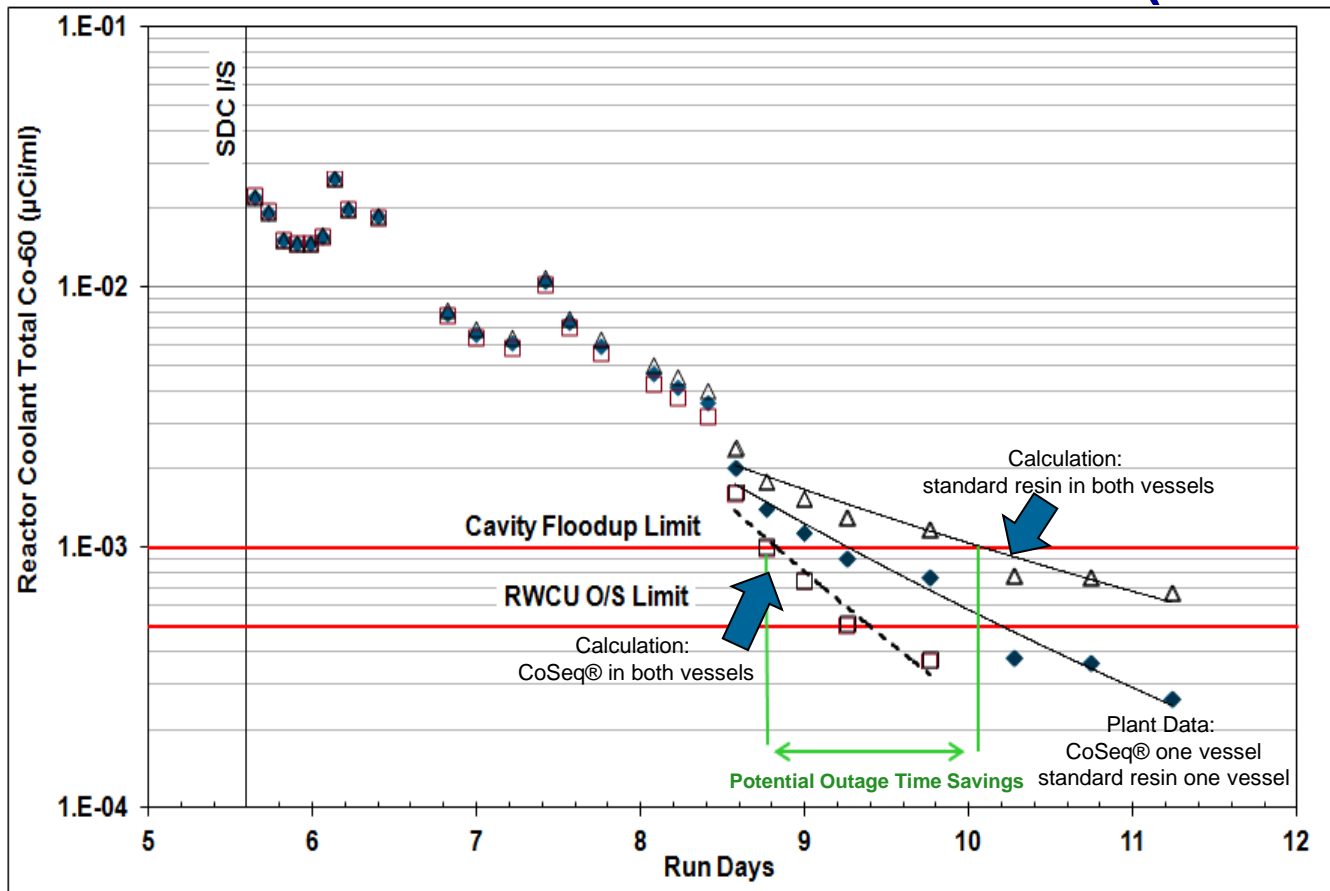
LaSalle 2



Clinton



Shutdown BWR Demonstration Results (Peach)



BWR RWCU CoSeq® Demonstration



■ Learnings:

- CoSeq® will out-perform standard cation exchange resins
- Higher efficiencies and longer run lengths observed
- Potential to reduce outage cleanup periods
- Due to reduced removal of other cationic species, use of any type of resin during should be evaluated carefully (sodium c impacts)
- No changes to cleanup systems or plant procedures



EPRI Patents and Licensing

- 3 patents submitted (US and Worldwide)
 - Patent #1 – Synthesis: AWARDED (US)
 - Patent #2 – Nuclear Applications – being reviewed
 - Patent #3 – Radwaste Applications – being reviewed
- CoSeq® registered in the US and Worldwide
- Licensed to a resin vendor and full scale production and sale underway (Purolite)
 - Milestone 1 (small scale production) – passed
 - Milestone 2 (large scale production) – passed
 - Included demonstration at actual BWR

Conclusions

- Co-60 removal was improved with **CoSeq®** use, especially after refueling outage reactor cavity floodup.
 - Lower Co-60 in cavity water correlates with lower refuel floor dose.
 - Critical path time may be less if Co-60 limits are met more quickly.
- During power operation, soluble Co-60 removal efficiency was higher and remained higher longer in the vessel with **CoSeq®** overlay compared to the control vessel.
- Even with high zinc concentrations [ppb], cobalt in low concentrations [ppt] was preferentially removed due to irreversible coordination binding of the ligand structure in the sequestration resin.
- No adverse conditions were experienced in the plant trials.

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