Los Alamos National Laboratory Developed Technology Proven Effective for Reducing Plant Radiation Levels in Light and Heavy Water Reactors

Asian ISOE ALARA Symposium
Tokyo, Japan
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Presented by:
Patricia J. Robinson, (n,p) Energy, Inc.

Presentation Outline

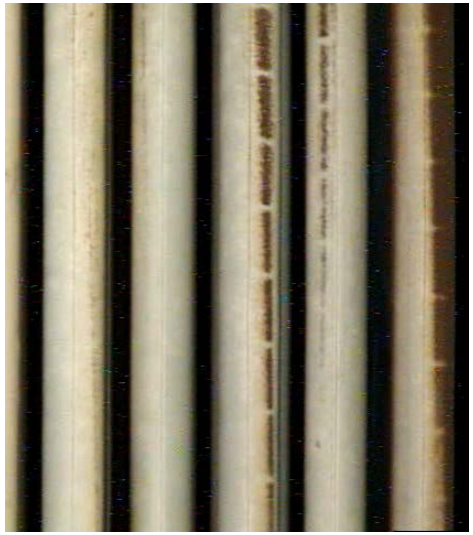
- How do you Reduce Source Term?
- Value of Reducing Radiation Source Term
- Brief Review Technology Origin
  - Los Alamos National Laboratory Polymer Filtration™ Science
- Engineering the Solution for Each Type of Reactor Design
  - PWRs
  - BWRs
  - CANDUs
- Results
- Opportunity for Asian Lead Units

How do you Reduce Plant Radiation Source Term?

- **Reduce Source Term by**
  - **1) Reducing CRUD on Fuel and**
  - **2) Reducing CRUD In Primary Circuit**
- **Sounds Simple --- But Required New Engineered Solution and New Invention**

Nuclear Fuel --Before

Nuclear Fuel -After



Initiative Value Proposition

- **Radiation Protection**
  - Collective Radiation Exposure Reduction
  - Full Spectrum of Impact: Reduced…
    - Dose Rates,
    - Contamination Levels,
    - Hot Particles,
    - Number of Locked High Radiation Areas

- **Component Reliability and Fuel Performance Improvement**
  - Reduces Root Cause for Stage #1 Seal Reactor Coolant Pump (RCP) leak rate
  - Decreases ….. CRUD Induced Power Shift (CIPS) Margin
  - Reduced Crud on fuel, improves Fuel Reliability (CILC)
  - Less Curies Generated and Available for Transport (CRUD)

Initiative Value Proposition

- **Outage Performance**
  - Critical Path Time Reduced
  - Incremental acceleration of every small task interfacing with RP Controls
- **Stakeholder/ INPO-WANO/ Regulatory Risk**
  - INPO/WANO Rankings
  - NRC: CIPS Margin Improved, Risk Reduction RP Related Violations
- **Environmental Effluents (Radwaste)**
  - Liquid Effluents -- Less Discharge of Curies --
  - Solid Waste-- Less Filters, Less Curie Surcharge, Less Costly Options for Disposal
  - Stakeholder Impact

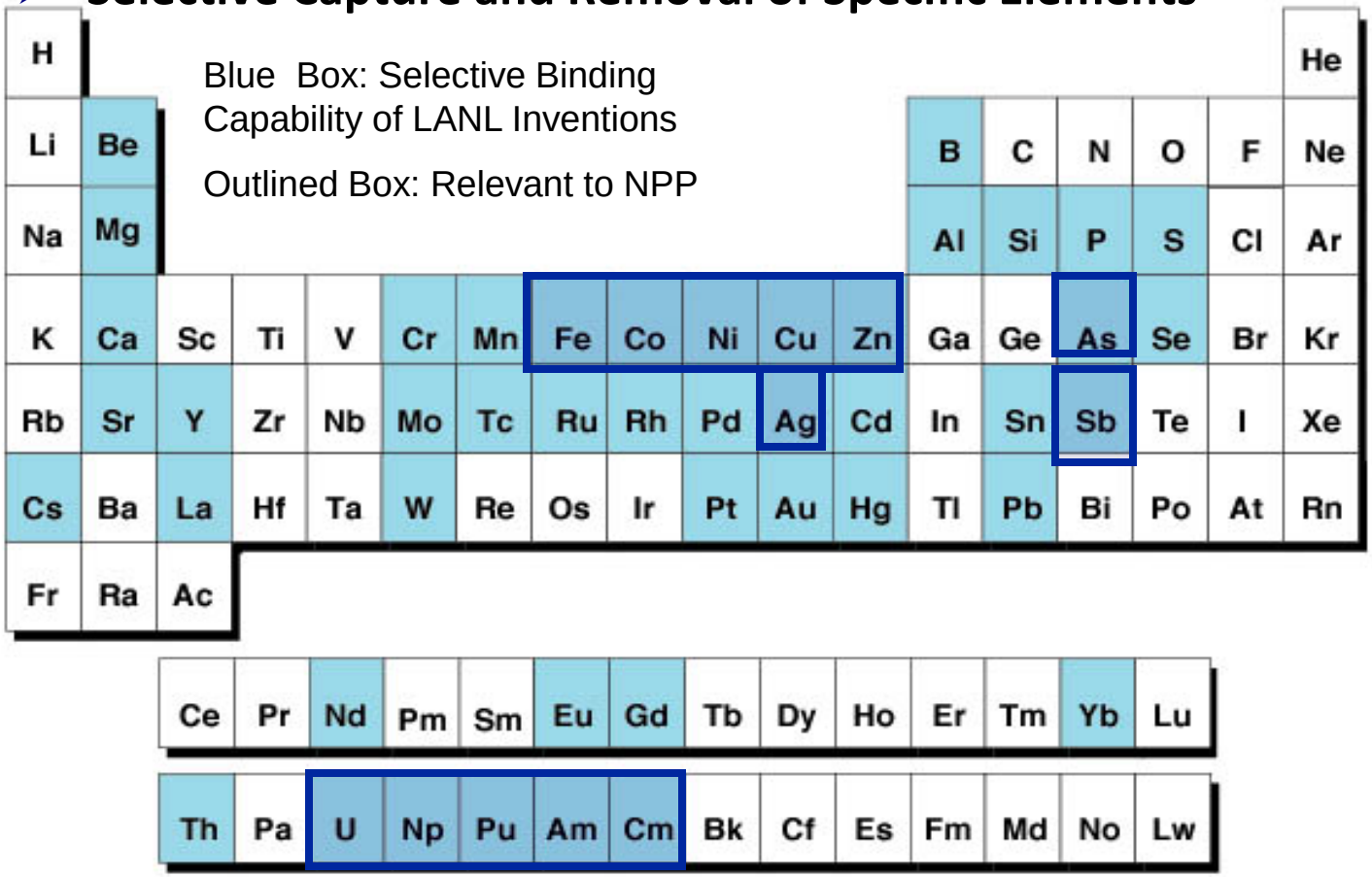
New Invention

- US DOE R&D Labororatory for Nuclear Technology
  - Discover science and technology, where challenges are solved for the Medicine, Space, National security and Nuclear Technology
  - $4 Billion R&D Annual Budget
- Los Alamos National Laboratory (LANL)
  - 118 R&D 100 awards since 1978
- Invented and Patented, Polymer Filtration Technology™
  - Issued Exclusive World-Wide Grant of Licensed Inventions to (n,p) Energy, Inc.
  - R&D 100 Award-Polymer Filtration Technology
- (n,p) Energy, Inc. (NPE) Licensed Technology from LANL
  - NPE Engineered a 2 Part Solution
    - Part 1: Reactor Shutdown Protocol (Sequence)
    - Part 2: PRC-01M Resin Media for Rx Coolant Clean-up

Los Alamos N.L. Science

R&D 100 AWARD Winner for Polymer Filtration Technology™

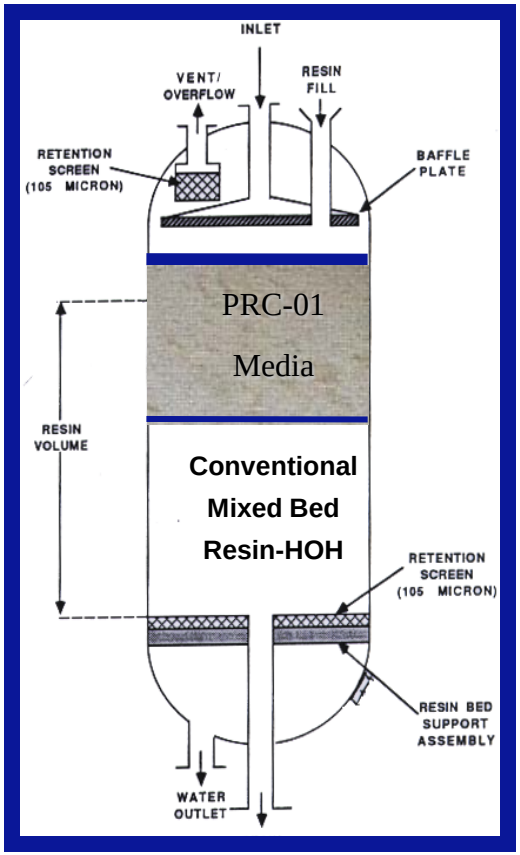
- **What Los Alamos Can do, depending on your need**
- **Selective Capture and Removal of Specific Elements**



How is PRC-01M Integrated?

Existing Plant Systems Chemical and Volume Control System (CVCS), Reactor Water Clean-up (RWCU), Fuel Pool Systems, Boron Recycle Systems and CANDU PHT

- **PWR: PRC-1 (bead) or BWR: PRC-2 (powdered)**
- **Existing Plant Equipment**
  - **PWR: Uses CVCS Demineralizer Vessel**
  - **Both: Spent Fuel Pool**
  - **BWR: Filter/Demineralizers**
    - **RWCU**
    - **FPC**
    - **Torus**
  - **CANDU**
    - **Primary Heat Transport**



PWR
Deep Bed Vessel

BWR
Precoat Filter/Demin

Lead Plants
NPE/PRC-01 Engineered Solution

- PWRs 3 Loops
  - Turkey Point-3,4
  - VC Summer
- PWR 4 Loops
  - DC Cook 1,2
- BWRs
  - Peach Bottom 2,3
  - Monticello
- B&W:
  - Davis Besse
- CANDU:
  - Bruce A/B

Completed > 120 Refueling Outages
with NPE/PRC Engineered Solution In Service

NPE Engineered Solution at USA, Mexico and Canada

PWR …120 Refueling Outages

BWR ….7 Reactors…5 Sites…30+ Refueling Outages

PWR Results

Turkey Point-3,4
VC Summer
DC Cook-1,2

Davis Besse

QuickTime™ and a
decompressor
are needed to see this picture.

FPL 1st Integration 12 years Ago

#1 Turkey Point 3/2000, #2 St Lucie-1 4/2000 # 3 VC Summer

Pat-San

PRC-01

Turkey Point-3,4 & VC Summer
Source Term Approach: Only Use of PRC-01

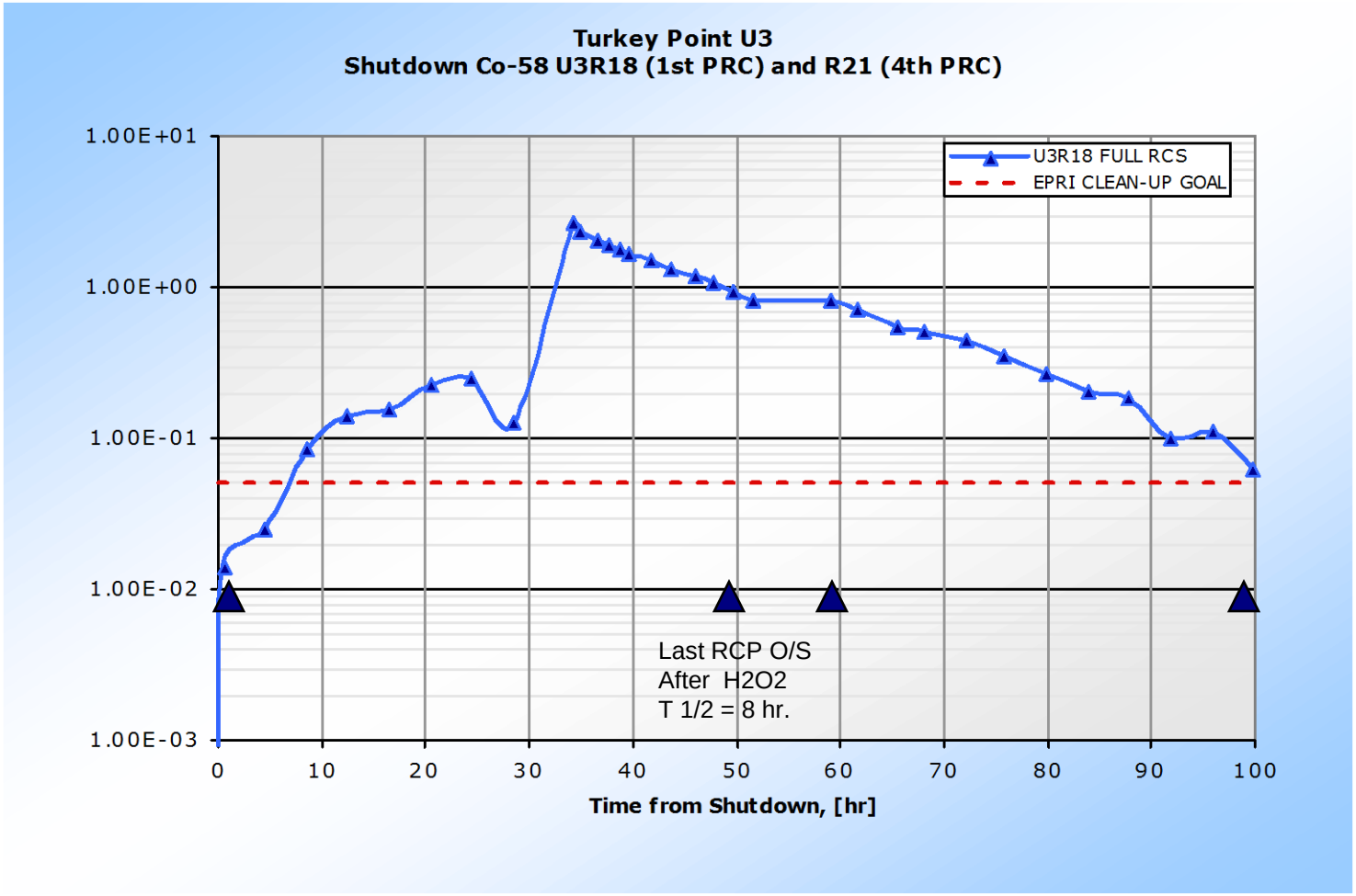
- **Turkey Point 3,4:**
  - Yes: Chemistry pH(t) = 7.1
  - Yes: PRC-01 Media Technology
  - No: Zinc, No Fuel Cleaning, No Elevated pH 7.2 to 7.4
  - Fuel Duty: Middle Fuel Duty
  - 13 to 18 EFPY SG, Inconel 600 TT
- **VC Summer**
  - Yes: Chemistry pH(t) = 7.1
  - Yes: PRC-01 Media Technology
  - No: Zinc, No Fuel Cleaning, No Elevated pH 7.2 to 7.4
  - Fuel: High Duty, AOA Susceptible
  - 7 EFPY SG, Inconel 690 TT

FPL Turkey Pt-3R18 (1st PRC)

RCS Shutdown Co-58

100 hrs to Clean-Up Goal

1 E-3 uCi/cc = 37 Bq/ cc

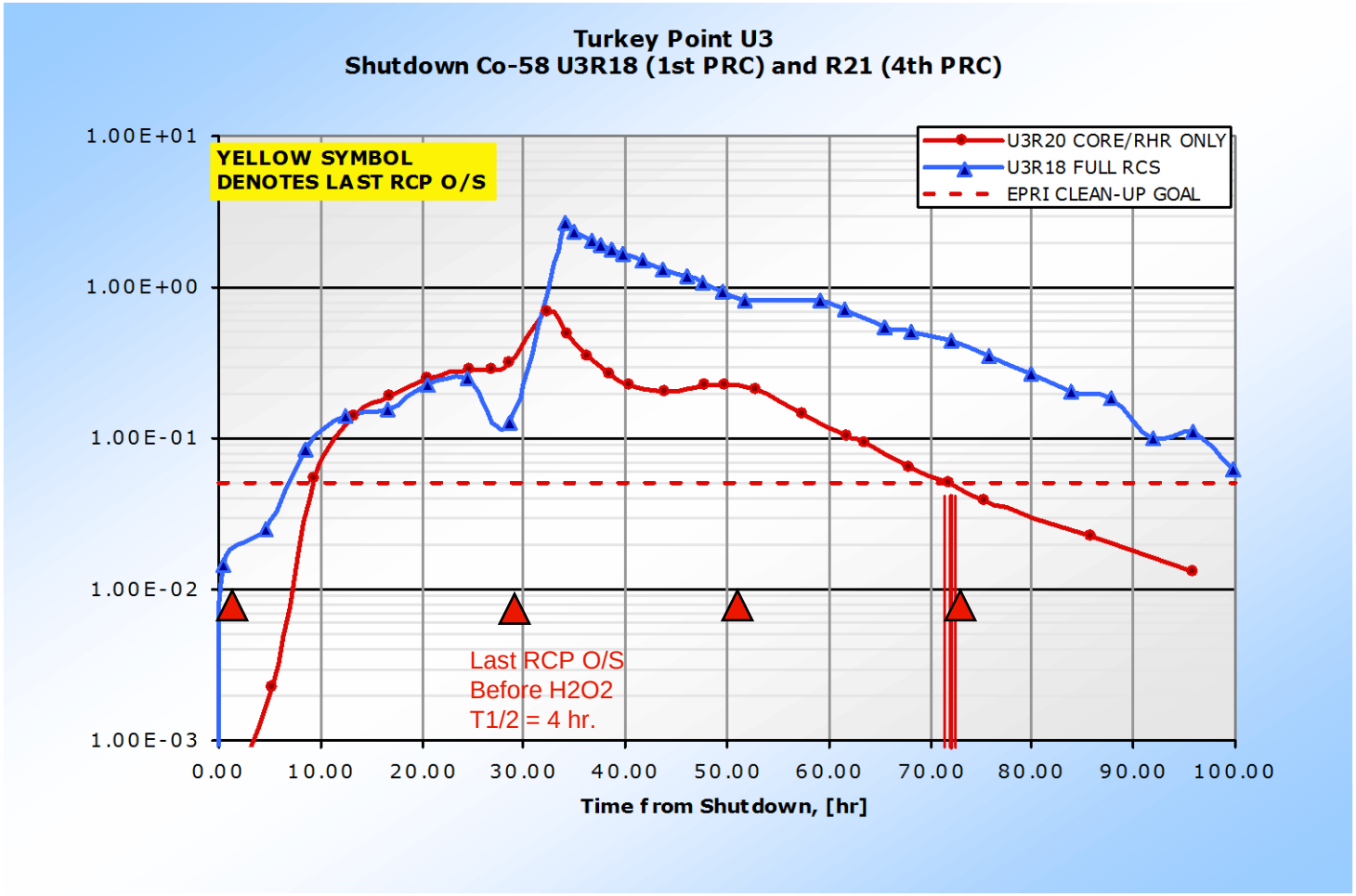


FPL Turkey Pt-3 R20 (3rd PRC)

Shutdown Co-58

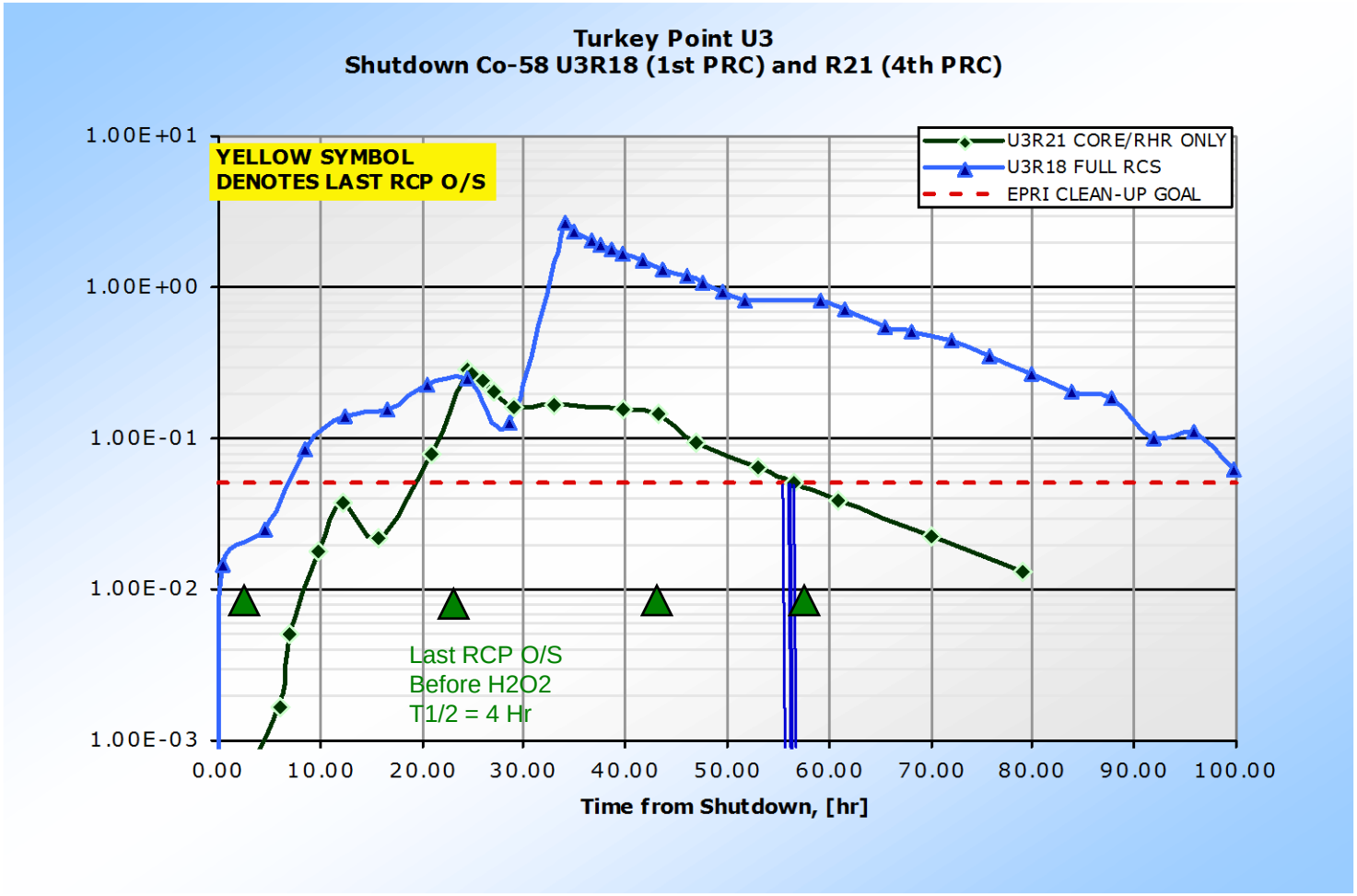
70 Hours to Clean-Up Goal

1 E-3 uCi/cc = 37 Bq/ cc

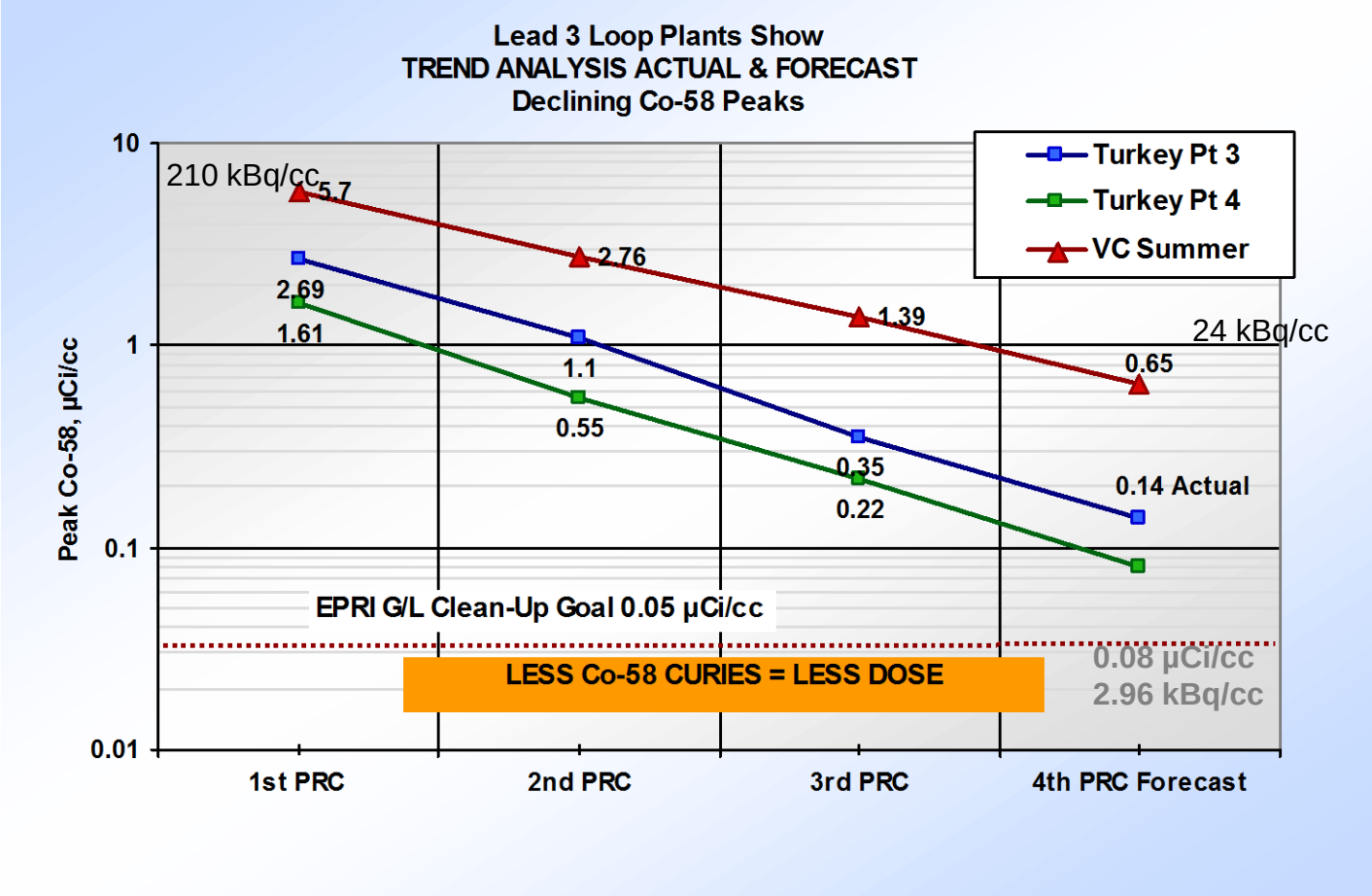


FPL Turkey Pt-3R21 (4th PRC)
Last RCP Off - Before Peroxide Injection
Shutdown Co-58 56 Hrs to Clean-Up Goal

1 E-3 uCi/cc = 37 Bq/ cc



Turkey Pt 3,4 & VC Summer Sustained, Predictable Decline in Co-58 & Co-60 Shutdown Peak

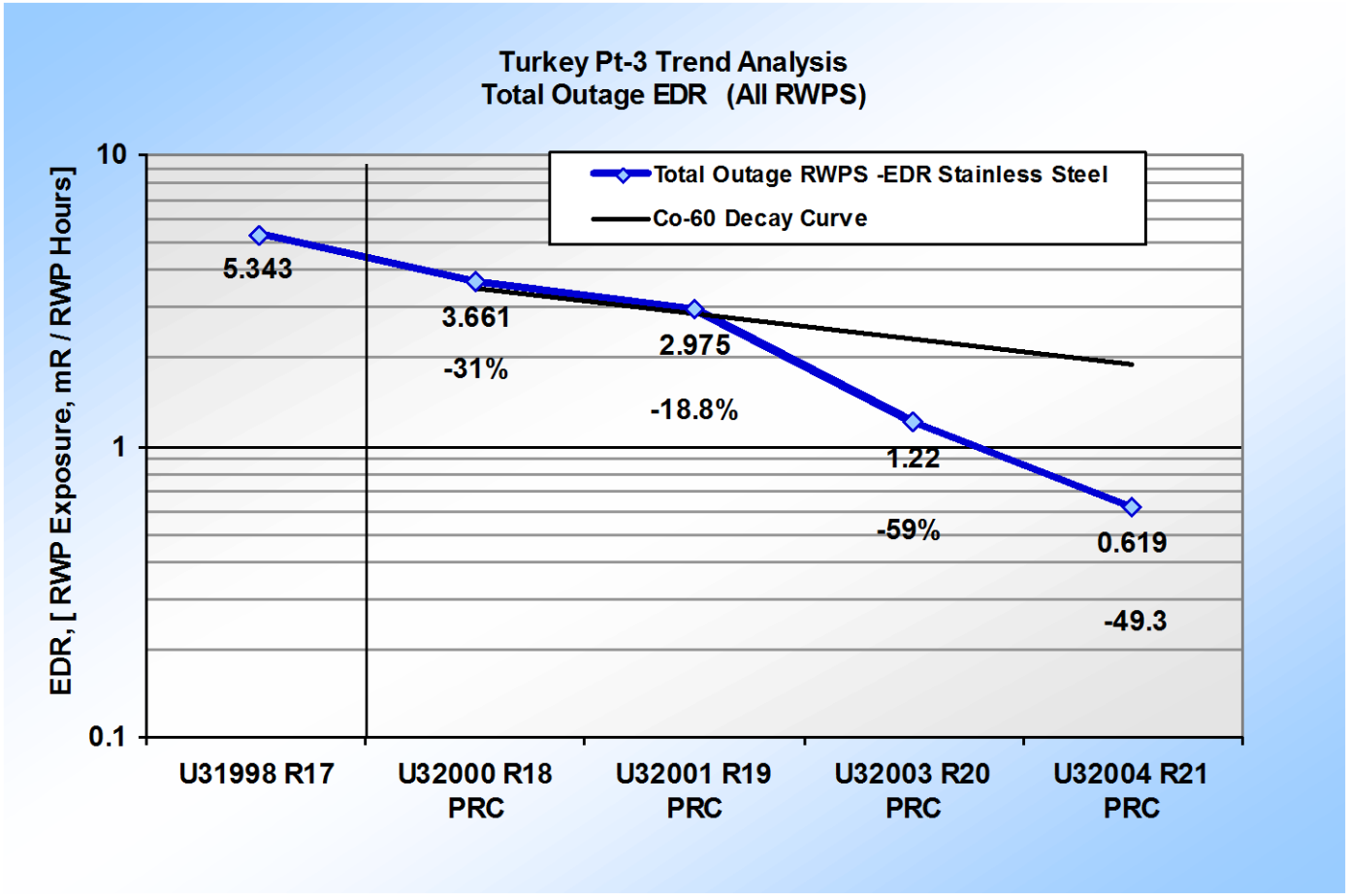


1 uCi/cc = 37 kBq/ cc

Effective Dose Rate Trending

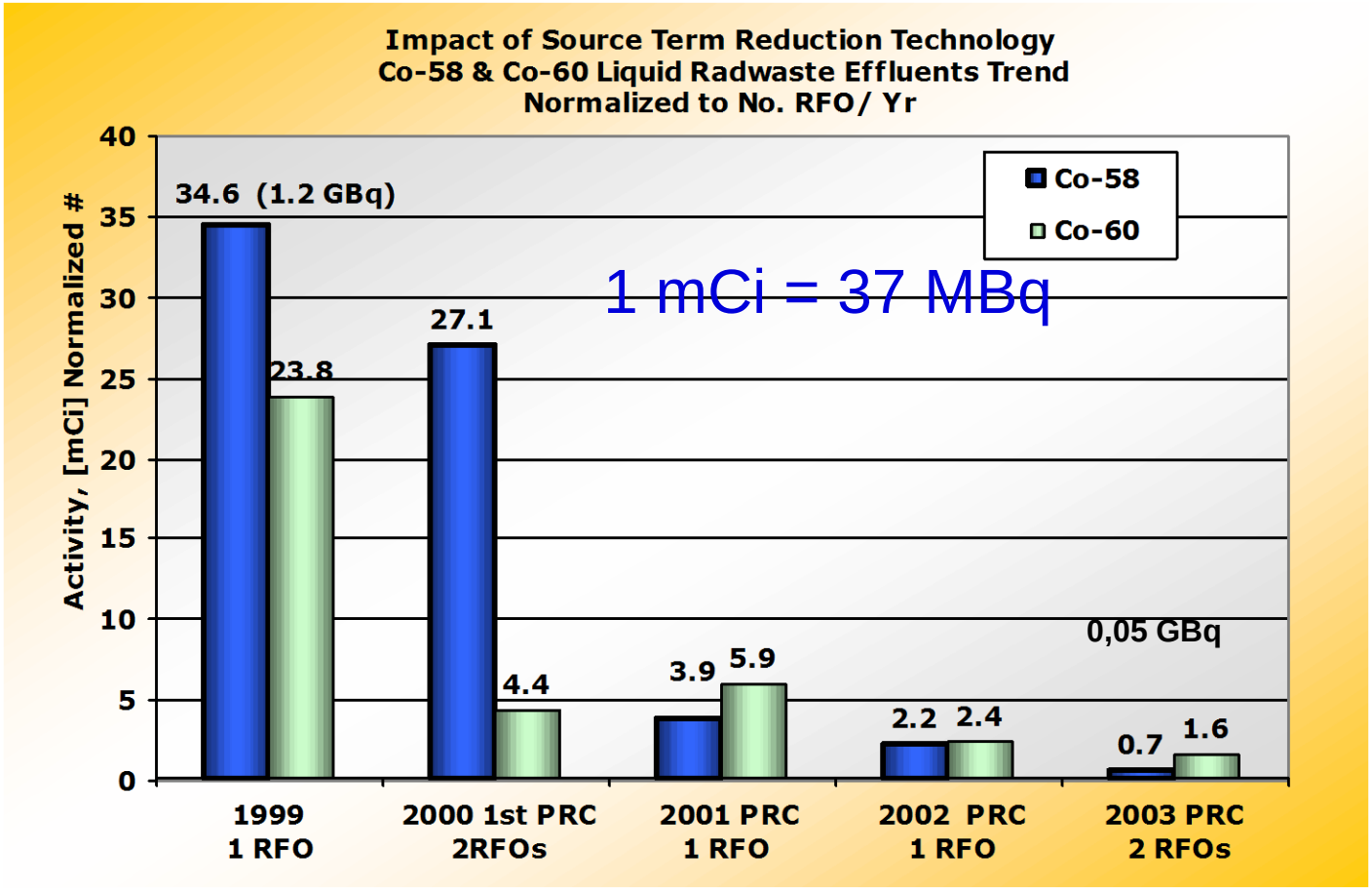
- Effective Dose Rate = $\frac{\text{Total dose for the job (mrem)}}{\text{Total time for job (hour)}}$
- Good Analysis Tool for RFO to RFO Comparison
  - Permits comparison between refueling outages with different scope of work in containment
  - Valid if shielding practice is consistent
  - Valid if methods are consistent
- RWP = Radiation Work Permit
- 1 mrem = 100 mSv

FPL Turkey Pt-3
Sustained Decrease in Outage EDR
Overall Before/After PRC-01 = - 88.4%

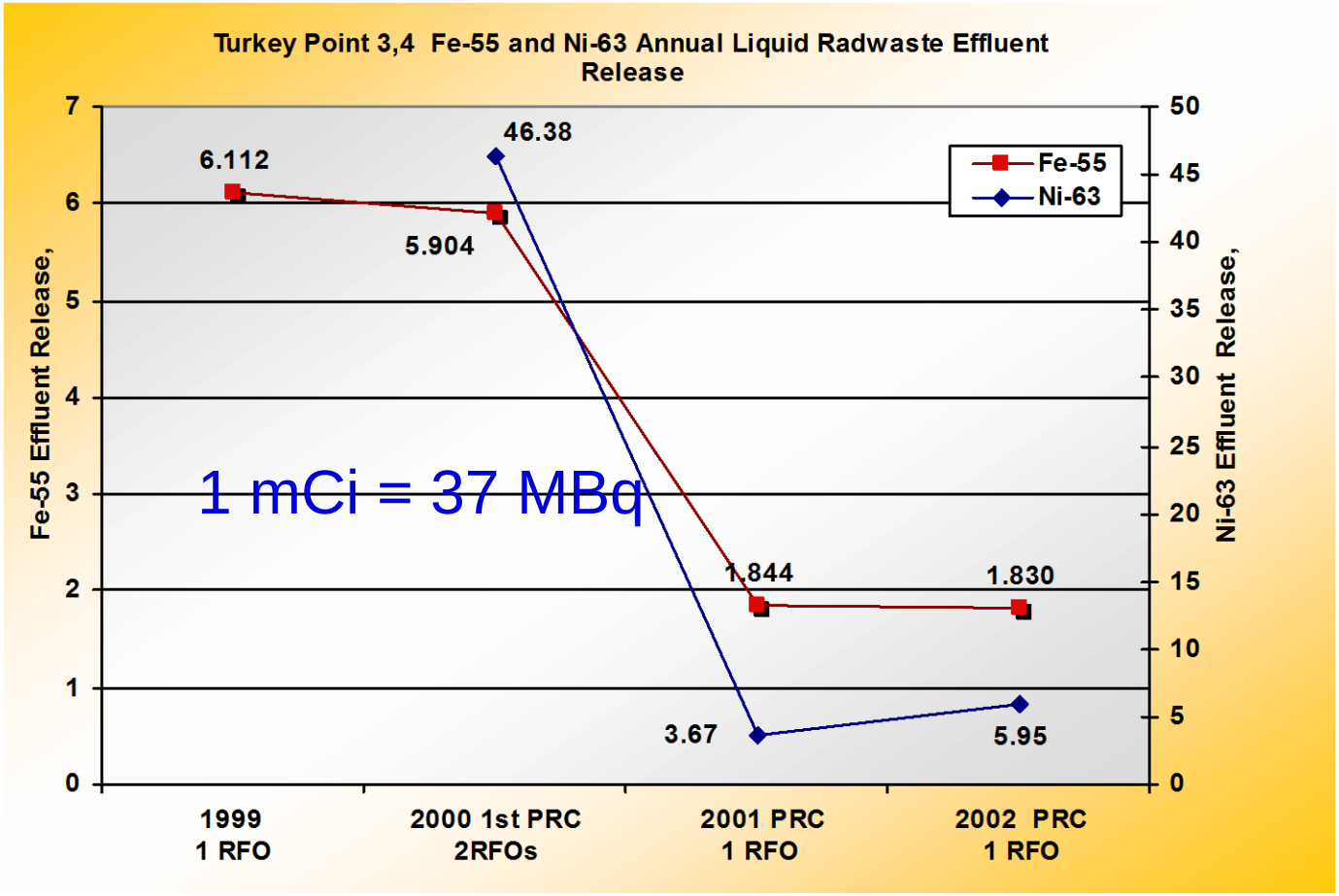


Annual Liquid Effluent Discharges
Co-58 and Co-60 Trend

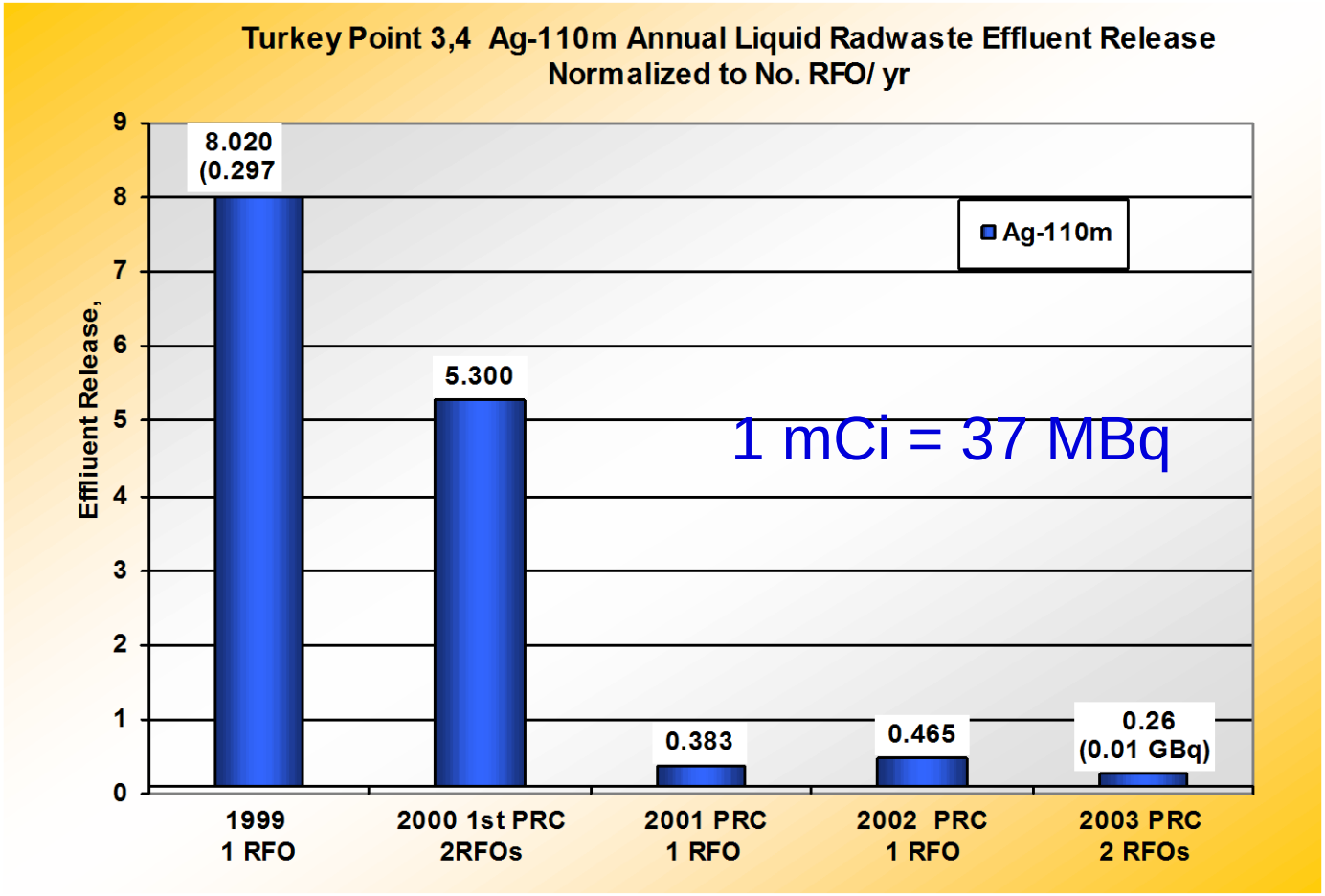
Liquid Radwaste Processing System:
Activated Carbon, Conventional Resins- No Ultra-filtration or Reverse Osmosis



Annual Liquid Effluent Discharges
Fe-55 and Ni-63



Ag-110m Decline



FPL Turkey Pt. 3,4 & VC Summer
Successful Source Term Reduction Summary

- **INPO Ranking Collective Exposure- Turkey Pt 3,4**
  - 4th Quartile in 2000, Avg RFO 140 to 160 REM
  - 1st Quartile in 2006, 1 Unit top Decile, 52.7 REM
  - INPO Good Practice for Source Term at Turkey Pt 3,4 and St. Lucie 1,2
- **INPO Ranking - VC Summer**
  - 3rd Quartile 2000, 140 to 160 REM
  - 1st Quartile 2006, RFO16 - 52 REM TLD
- **Effective Dose Rate Reduction**
  - 93.3% reduction in effective dose rate for Containment RWPS
  - 90% reduction in EDR for all RWPs
- **Avoided Occupational Radiation Exposure for multiple RFOs**
  - 325 REM (3.25 Sv) estimated of avoided occupational exposure for Turkey Pt U3, same for U4 LLW Disposal Reduction Curies and Disposal Costs
  - $250,000 USD avoided per RFO in primary resin curie surcharge for Low Level disposal
- **Faster Shutdown Sequence**
  - 26 hours earlier for last RCPs to be taken out of service (O/S)

Turkey Point-3,4 Summary (cont.)

- **- 60.0%**
  - **Reduction in number of High Radiation Area**
- **- 35%**
  - **Reduction in contract HP staff, $400,000 avoided costs every RFO.**
- **- 76%**
  - **Reduction in Hot Spots**
- **- 49 X (fold)**
  - **Reduction in annual effluent activity discharged for Co-58 and 15 fold for Co-60**
- **- 87.7 %**
  - **Reduction in Ni-63 annual effluent activity discharge, and 70% for Fe-55**

- **1st World Record Low Dose Performance for U4 in 2005.**
  - **5.407 REM (54.07 mSv) U4 RVH**
- **2nd World Record Low Dose Performance for U3 in 2005.**

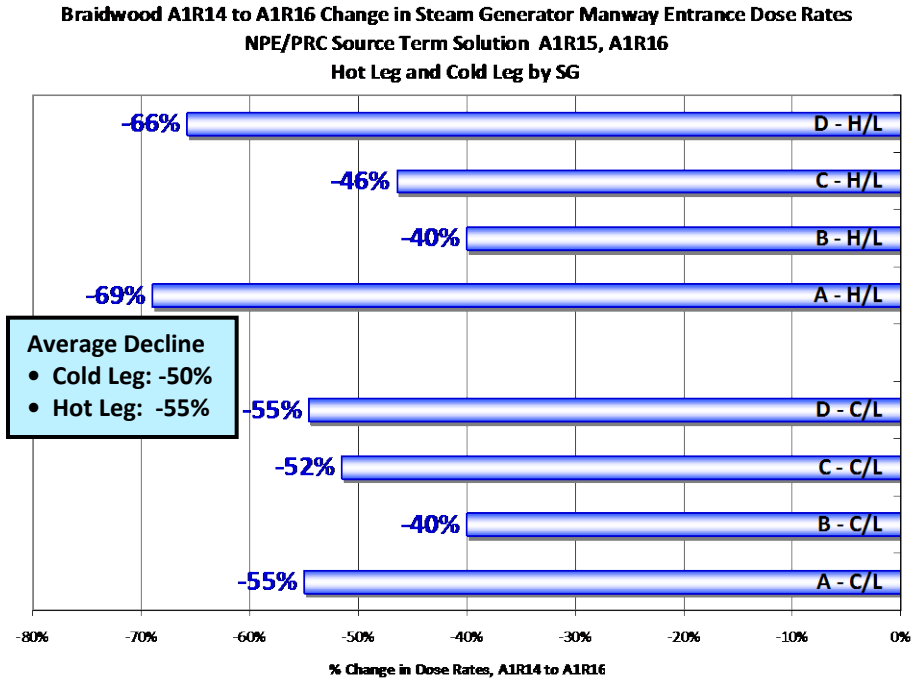
Benchmarking
Braidwood -1 Improving Performance

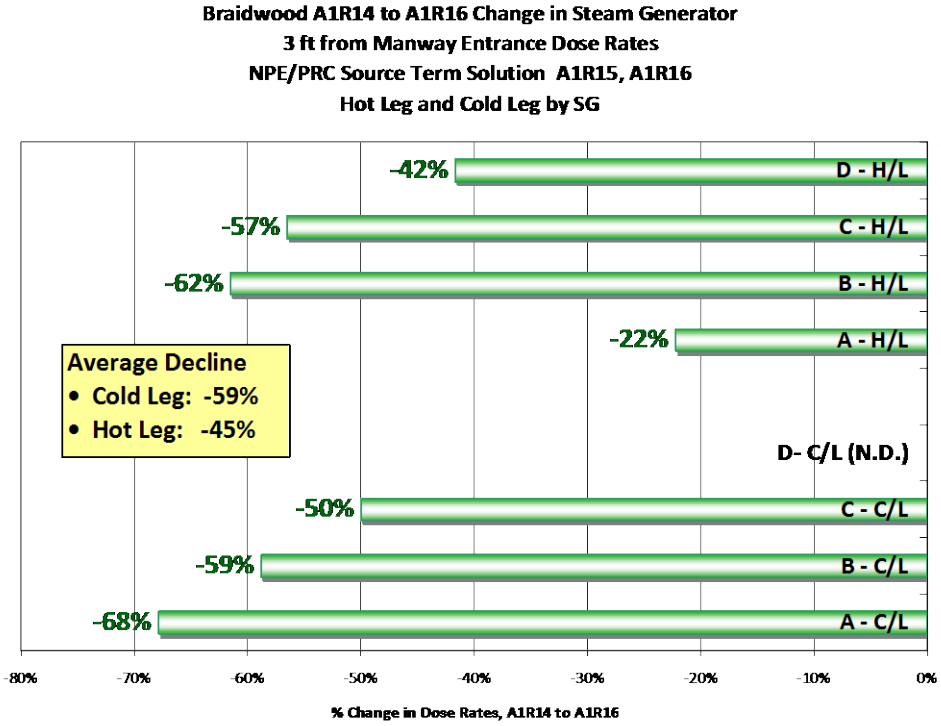
- **Braidwood-1 Implemented NPE/PRC Technology**
  - A1R15 First Implementation
  - A1R16 2nd Improved Implementation
- **Byron-1 Implemented Ortho-MacroPorous Resin**
  - B1R15 3rd Use of Macroporous, 2nd Otho Macroporous
  - B1R16 Ortho Macroporous
  - B1R17 Orth Macroporous

NICKEL CORE CRUD RELEASE/REMOVAL					
	Ni, [gr.]	% Change		Ni, [gr.]	% Change
A1R14	4012.000		B1R15	1936.000	
A1R15	3589.000	-10.5%	B1R16	3500.000	80.8%
A1R16	1467.00	-59.1%	B1R17	3212.00	-8.2%
Decreased CRUD		-63%	Increased CRUD =		66%

Braidwood A1R16 Source Term Success: SRMP

- **A1R14 to A1R16 Significant Decline In Dose Rates in SG Manway Entrance and 3 ft**
- **SG Manway Entrance:**
  - CL -44%, HL -53%
- **Tubsheet MP:**
  - CL -59%, HL -45%






BWR

Monticello R22 to R23 Results

PRC Use R22 RFO, Cycle, R23

April 2007

- -28%
  - Decline in BRAC Points
  - Main Circuit Piping- Standardized Locations
  - 2003 to 2007: Declined 28.5 %
- -38.5%
  - Decline RPV Effective Dose Rate
  - R22: EDR =1.45 mRem/RWP-hr
  - R23: EDR = 0.89 mRem/RW-hr
  - Change: - 38.5 %
- -71.1 %
  - Fuel Floor (Fuel Move/Inspection/CRB Replace)
  - R22: 0.78 mRem/RWP-hr
  - R23: 0.21 mRem/RWP-hr
  - Change: - 71.1 %

Vermont Yankee R25 to R26 Results

PRC Use R25 RFO, Cycle, R25

May 2007

- **-28%**
  - Decline in A Recirc Suction
  - Main Circuit Piping- Standardized Locations
  - 2005 to 2007: Declined 28.5 %
- **-48.%**
  - Decline IVVI RWP Dose
  - 16.76 REM Planned IVVI RWP Dose
  - 8.172 REM Actual IVVI RWP Dose
  - Declined: -48%
- **-43.4 %**
  - Drywell RWP Dose
  - 21.21 REM Planned RWP Drywell Dose
  - 12.0 REM Actual RWP Drywell Dose

Radiation Safety Improvement Results

LANL/ NPE Engineered Solution for Reducing Source Term

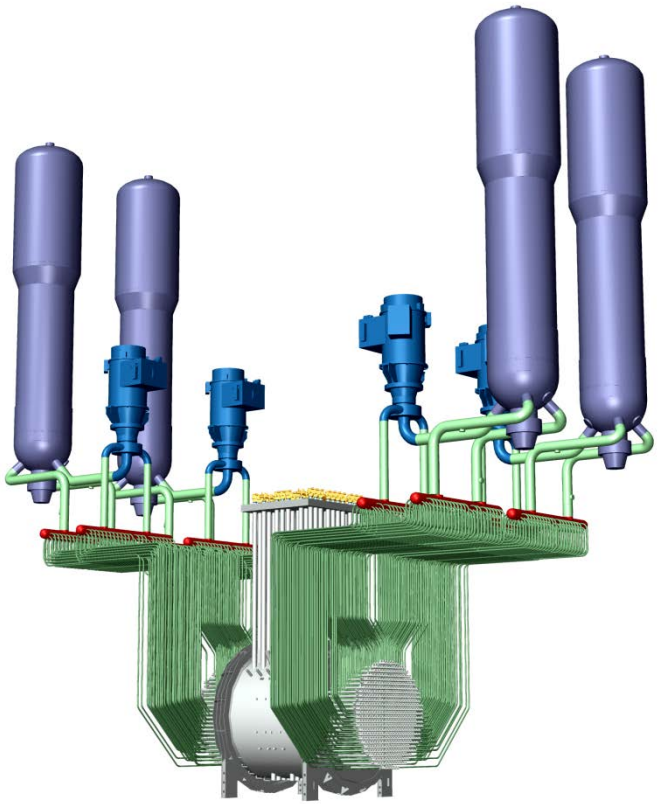
- Peach Bottom 3R 15 and 2R16 Drywell Dose Rates Reduced
  - Permited Drywell Down Post from Locked High Radiation Area to High Radiation Area
  - Support Outage Performance
- Platform Post Removal Dose Rate
  - 20 to 30 times Lower Dose Rate
  - (when Benchmarked to Limerick-1)
- Platform Contamination Levels
  - 1000 times lower smearable contamination
  - (when Benchmarked to Limerick-1)

- PBAPS 3R17: Station Low Dose Record Achieved
- PBAPS 2R16: Station Low Dose Record Achieved

BWRs

- Application on Reactor Water Clean-Up (RWCU)
  - 100% time
  - Refueling
- Expanding to Condensate Polishers
  - Start-up Rinse In
  - Expanding to On-Line Portion of CPS

CANDU's: Bruce Power
Bruce A/B

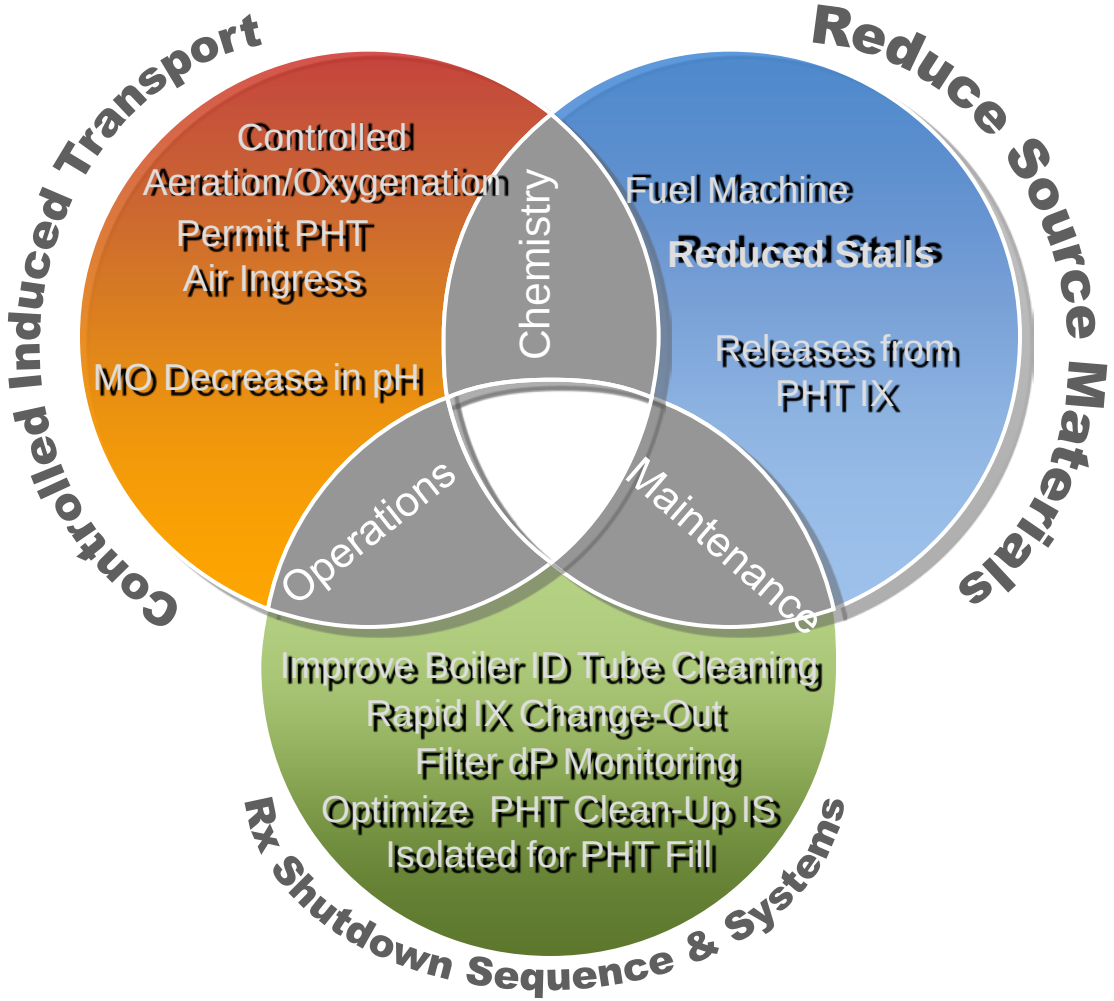


CANDU: BRUCE POWER

Operations-Maintenance-Chemistry

7 Element Solution- Media is 1 Element

Only as Effective as Weakest Link



Discovery: Bruce BU7 Activity Transport
Co-60 Increase 1,000 X, Sb-124 Increase 10,000 X

Bruce Power

Standard PHT

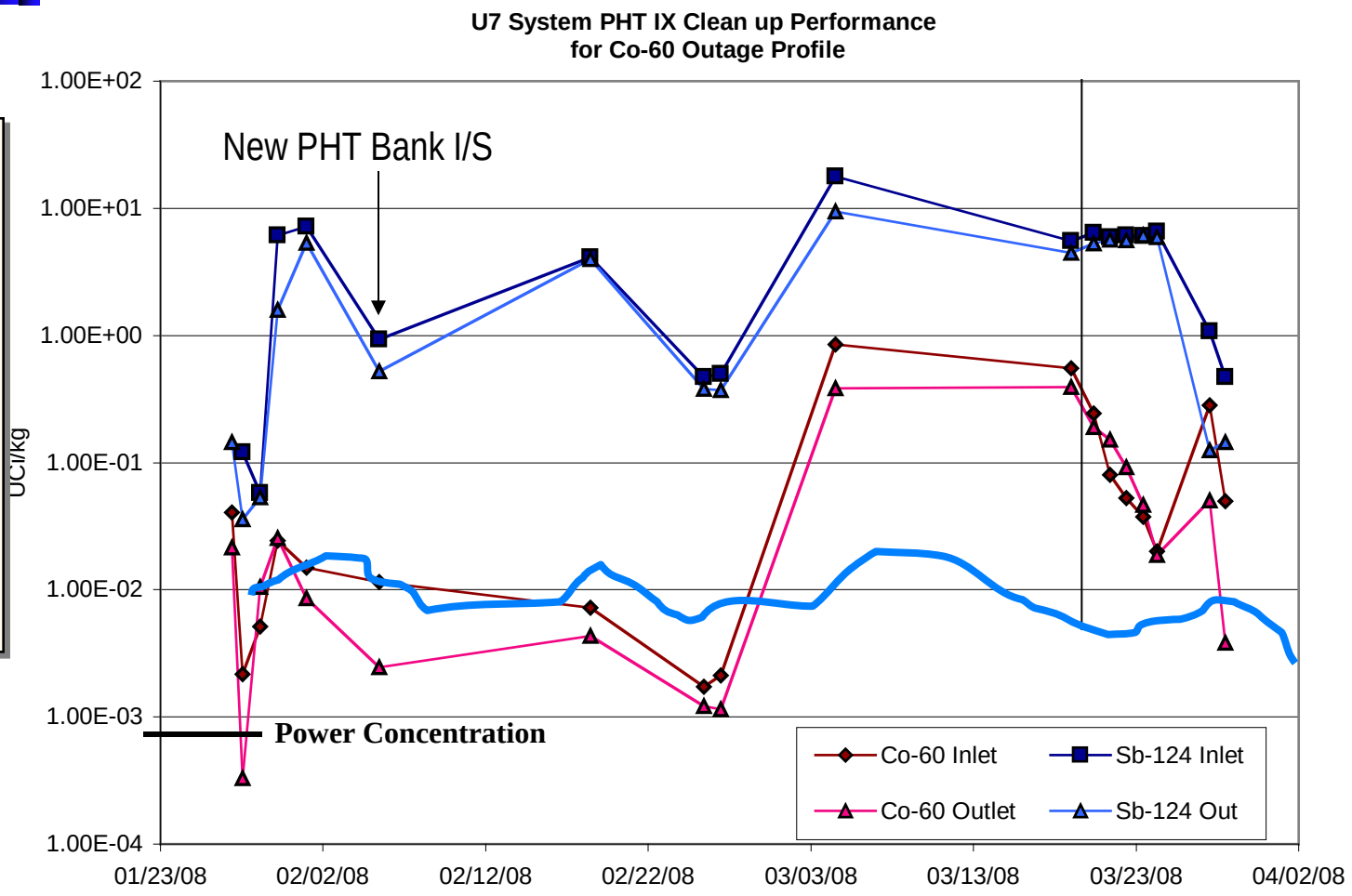
Ion Exchange Resin

Shows Almost No

Removal of

Co-60 or Sb-124

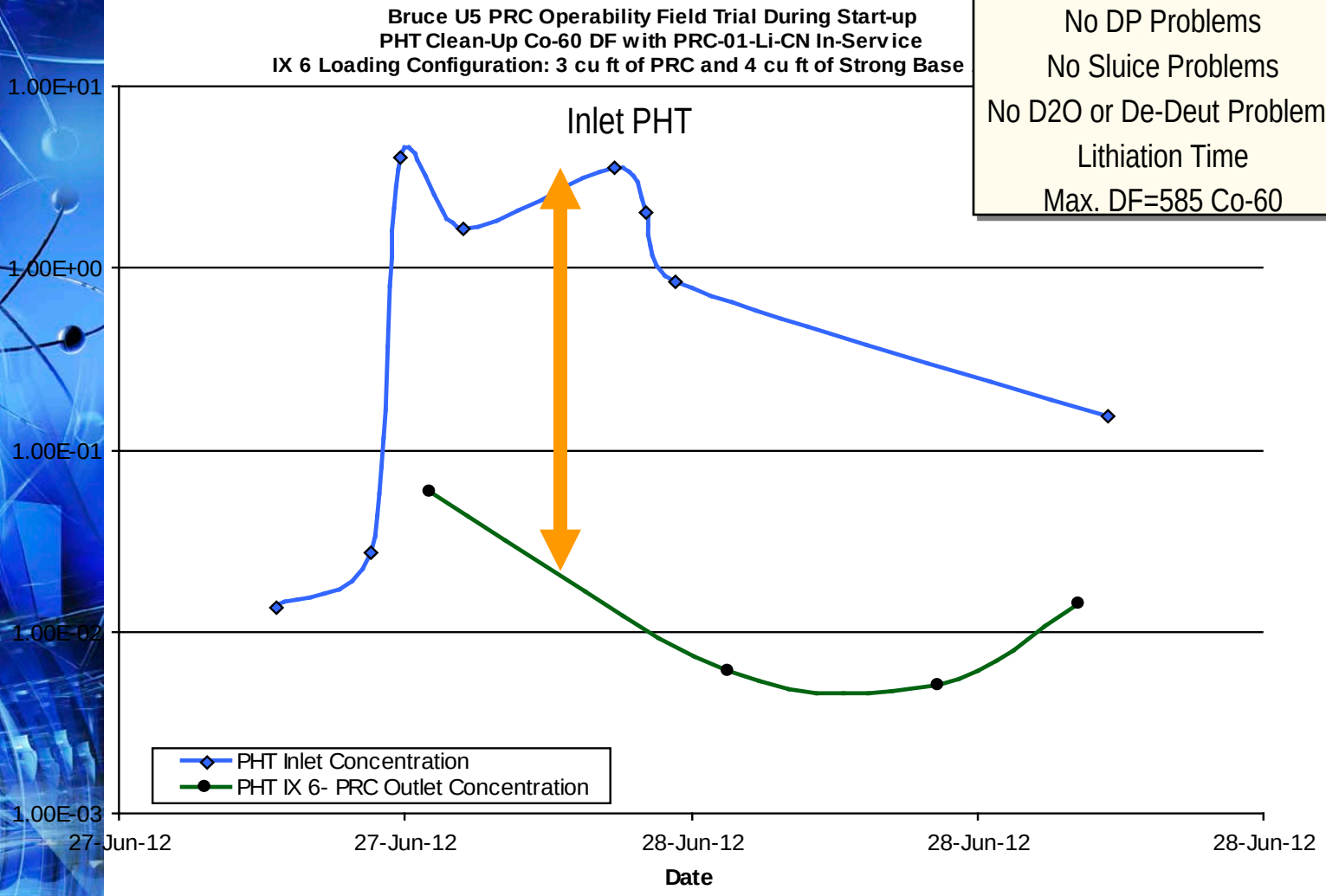
Entire Outage



Results: PHT System Bruce B-851 Outage

Full System Operability Trial PRC-01M-Li-CN

Full Scale Operability Test
No DP Problems
No Sluice Problems
No D2O or De-Deut Problems
Lithiation Time
Max. DF=585 Co-60



Collaboration Opportunity for Asian Reactors

- Technology Full Developed and Demonstrated Successful
  - More than 10 years of Operating Experience
  - Lead PWRs Now Lowest Dose Plants in US
    - DC Cook-1,2 4 Loop PWR Design
    - VC Summer, 3 Loop Design
    - Davis Besse, B&W Design
- BWR and CANDU Solution Developed
  - Monticello, Peach Bottom-2,3 BWR Design
  - Bruce B, Unit 8 CANDU Design
- Searching for a Lead Plant in Asia
  - Collaboration with US NPE Engineers and LANL
  - Exempt Technology Use License Fees
  - Please Express Interest to Ms. Robinson

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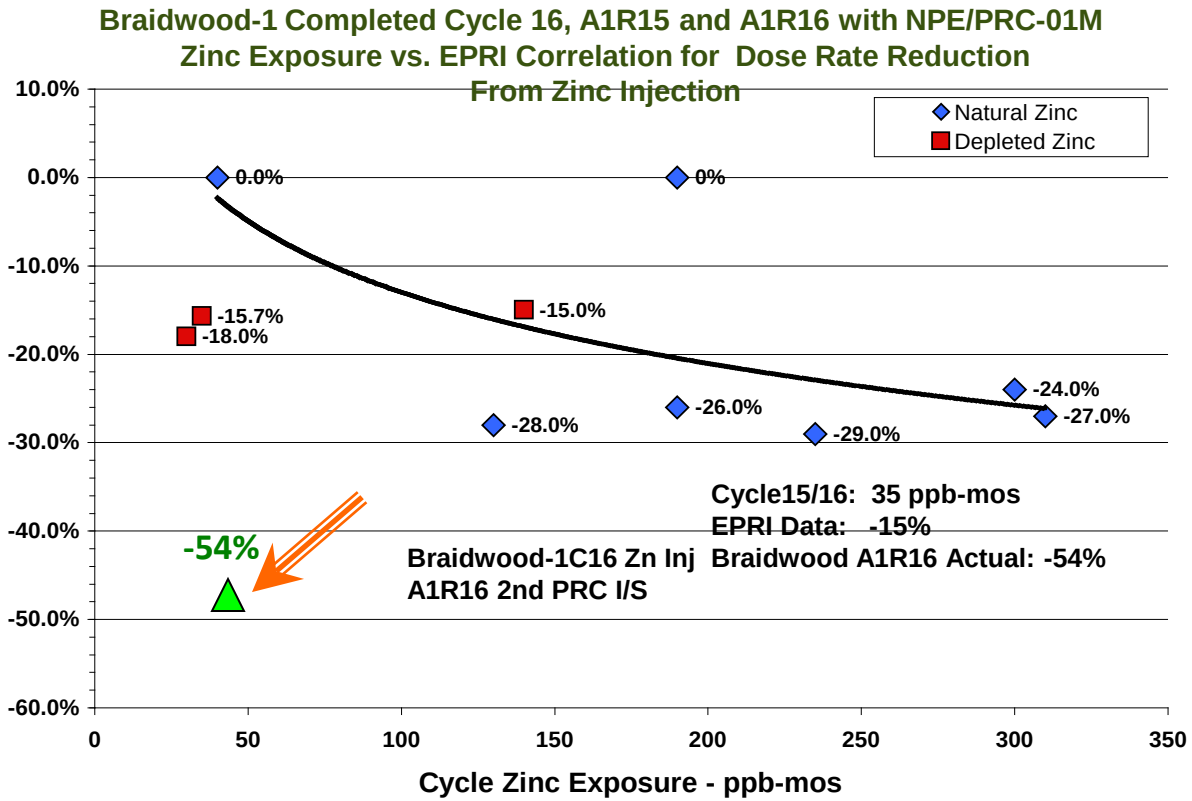
QuickTime™ and a decompressor are needed to see this picture.

Thank You Very Much for Your Attention
ご清聴ありがとうございました

Parsing Zinc Injection vs. NPE/PRC Engineered Solution

- **EPRI Zinc GL: 0 to -15 % Dose Reduction, 35 ppb-mos**
  - Bugey 2, Sequoyah-2, Palisades and Seqyoyah-1 show no Dose Rate Reduction
- **Braidwood: -54% Dose Reduction with NPE PRC-01M**
  - All NPE/PRC Plants Show Signifcant and Sustained Dose Reduction, without Zinc Injeciton.



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

Zinc Related Fuel Failures Documented By EPRI
Cost of Failure: Up to $40M-$80 M/event

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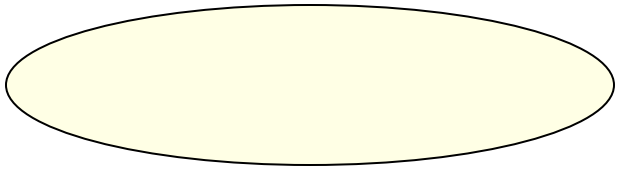
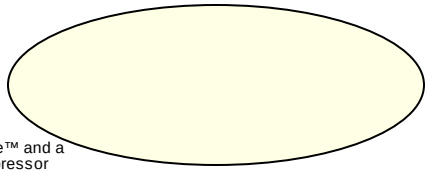


- **EPRI Fuel Reliability Program**
- **Zinc Injection Fuel Failures Recently Reported by EPRI**
- **“Take Action to Reduce CRUD on Fuel”**



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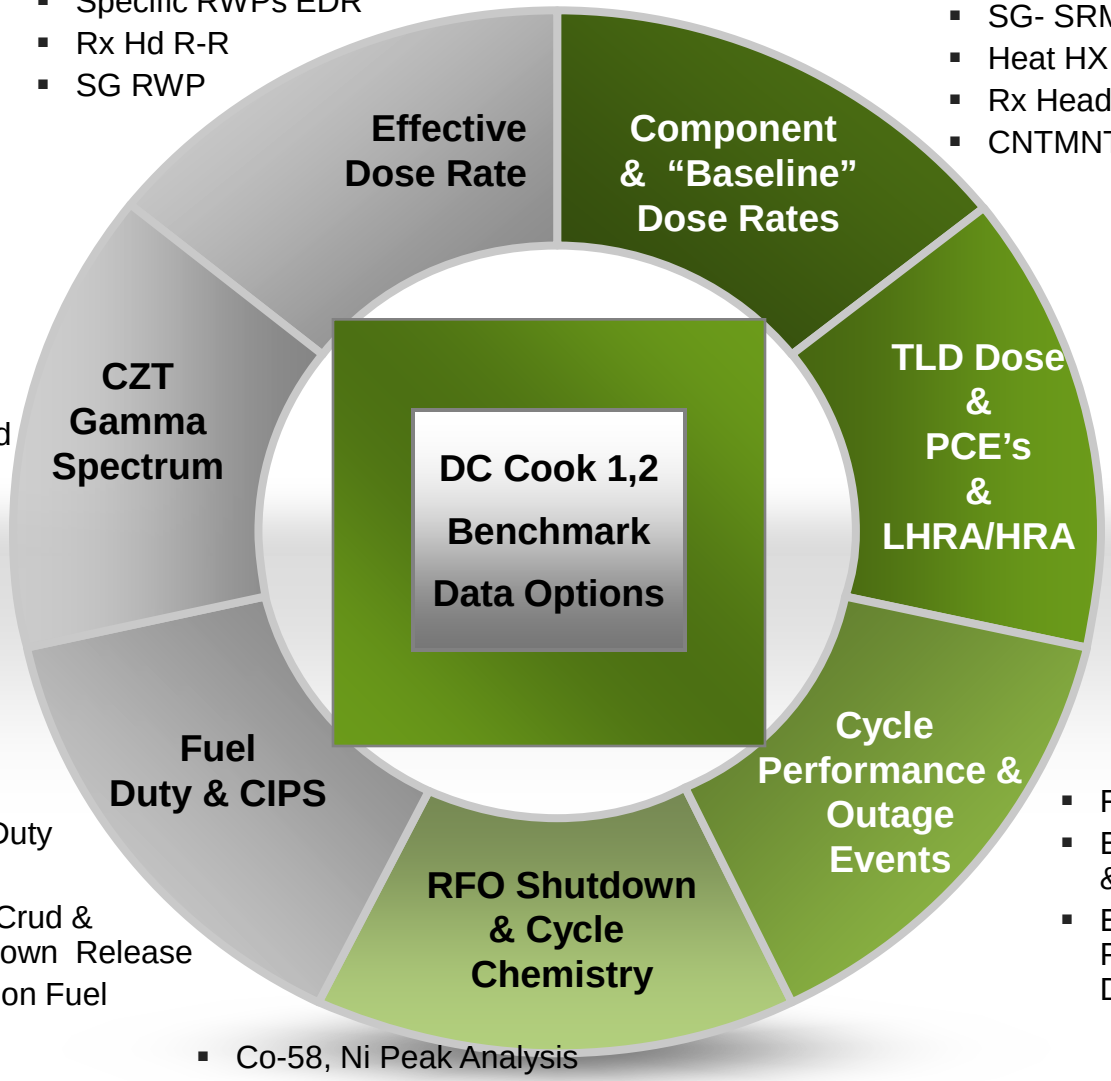
Metrics and Measures

- Measurement Instruments
- Dose Rates
- Baseline- CNTMT Monitors
- SG- SRMP
- Heat HX
- Rx Head D.R
- CNTMNT GA

- Specific RWPs EDR
- Rx Hd R-R
- SG RWP



- Field Trials
- Gamma Spectrum
- Energy Emission Rate
- Pipewall Deposited Activity Estimate

- ED TLD Buyback
- PCE's
- # of LHRA/HRA

- Fuel Duty
- CIPS
- Core Crud & Shutdown Release
- Mass on Fuel

- Forced Outages
- Execution of Shutdown & Outage Plan
- Equipment Performance e.g CVCS Demin & Filter

- Co-58, Ni Peak Analysis
- Zn/ No Zinc
- Cycle Co-60 Correlation with HL Dose Rates
- Stranded Activity- LISV

CY 2000: First of a Kind Engineered Solution Developed for US PWRs

- Early 1998… Collaboration Process Engaged
  - Florida Power and Light/ LANL/ NPE
- Florida Power and Light Turkey Point 3,4
  - Sponsored Research & Development -First of a Kind Engineering.
  - $1.2 M Investment by Florida Power and Light
  - Developed Shutdown Sequence (Protocol) and PRC-01M Media

B&W Design

QuickTime™ and a
decompressor
are needed to see this picture.

2011: Davis Besse- RVH Planned 128 REM; Actual 40 REM
RFO 16 to 17M - Two Core Rotations