A PWR and BWR Source Term Reduction Perspective and Engineered Solution

Agenda:

- Invention
- Mechanisms Driving Shutdown Deposition
  - Colloids
- Utility Actions to Validate Technology Solution
- How and Why PRC-01M Technology Works
- Works Evidence it Does Work in Nuclear Power Plants
- O&M Cost Savings an Example Salem 1,2
  - Value in Reducing O&M Costs in USA

Reference Information

Unit Conversion:

- Radioactivity: 1 uCi * (37,000) to = Bq
- Radiation Dose: REM *(.01) to = Sv
- Flow Rate: Gallons / Min (GPM) divide by 15.85 to = kg/s

Acronym Key:

- RWCU: BWR Reactor Water Clean-Up
- RHR: Residual Eat Removal System
- RCS: PWR Reactor Coolant System
- CVCS: PWR Chemical and Volume Control System
- RCP: PWR Reactor Coolant Pump
- IX: Ion Exchange Resin
- LANL: Los Alamos National Laboratory
- ROI: Return on Investment

Background

Opportunity to Provide Sustainable O&M Cost Reductions

Los Alamos National Laboratory (LANL) Developed and licensed new technology Innovation: A Modified Conventional IX Resin, Colloid Removal Capability

- LANL R&D $20M, Award R&D 100 Award for Patented Technology
- Exclusive World Wide Grant of License to (n,p) Energy Nevada, Inc., Small WOB Business, as part of US Industrial Competitiveness Initiative
- FP&L Turkey Point-3,4: $1.6 M investment for First of a Kind Application in 1998-2000
- Invention: New Resin that acts like Ultra-Filters & Removes Extremely Small Particles, Not Currently Removed by CVCS, < 0.05 um to > 0.001 um

Technology Developed and Owned by LANL, so no information available from EPRI. Only ISOE Utilities has information

Corrosion Product Formation, Transport and Deposition -- A Dynamic Complex Set of 15 + Mechanisms

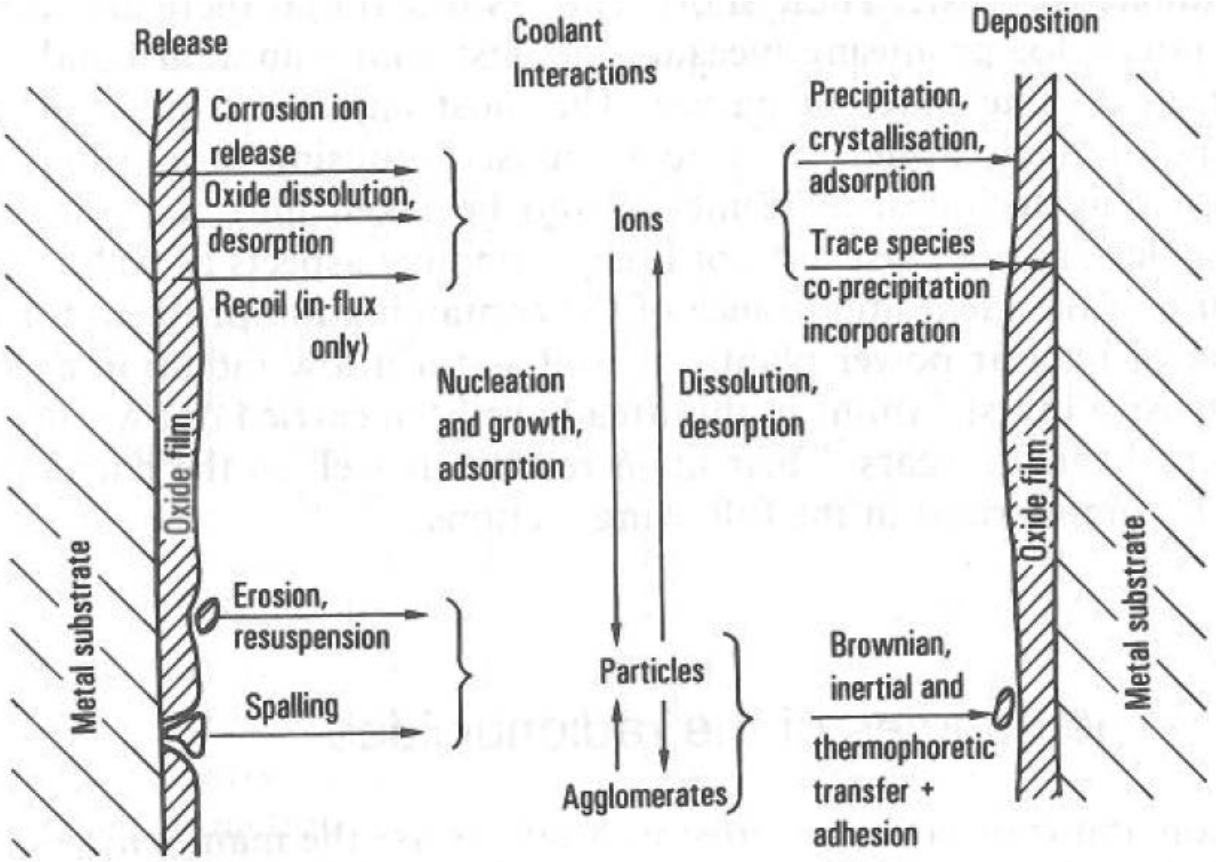
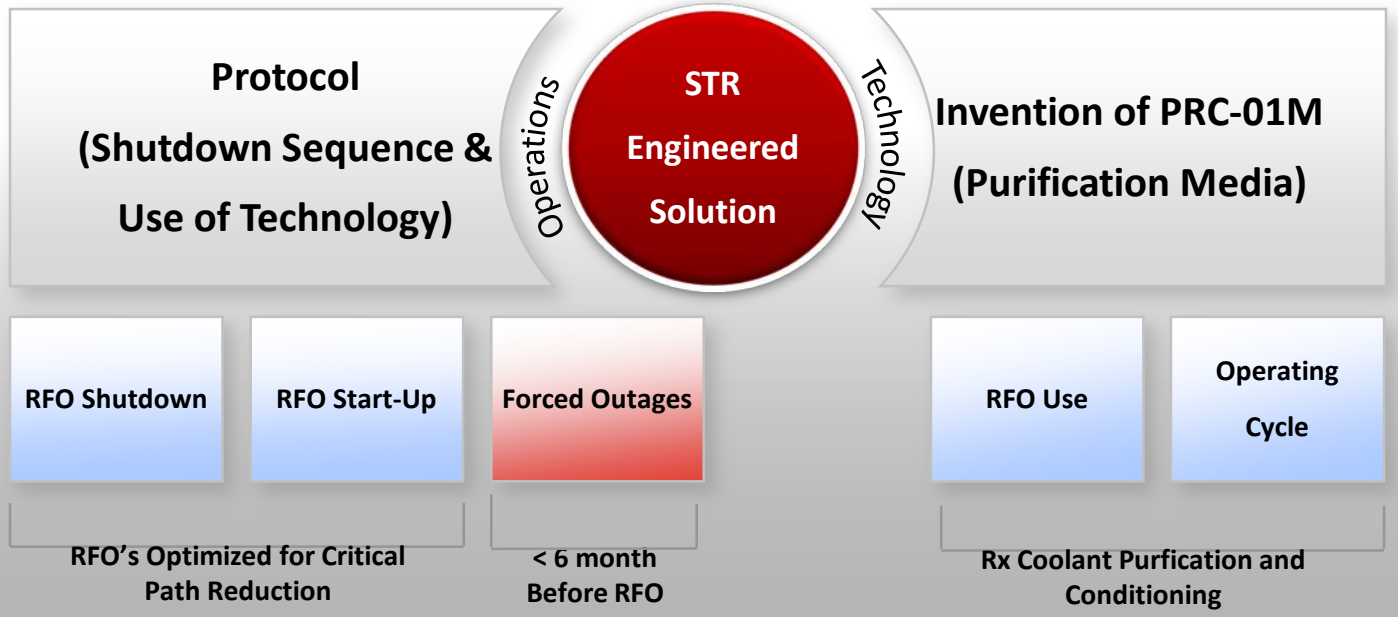
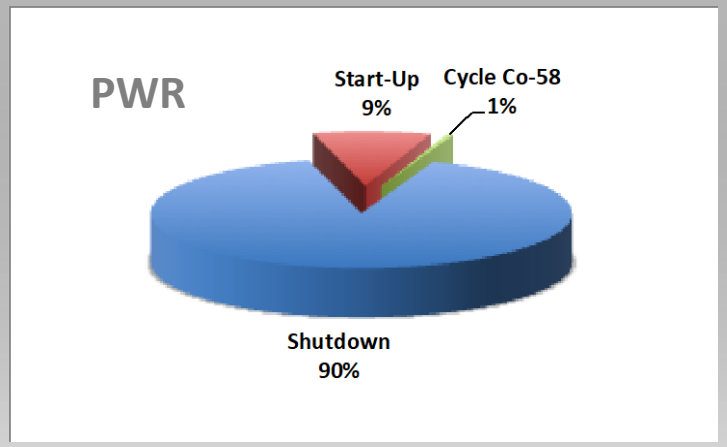


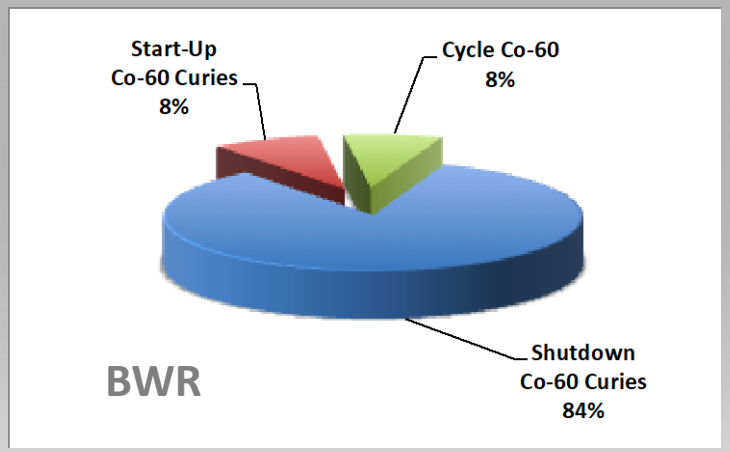
Figure 4.2. PWR Corrosion product, transport, and deposition mechanism (Rodliffe et al, 1987, by courtesy of IAEA)

STR: Two Part Solution BWR & PWR
85% to 90% Co-58 Co-60 Transports at Shutdown

Optimization of Shutdown Methods to Full Enable Technology







What does PRC-01M do Different? Removes Iron & Iron Colloids plus

Colloids– And NOT Mechanically Filterable in Rx Purification Systems

Iron Colloids- <.01 um > .001 um

20 million to 100 million particles/ Liter formed at Shutdown

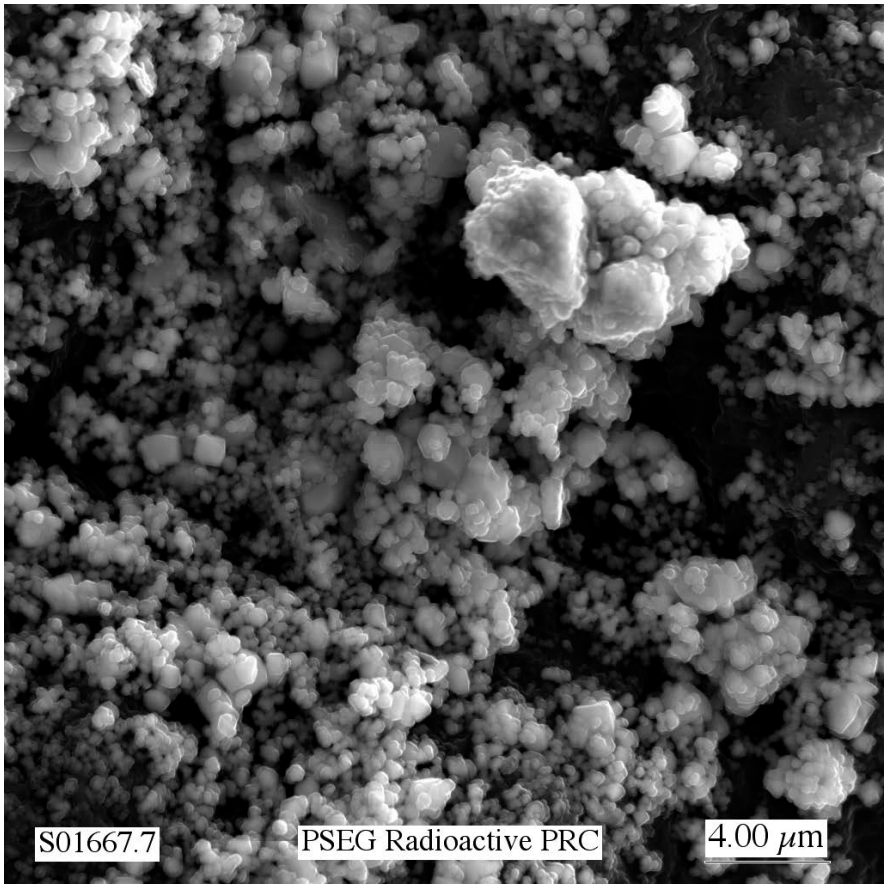
RCS Iron 5,000 times greater mass concentration than Co-58 & Co-60

Fe-Oxyanions Deposits First & controls deposition Ex Core

- Crud Traps, Pumps, Valves, Dead Legs

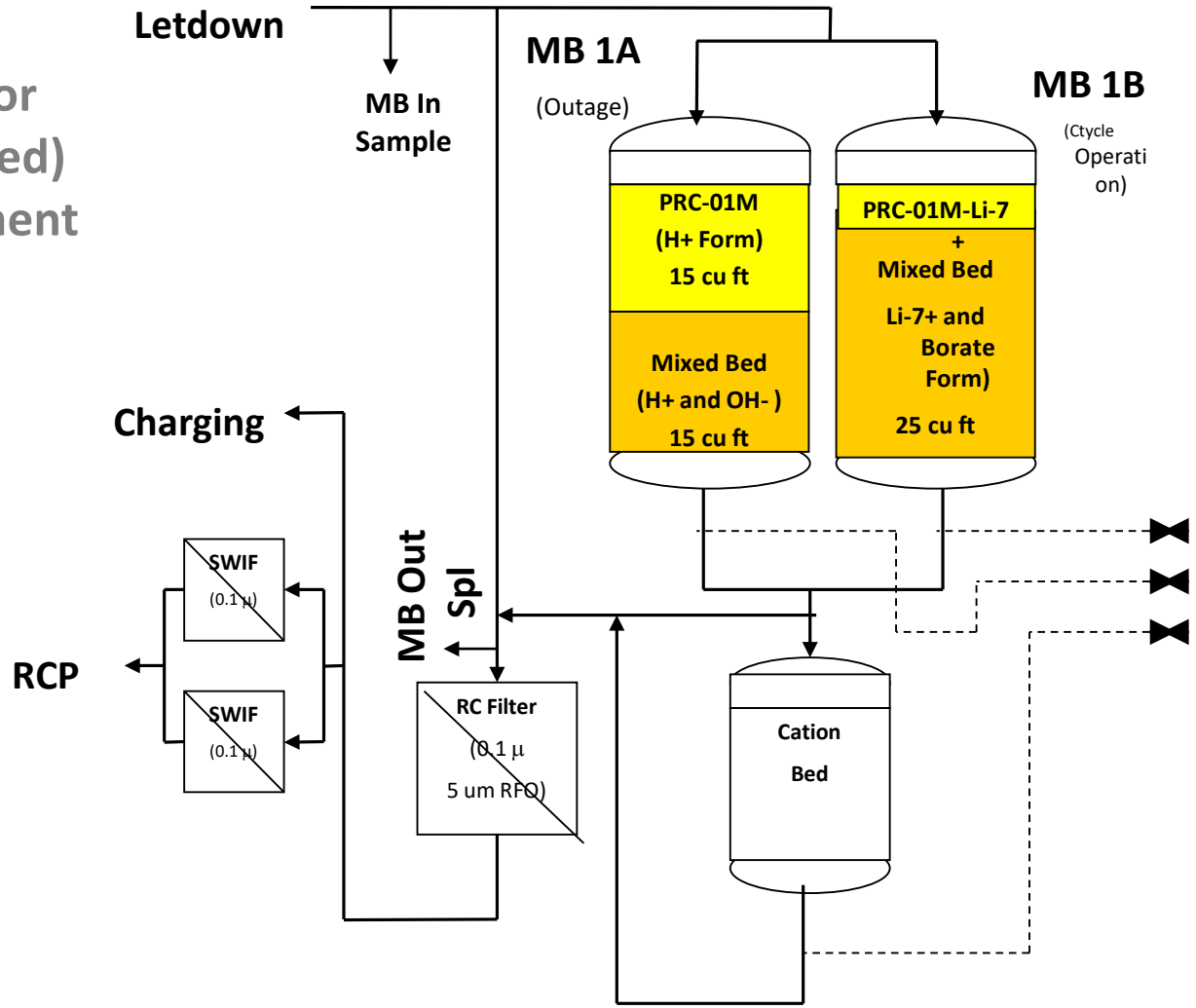
Co, Co-58 & Co-60 diffuses to Fe-Oxyanions & traps in structure resulting in Elevating Dose Rates

PRC Technology Breaks Deposition Mechanism

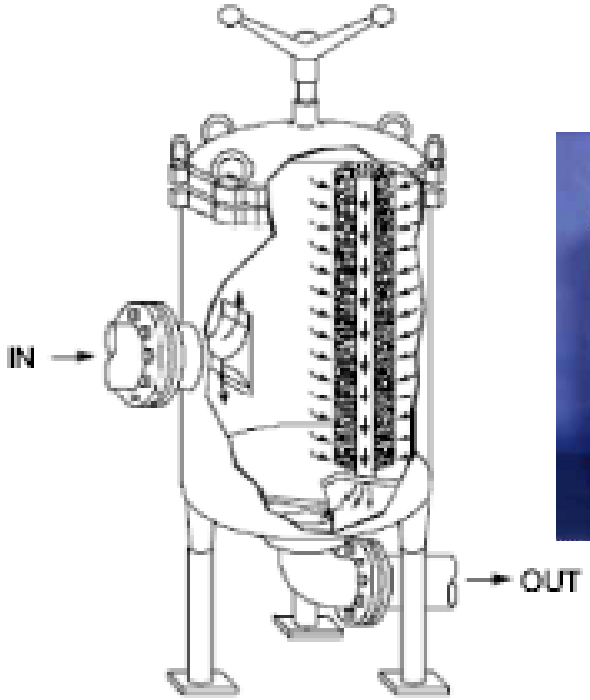


Replaces Conventional Resin in CVCS with PRC-01M & Mixed Bed Resin Loadings

PWR: PRC-01 (bead) or
BWR: PRC-2 (powdered)
Existing Plant Equipment



BWR Filter/Demineralizer
Septa Precoat and Deep Bed Demins



POWDERED RESIN FILTER DEMINERALIZER

- Systems:
  - RWCU
  - FPC
  - Suppression Pool
  - Submerged Demin

Since then…Utilities/Plants that Implemented LANL Technology, 90+ Rx-Yrs PWR/BWR Use

Exelon

- Braidwood-1,2 – 8 years
- Byron-1,2 – 6 years
- TMI – 6 years
- Ginna – 4 years
- Peach Bottom 2,3 - 7 yrs (BWR)

First Energy Fleet

- Beaver Valley-1,2 – 13 yrs
- Perry- 6 years (BWR)
- Davis Besse – 10 yrs

NextEra

- Pt. Beach -1,2 – 8 yrs

American Electric Power

- DC Cook-1,2 - 13 YRs

Xcel Energy Fleet

- Prairie Island-1,2 – 6 yrs
- Monticello- 13 yrs (BWR

FPL

- Turkey Point-3,4 – 12 yrs
- St Lucie- 1,2 – 7 yrs

Entergy

- Palisades- 3 yrs
- Vermont Yankee- 4 years

SCANA

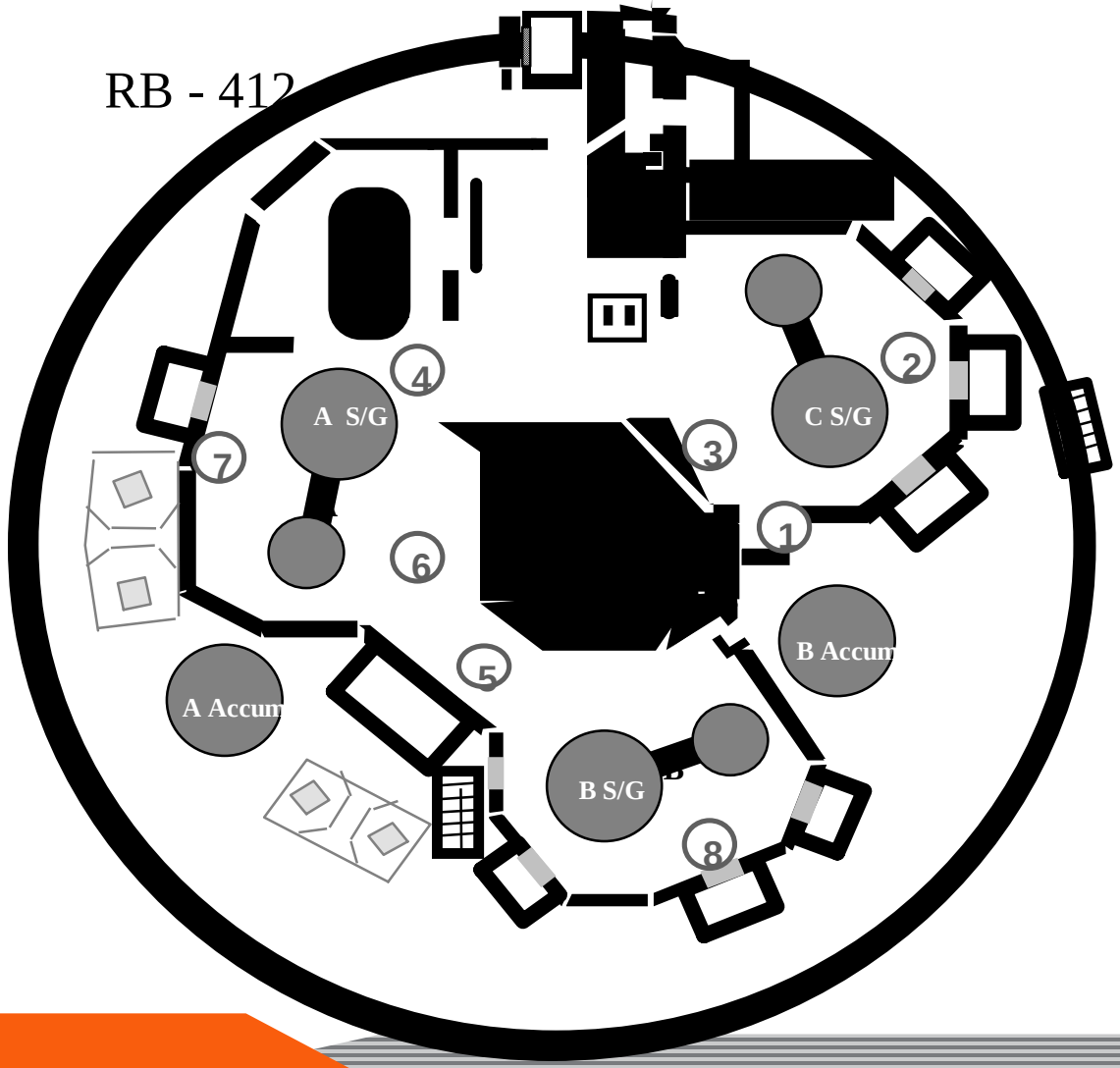
- VC Summer – 13 yrs

PWR Results
Wide Range of Design and Conditions

- High pH 7.2 to 7.4
- Low pH 6.9 Modified
- Non Zinc Injection Plants
- Zinc Injection Plants
- Failed Fuel Cycles

- High Duty Cores
- Low Duty Cores
- B&W Units
- W Units, 2L, 3L & 4L
- CE Units

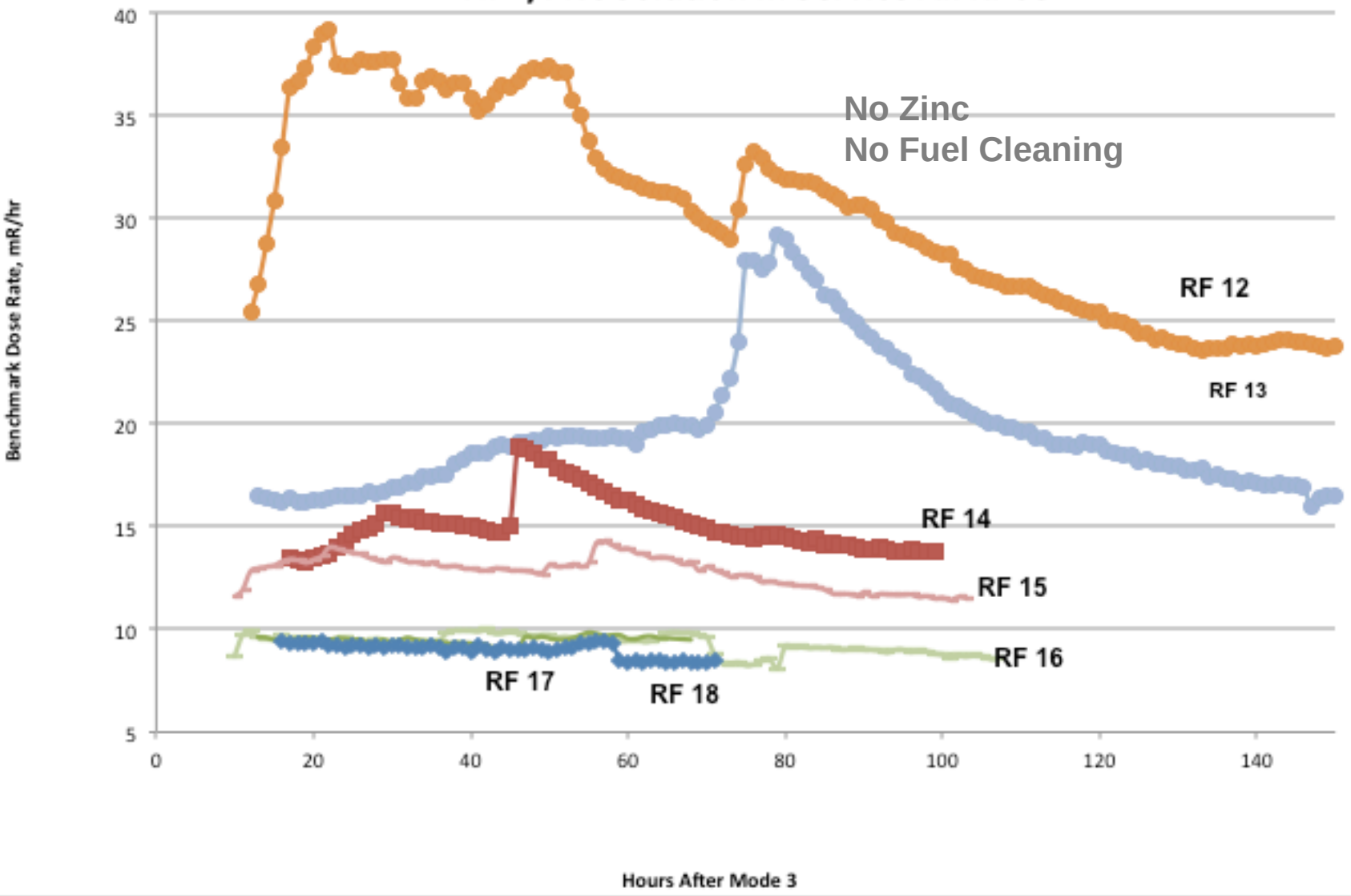
VC Summer- W 3L Benchmark Dose Rate Data for Outage Dose Performance with PRC-01M Technology



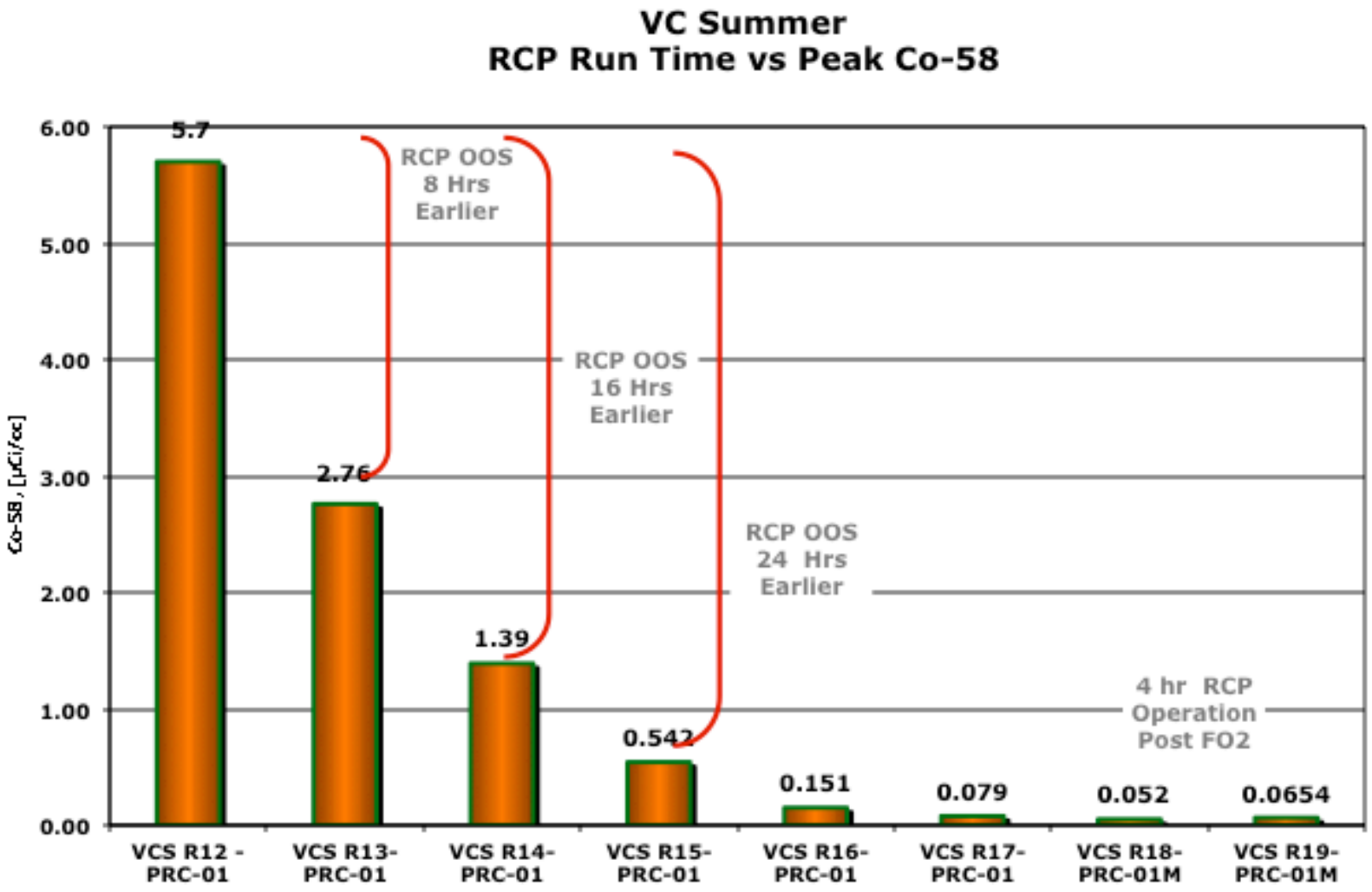
- pH 6.9 to 7.1
- No Zinc
- No Fuel Cleaning

- **Metrics**:
- Avg. of 8 general area dose rates
- 2 Lower Levels of Containment
- Electronic Dosimeters placed throughout Containment
- Correlates to total outage dose
- Since RF10 to 22

VC Summer RF 12 to 18 Baseline
ED Dose Rates During Cooldown
NPE/PRC Solution In Service All RFOs



VC Summer- Impact on Critical Path as Source Term Declines



*R12 had 1 peak in AR 2.42 and a second at FO2 3.32 totalling 5.7 uCi/cc.

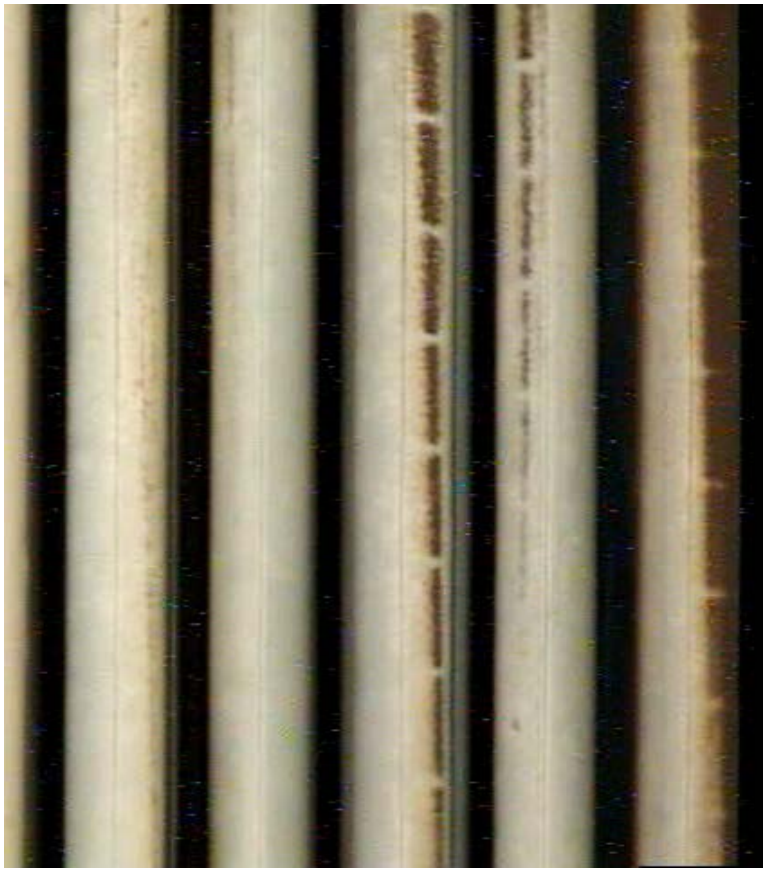
VC Summer Core Crud Reduction--
No Ultra-Sonic Fuel Cleaning – No Zinc Inj – Yes PRC-01M

2003 Highest Power Zone Cycle 14 (grid 6)

3rd RFO with NPE/PRC-01 Solution

2006 Highest Power Zone Cycle 16 (S33)

After 6th RFO with NPE/PRC-01



Exelon Performed "Technology Vetting" to Determine "Best Developed & Available Technology" 2010- 2014

In 2010, Exelon CNO and Board Member, Identified Alternative Solution to STR

- Through Exelon CNO Participation on AEP NSRB participation;
- Exelon Board Members and Board Oversight Committee Processes

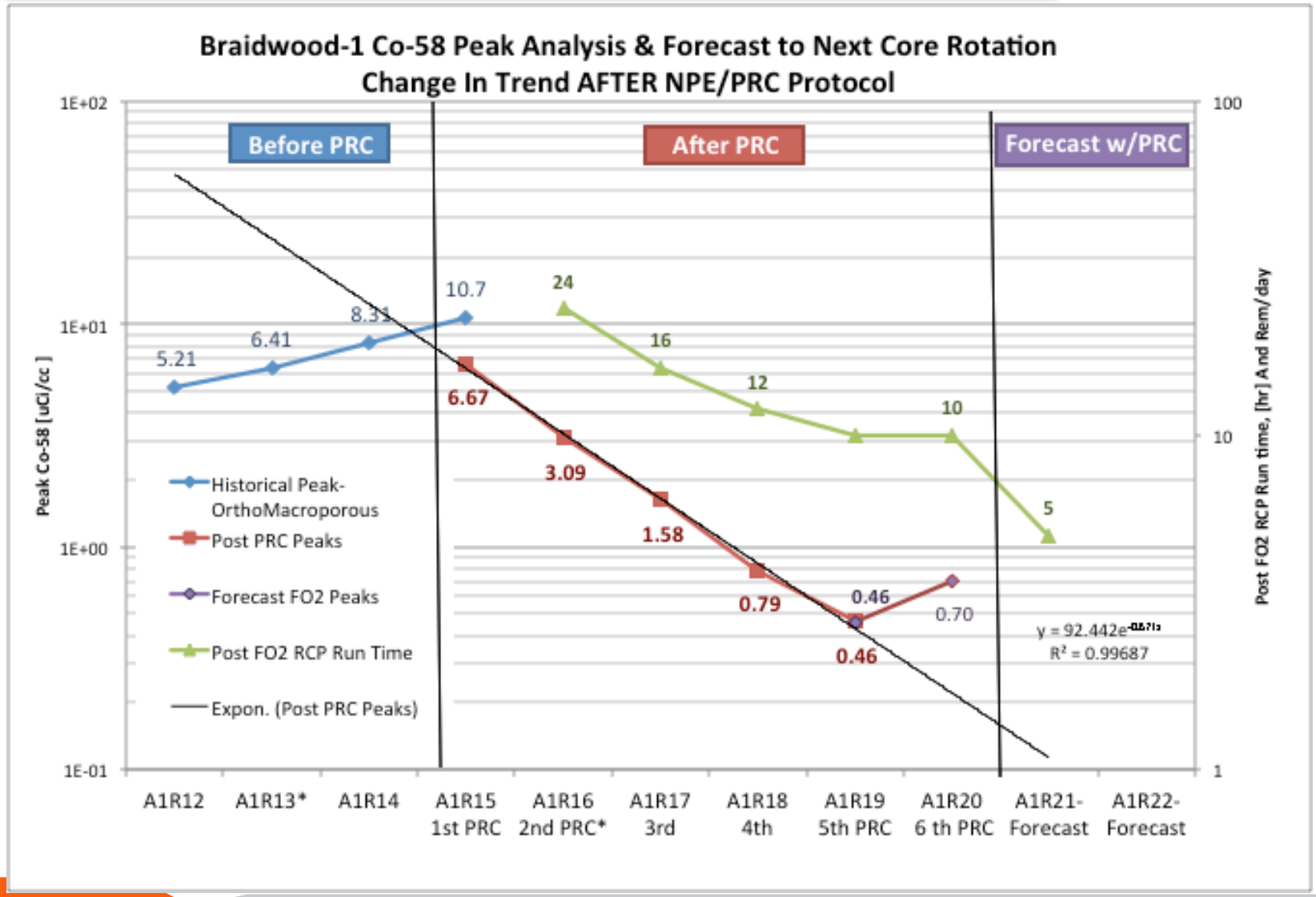
AEP Reported Results: Reduced Critical Path Time, Reduced Radiation Exposure, Reduced Dose Rates, Worker Productivity Gains, Reduced O&M Costs

CNO Directed COO to Conduct a Careful and Critical Process to Select Best Developed Technology

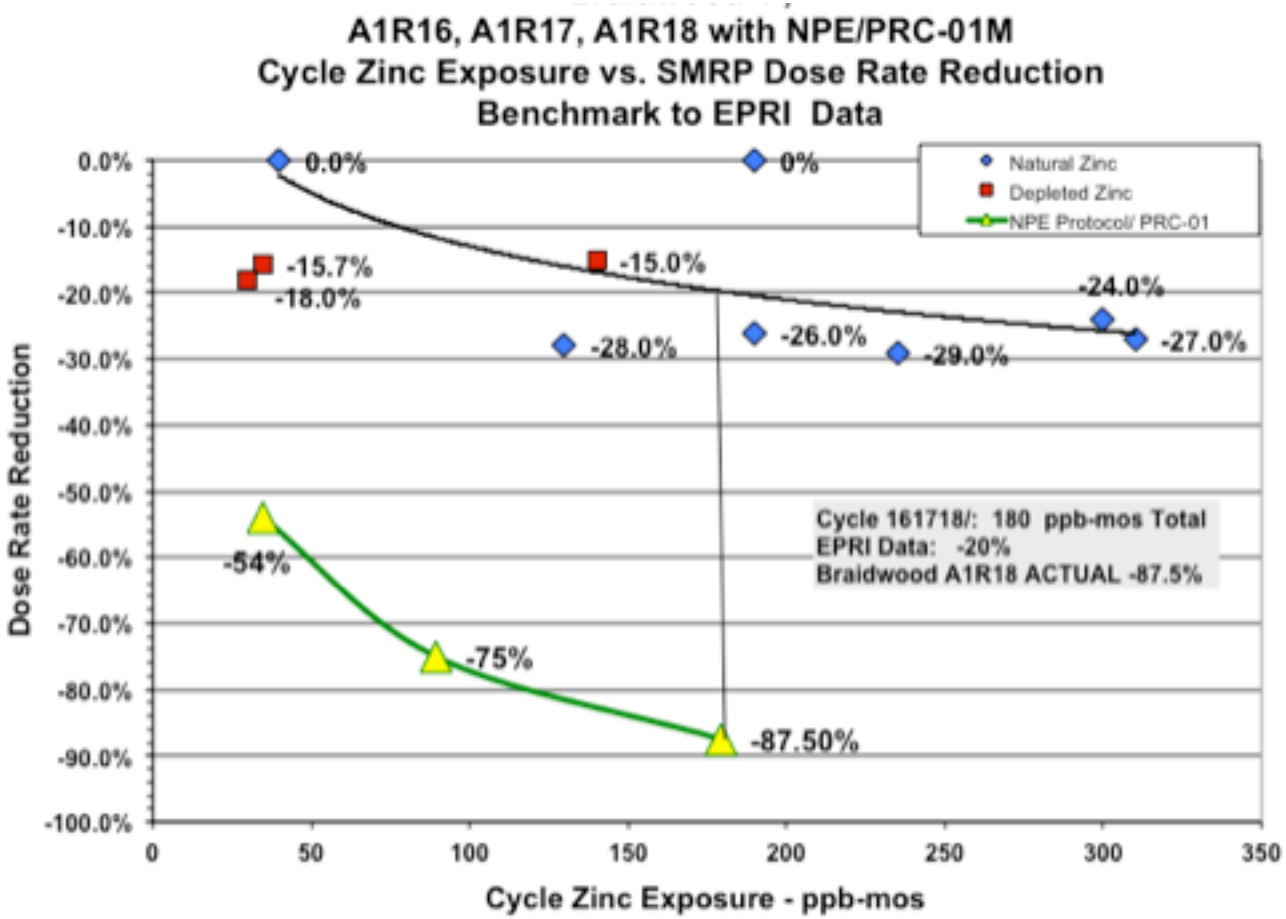
- Braidwood-1,2 and Byron-1,2
- Selected as "Vetting Units"

as they are identical in Design, SG Material, Commercial Operation (Byron-1,2 one op cycle longer), pH and Zn chemistry

Exelon Deployed PRC-01M to Their PWR Fleet Based On Performance, O&M Cost Savings

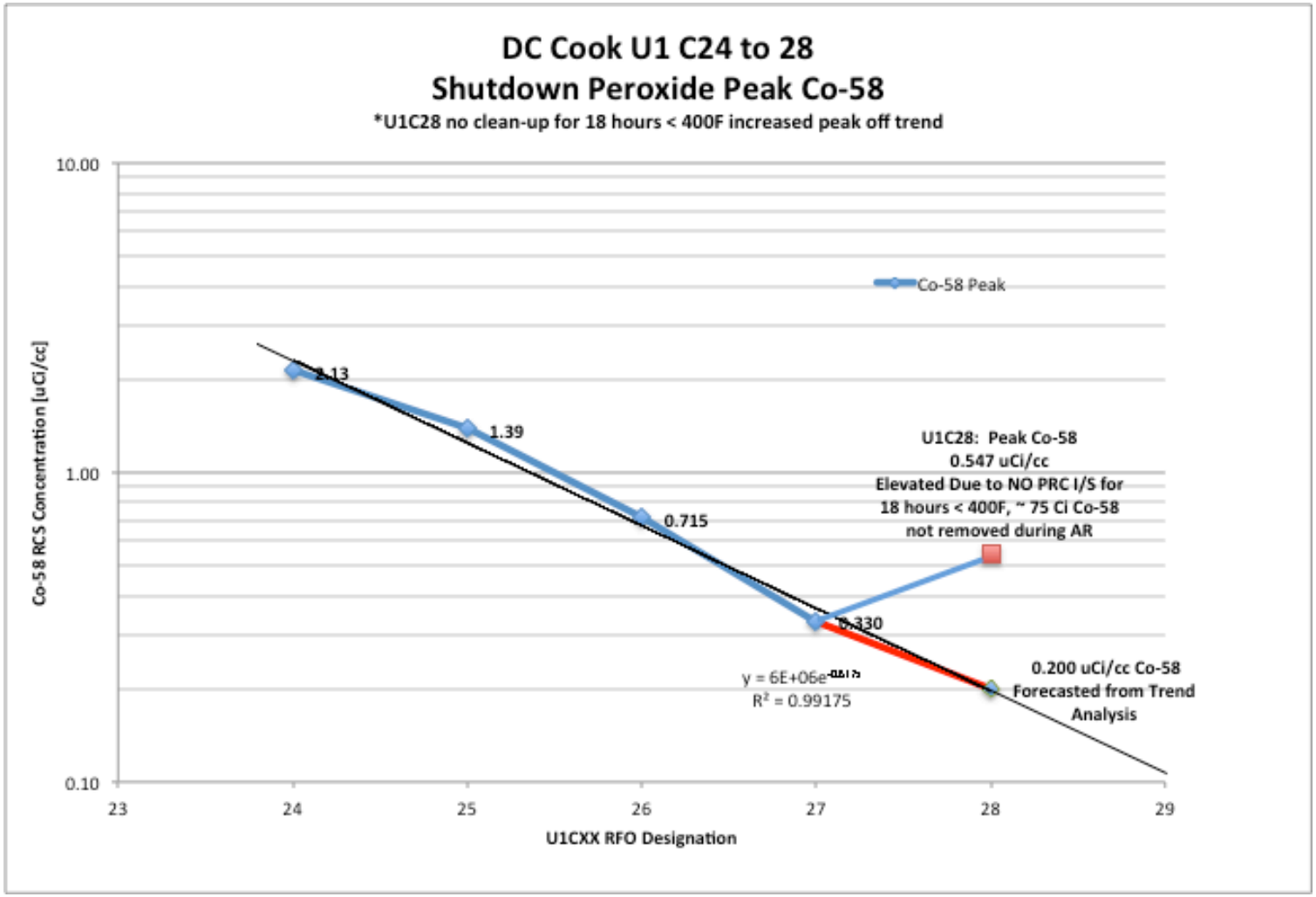


Exelon Vetting Results:
PRC-01M Bettered Zinc Injection for Dose Rate Reduction



Reference: EPRI 1001020 plus new DCPP cycle 10 and data; A1R16

NPE/PRC-01M Impact on Declining Peak Co-58
DC Cook-1 Ice Condenser (W 4 Loop, I-690 SG) No Zn No UFC



Salem-1,2 Compelling Sr. Leadership Team O&M Sustainable Cost Reduction Opportunity

Action: Salem-1 & Salem-2

•Implementation of PRC-01M Resin in CVCS and SFP Demineralizer 2R23

•NPE Provide best practice use alignment during RFO Shutdown/Start-Up

Near term Value Proposition: Salem-2R23

•**Reduce RCP Run time** from planned 12 hours to 5 hours, while NOT degrading radiological conditions, through use of PRC-01M technology.

•**Eliminate use of Elastomer Coating in Cavity**, to save $120,000 in costs, recover labor, and reduce cavity decon from 6 to 8 hours to 4 to 5 hours by using PRC-01M for shutdown and opportunity based alignment of SFP with PRC-01M to cavity.

•**Eliminate HE- UFC:** Recover Critical Path Time, 10 hrs, $500,000 , plus $100,000 Service Cost

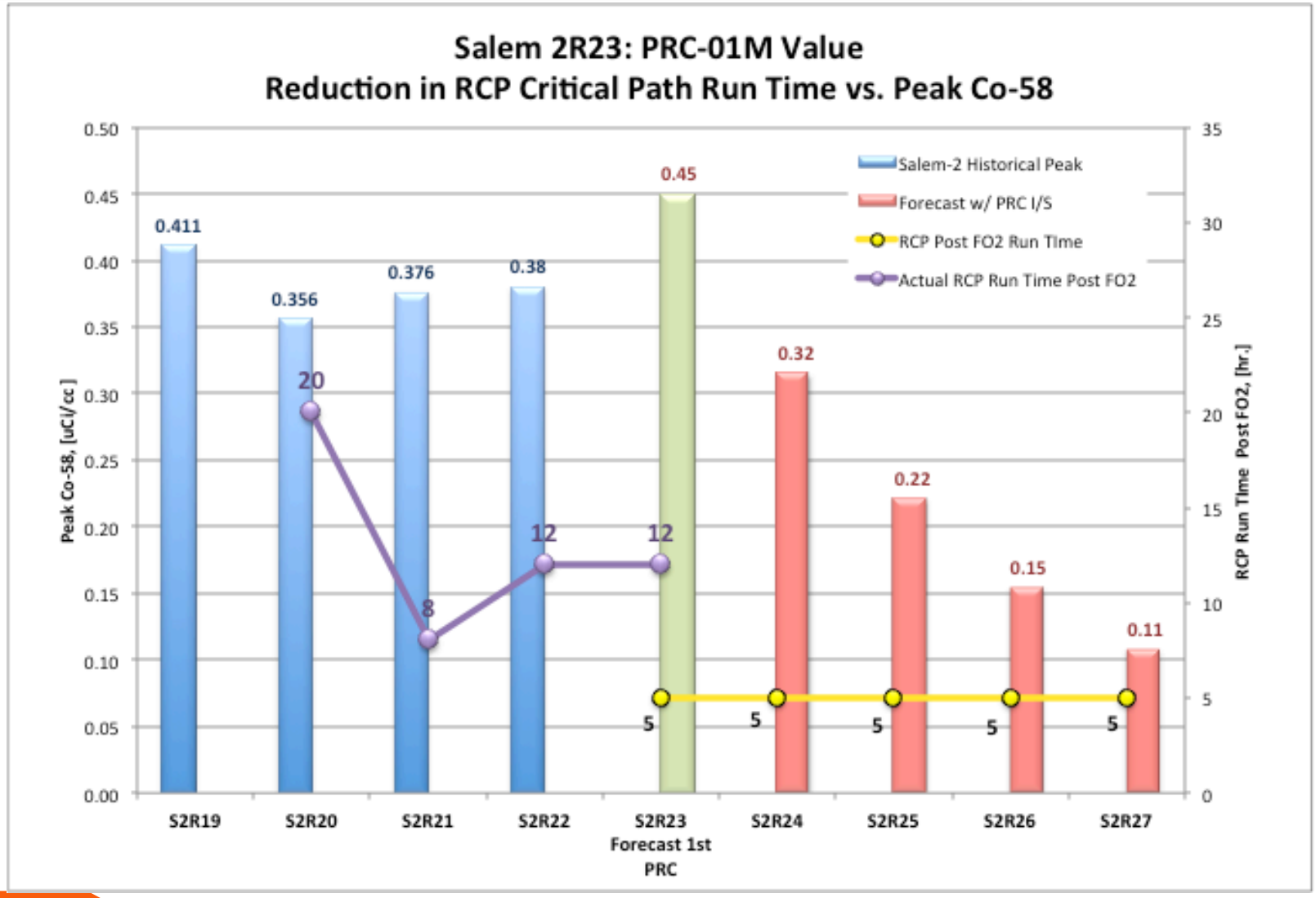
•**Reduce dose rates -25% to -35%** in 2 lower levels of containment. Reduces contamination, shielding packages, # LHRA and # of HRA's for worker briefs. Recovery of 5% to 10% of RWP labor hours.

•**Near Term Value for S2R23**: 7 hour Shortened RCP CP Time= $350,000; $120,000 Cavity Coating; 90,000 RWP hrs @ $120/ labor hour, 5% to 10% recovery = $500,000 to$1,080,00

Salem-2R23: 1st RFO PRC-01M Application Return on Investment: 1.8 to 9.0

	Improvement Opportunity	Value Basis	$ Value	Outage Goals
Critical Path Time	8 hour Reduction - 7 hr RCP - 2 hr Cavity Decon	$50K/ CP Hour	$ 450,000	Yes
Dose Rates	-25 to -30% 2 Lower Levels of CNTMT;- 50% Fuel Floor	10 REM @$10,000/REM	$ 100,000	Yes
RCA Worker Productivity Gain	~5% to 10% estimated 90,000 RWP-hrs	9,000 RWP HR @ $120/ Labor Hr	$540,000 to 1,080,000	Yes
Eliminate Cavity Decon Elastomer Costs	No Elastomer Coating Costs; Recovery of Labor	$120,000 Elastomer Costs	$ 120,000	Yes
Elimiminate HE-UFC	Recovery 10 hours Critical Path Time	$50K / CP Hour	$500,000	Yes
		Subtotal O&M Savings per RFO =	**$1,710,000 to $2,250,000**	
4L W Cost of Technology, PRC-01M, Svcs	**Cost $250,000 1st RFO**	**ROI CP Only = ROI CP + Elastomer= ROI All**	**1.8 2.2 6.84 to 9.0**	

Salem-2R23 to SR26
Reduction in RCP Run Time Sustained



Salem-2R23 to R26: Return on Investment 9.4 to 16.5 4 RFOs- Expanded O&M Cost Savings

2R23 to 2R26	Improvement Opportunity	Value Basis	$ Value	Outage Goals
Critical Path Time	8 hour Reduction - 7 hr RCP - 2 hr Cavity Decon	$50K/ CP Hour	$ 450,000 *4= $1,800,000	Yes
Dose Rates	-25 to -30% 2 Lower Levels of CNTMT;- 50% Fuel Floor	10 REM @$10,000/REM	$ 100,000 *4= $400,000	Yes
RCA Worker Productivity Gain	~5% to 10% estimated 90,000 RWP-hrs	9,000 RWP HR @ $120/ Labor Hr	$2,200,000 to 4,320,000	Yes
Eliminate Cavity Decon Elastomer Costs	No Elastomer Coating Costs; Recovery of Labor	$120,000 Elastomer Costs	$ 120,000 *4= $460,000	Yes
Reduction in Class B/C Resin Disposal	Reduction from 2 Class BC Shipments/yr to 1 Class BC in 10 years.	$250K/Class BC Liner Barnwell Starting after R24 6 liners @ $250K	$1,500,000	No
		Subtotal O&M Savings per RFO =	**$6,360,000 to $8,480,000**	
4L W Cost of Technology, PRC-01M, Svcs	**Cost R23 to R26 $900K**	**ROI All**	**9.42 to 16.5**	

What else do you need to know?

You have the Same Opportunity at your Station for Improvement on STR

- It's easy
- It works
- Cost/Benefit Guaranteed

  … and your chemist may not have information on this invention

" For every expert, there is an equal and opposite Expert…

…..but for every **FACT** there is not necessarily an equal and opposite fact"

Thomas Sowell's, Vision of the Appointed

Questions?

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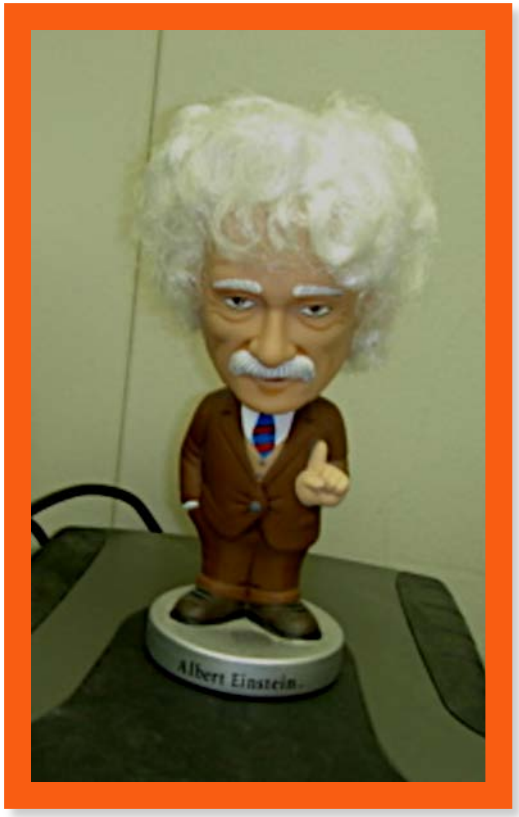

Acknowledgements:

LANL Research Team Lead by Dr. B. Smith

- **20 Yrs of R&D**

FP&L Turkey Point and St. Lucie- Chemistry, RP, Engr.

- **Supported All Development Work**
  - **2 years of Testing**
- **First of a Kind Engineering Use in 2000**

US NPP - RP Collaborators