US DOE Los Alamos National Laboratory Technology Development for Reducing Plant Radiation Levels in PWRs, BWRs and CANDU's

2012 ISOE/NATC International ALARA Symposium

Ft. Lauderdale, FL

Patricia Robinson,(n,p) Energy, Inc.

Presentation Outline

- Introduction
- Brief Review Technology Origin
  - Los Alamos National Laboratory Polymer Filtration™ Science
- Engineering the Solution for <u>Each</u> Rx Type
  - PWRs
  - BWRs
  - CANDUs
- Summary of Results

Who is Los Alamos N.L.?

- 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 N.L. Major Awards
  - 118 R&D 100 awards since 1978
- Invented and Patented, Polymer Filtration Technology™
  - Exclusive World-Wide Grant of Licensed Inventions
  - R&D 100 Award-Polymer Filtration Technology
  - (n,p) Energy, Inc.- Single and Sole Licensee
  - NPE is not a Resin Vendor… We provide a 2 Part Engineered solution

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**

Blue Box: Selective Binding Capability of LANL Inventions

Outlined Box: Relevant to NPP

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac															

Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lw

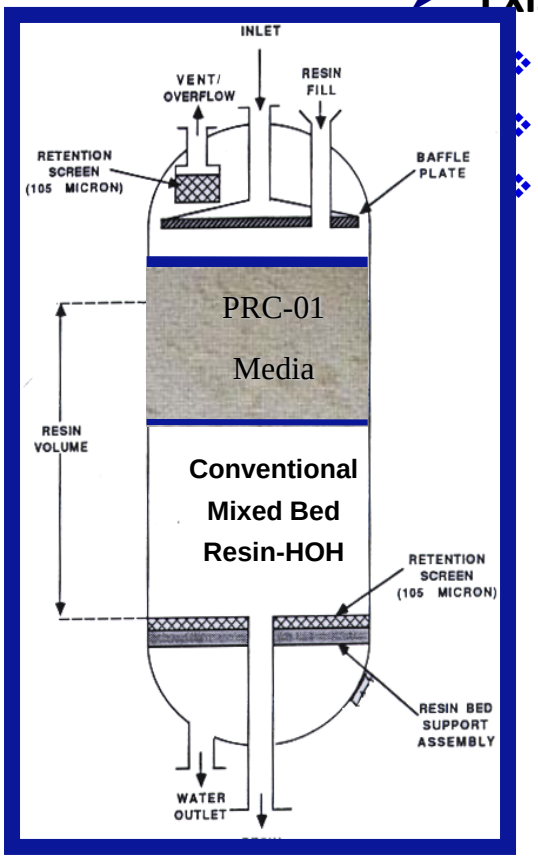
CY 2000: First of a Kind Engineered Solution Developed for US PWRs

- 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

How is PRC-01M Integrated?

Existing Plant Systems CVCS, Fuel Pool, Boron Recycle

- PWR: PRC-1 (bead) or BWR: PRC-2 (powdered)
- Existing Plant Equipment
  - PWR: Uses CVCS Demin
  - Both: Spent Fuel Pool
  - BWR: Filter/Deminerali
    - RWCU
    - FPC
    - Torus



PWR
Deep Bed Vessel

BWR
Precoat Filter/Demin

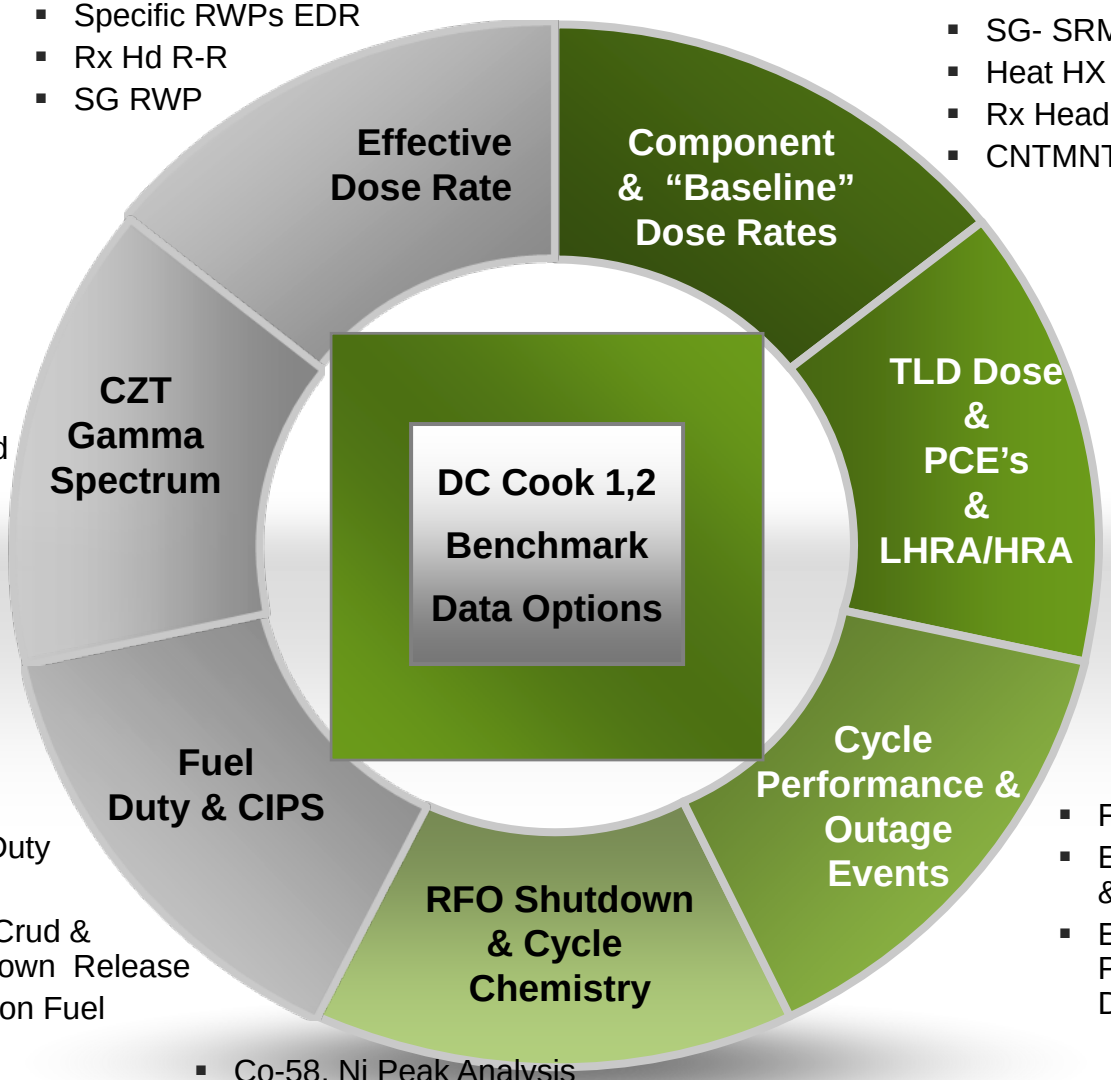
Lead Plants
NPE/PRC-01 Engineered Solution

- PWRs 3 Loops
  - Turkey Point-3,4
  - VC Summer
- PWR 4 Loops
  - DC Cook 1,2
- BWRs
  - Peach Bottom 2,3
  - Monticello
- Colmpleted > 120 Refueling Outages wit PRC-01/PRC-01M
- B&W:
  - Crystal River (First-Trial)
  - Davis Besse
- CANDU:
  - Bruce A/B

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

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 11 years Ago

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

Me

PRC-01

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

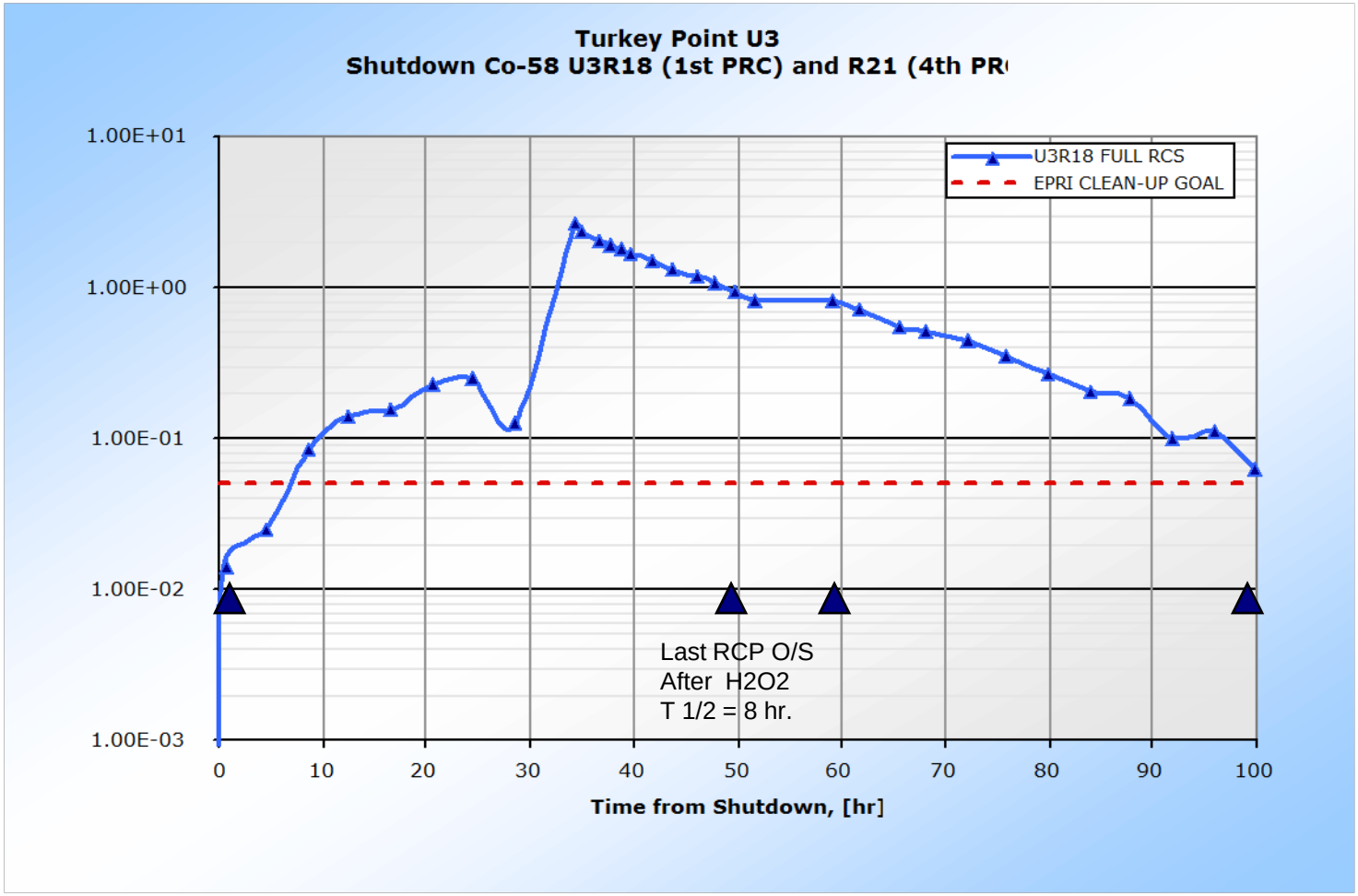
- **Turkey Point 3,4:**
  - Yes: Chemistry pH(t) = 7.1
  - Yes: PRC-01 Media Technology
  - No: Zinc, No Fuel Cleaning, No Elevated pH 7.2 to 7.4
  - Fuel Duty: Middle Fuel Duty
  - 13 to 18 EFPY SG, Inconel 600 TT
- **VC Summer**
  - Yes: Chemistry pH(t) = 7.1
  - Yes: PRC-01 Media Technology
  - No: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

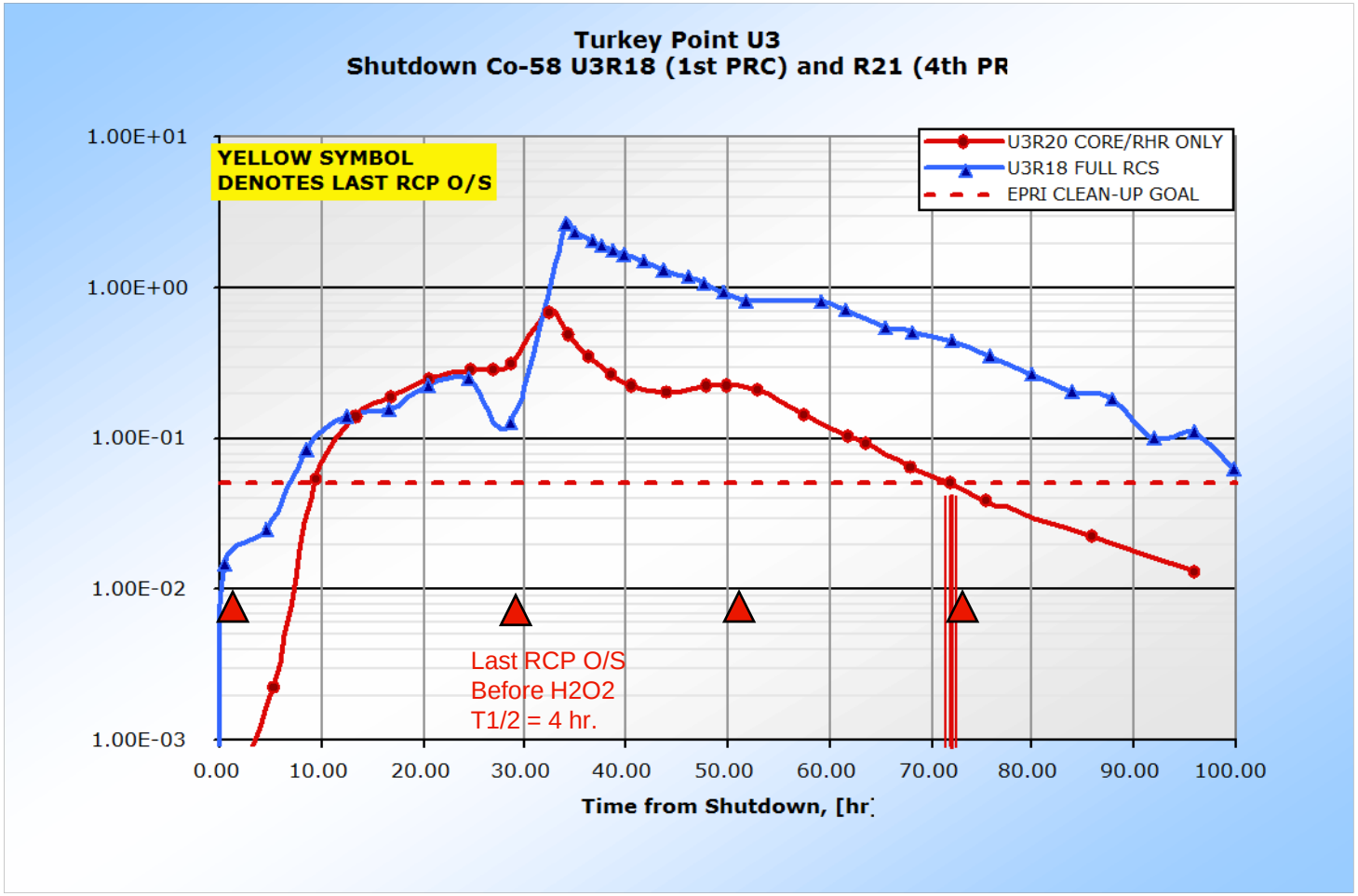


FPL Turkey Pt-3 R20 (3rd PRC)

Shutdown Co-58

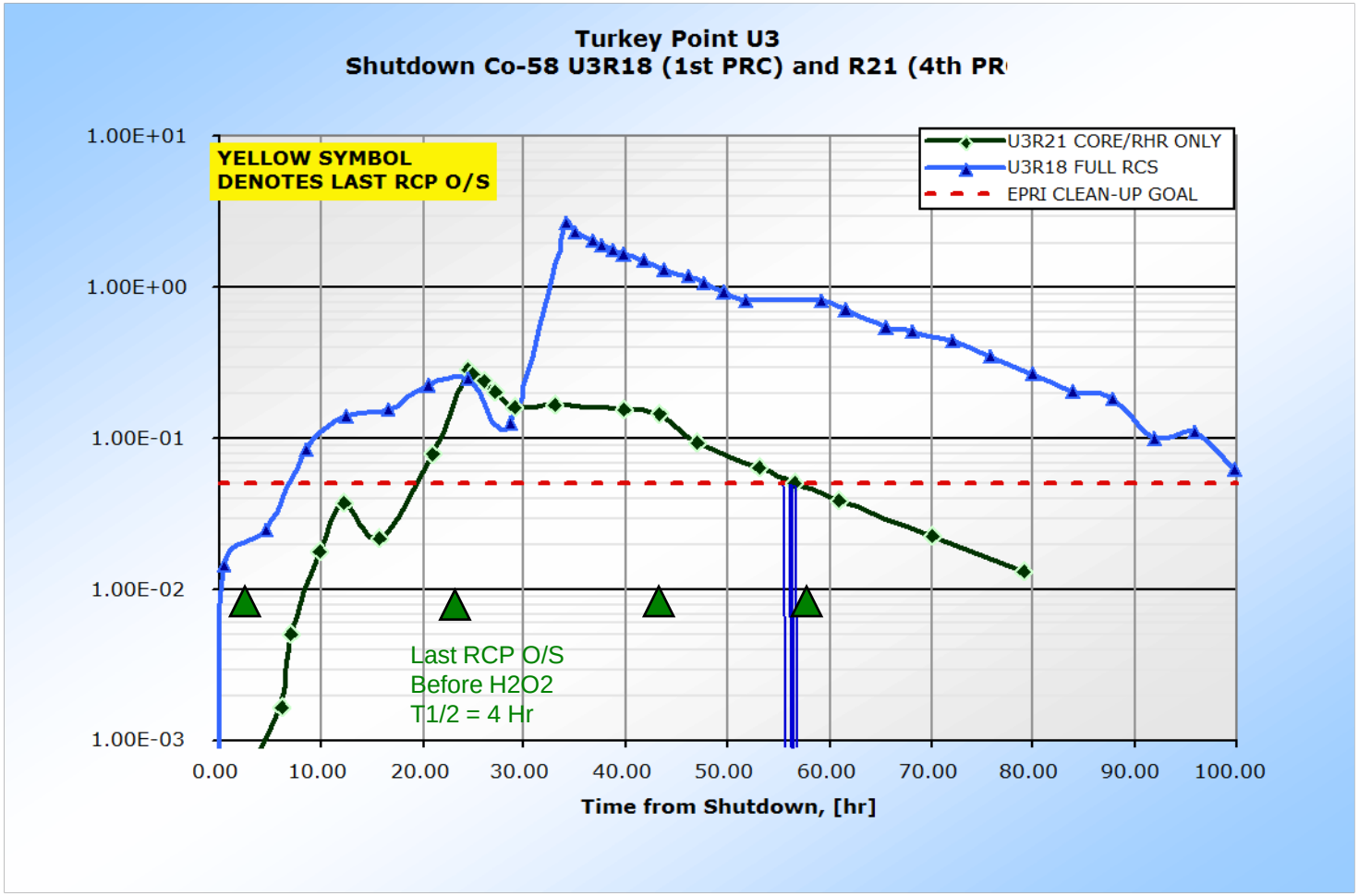
70 Hours to Clean-Up Goal

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

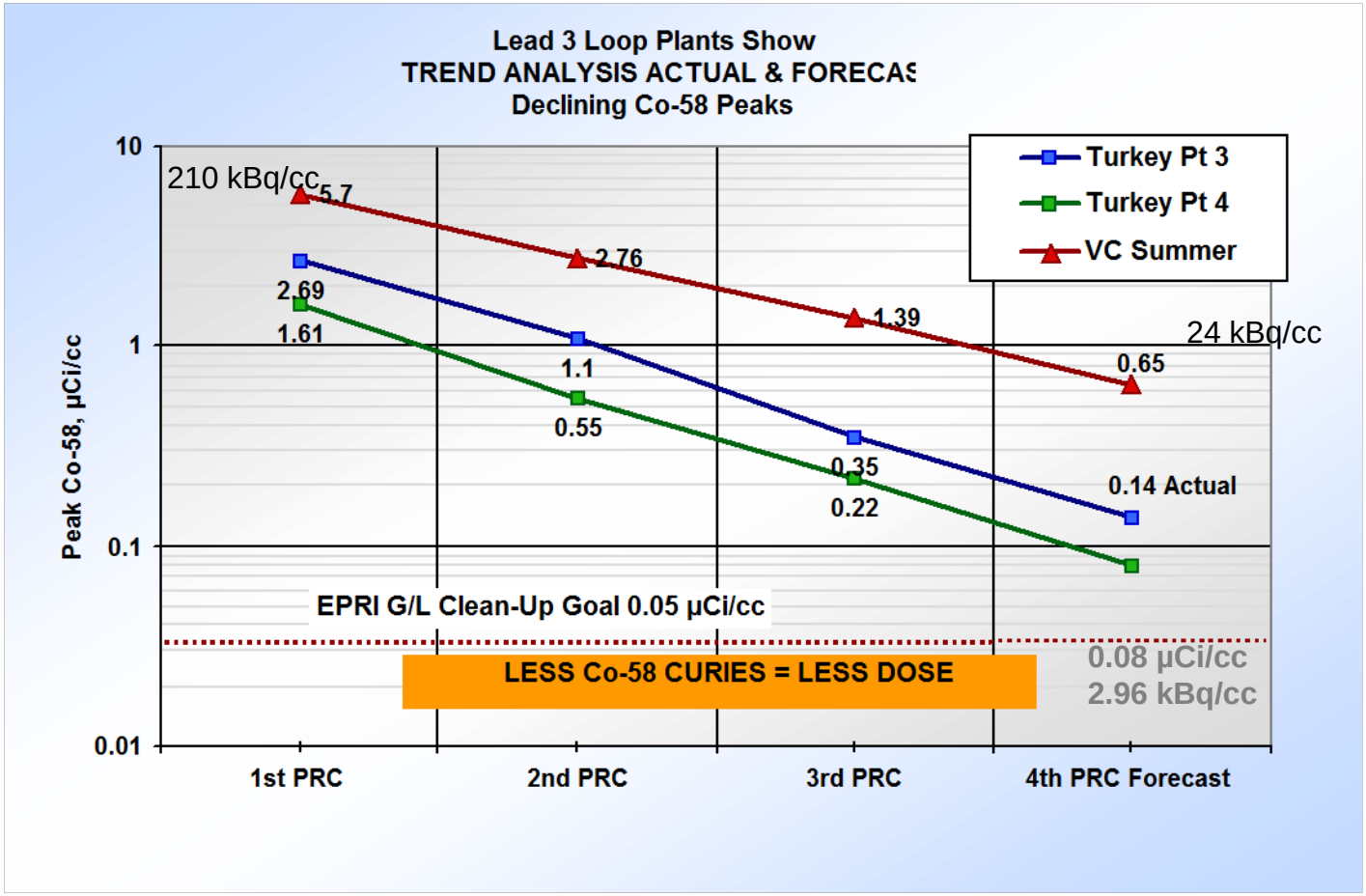


FPL Turkey Pt-3R21 (4th PRC)
RCSP OOS Before Peroxide Injection
Shutdown Co-58 56 Hrs to Clean-Up Goal

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



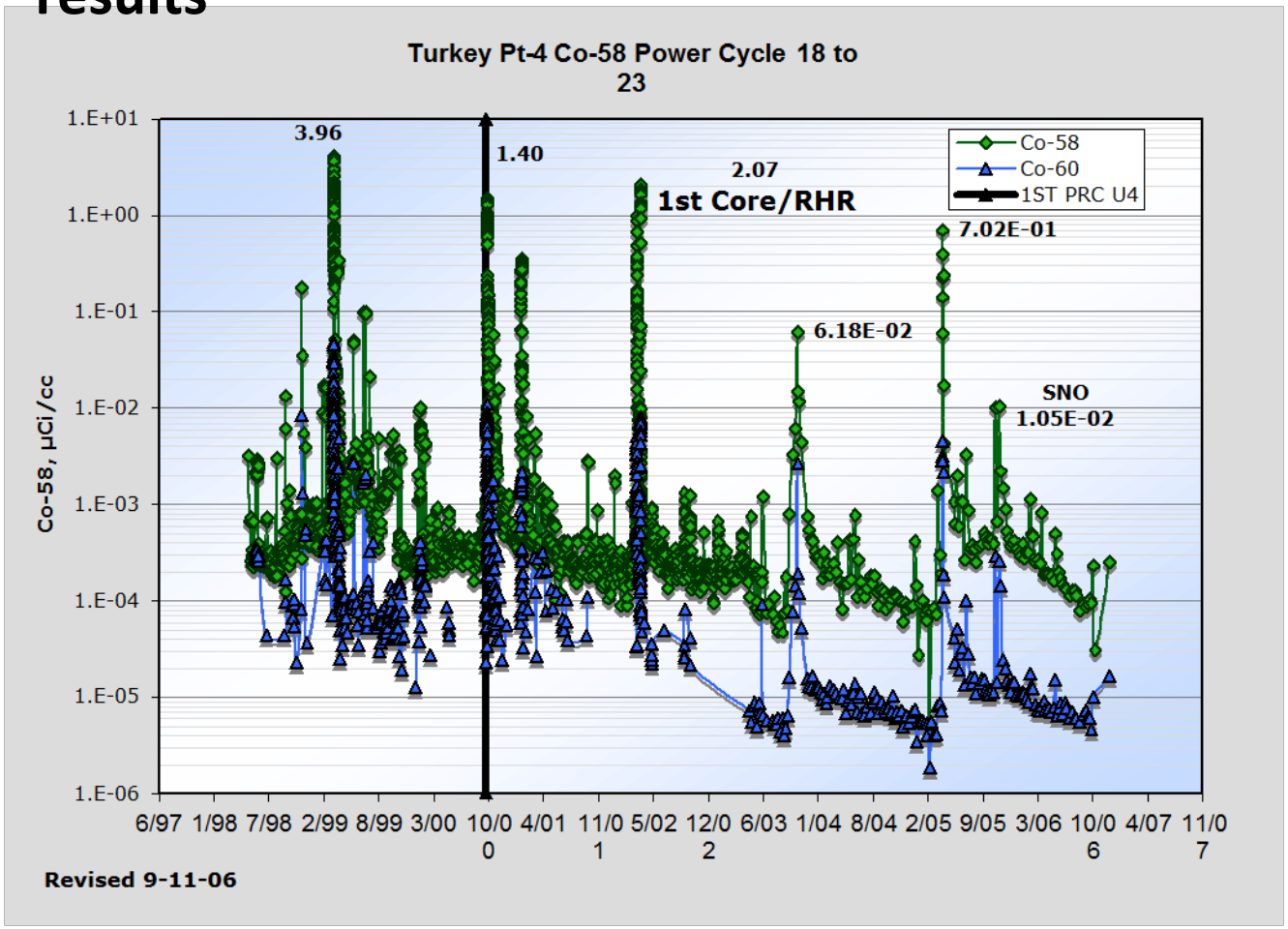
Turkey Pt 3,4 & VC Summer Sustained, Predictable Decline in Co-58 & Co-60 Shutdown Peak



1 uCi/cc = 37 kBq/ cc

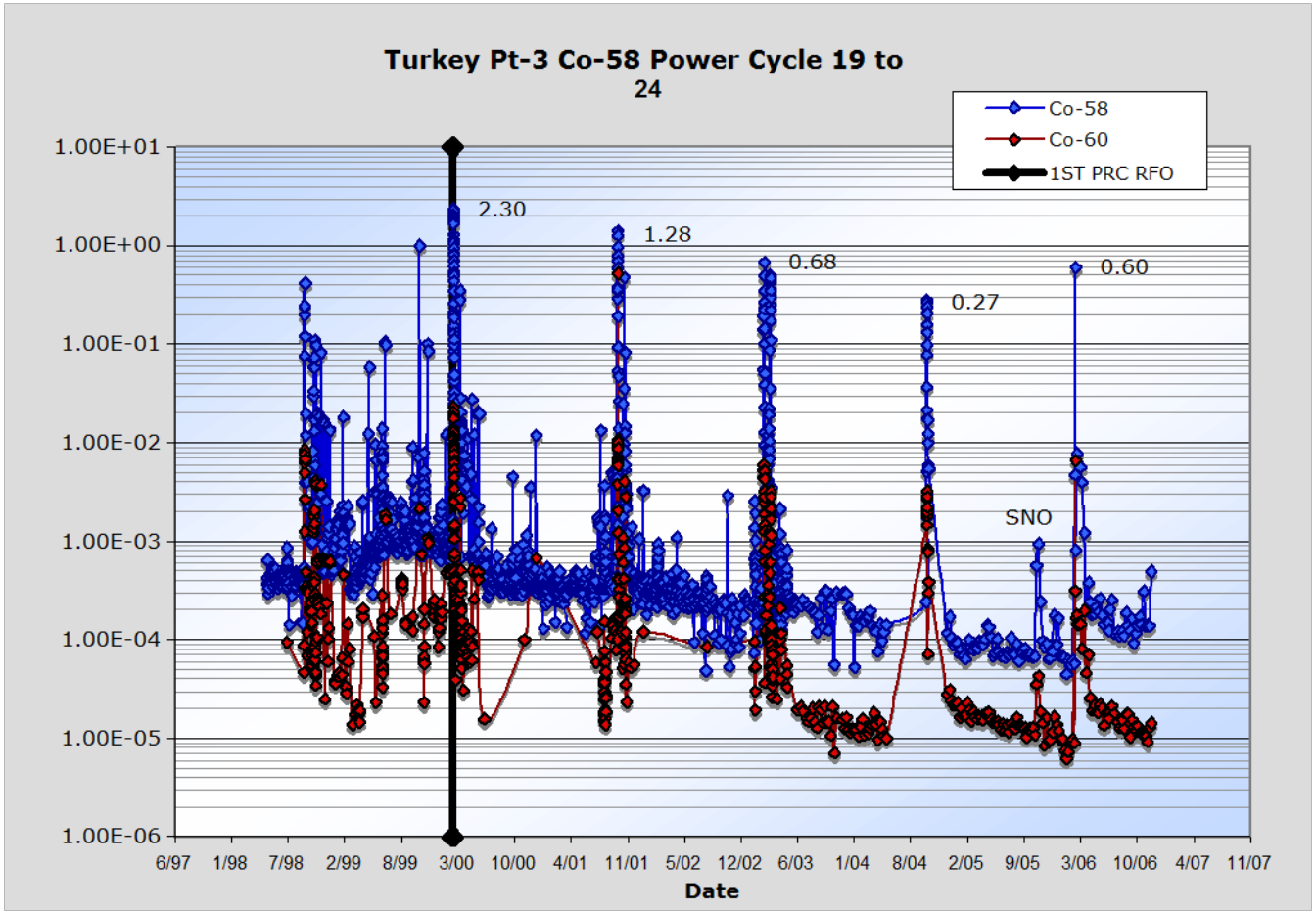
Declining Co-58 and Co-60 at Power Reactor Coolant Concentrations

- Long duration steady state cycles yield best results



Both Units…

- **Co-60 Decline at Power Drives Lower Containment Dose Rates for RFO**

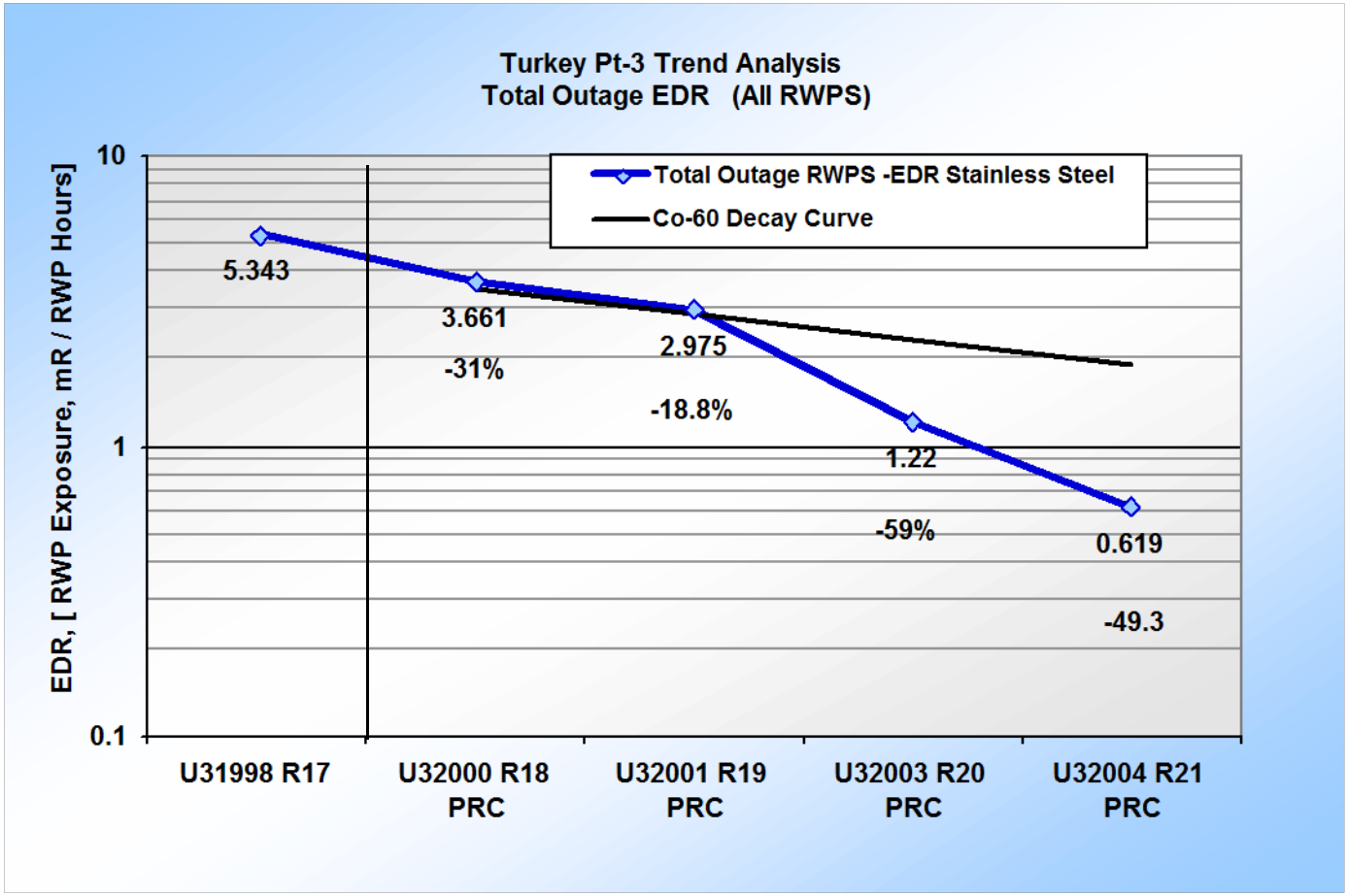


Effective Dose Rate Trending

- 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%

1 mrem = 100 mSv

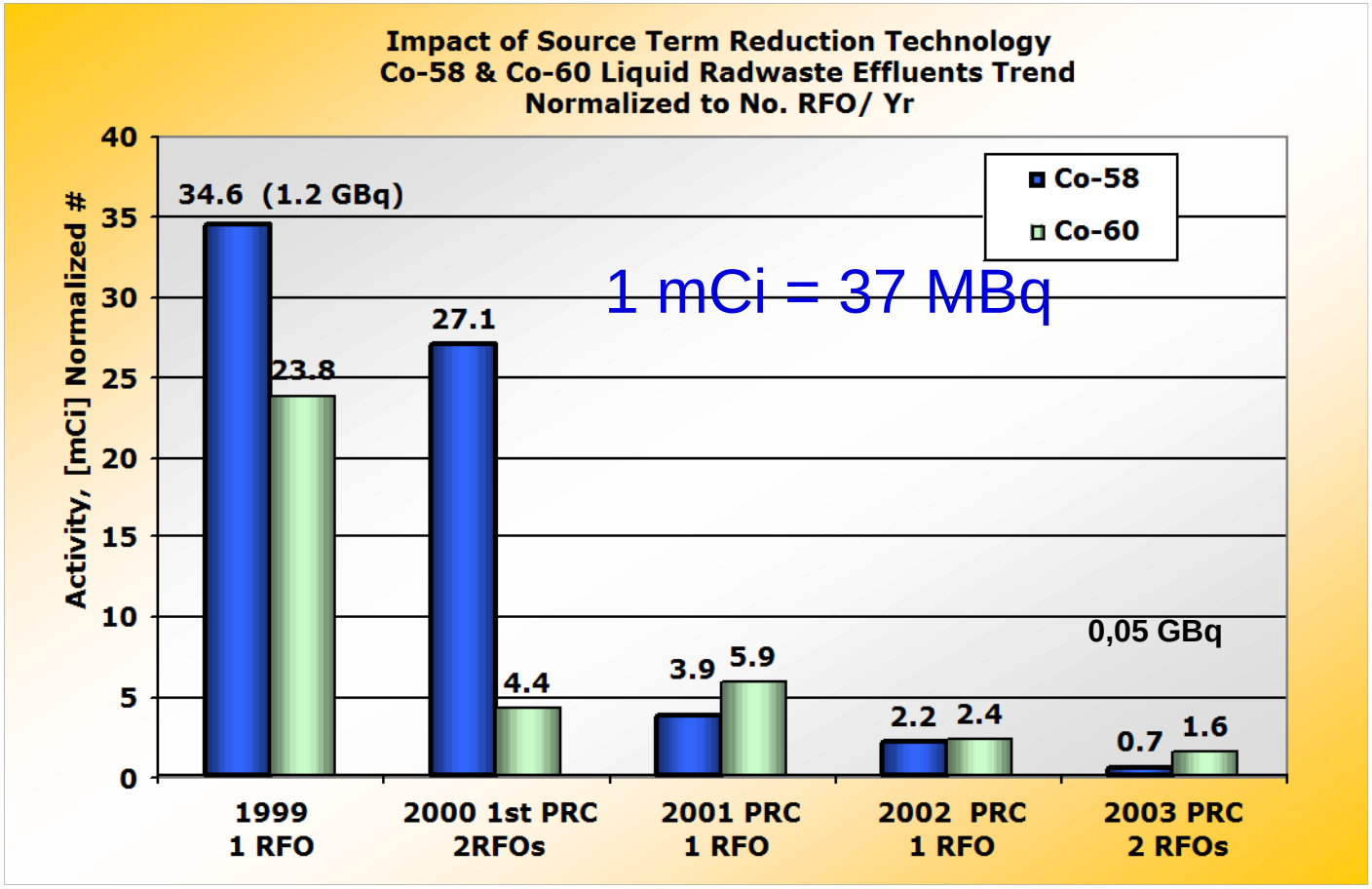


Reduced Volume and Curies for Waste Disposal

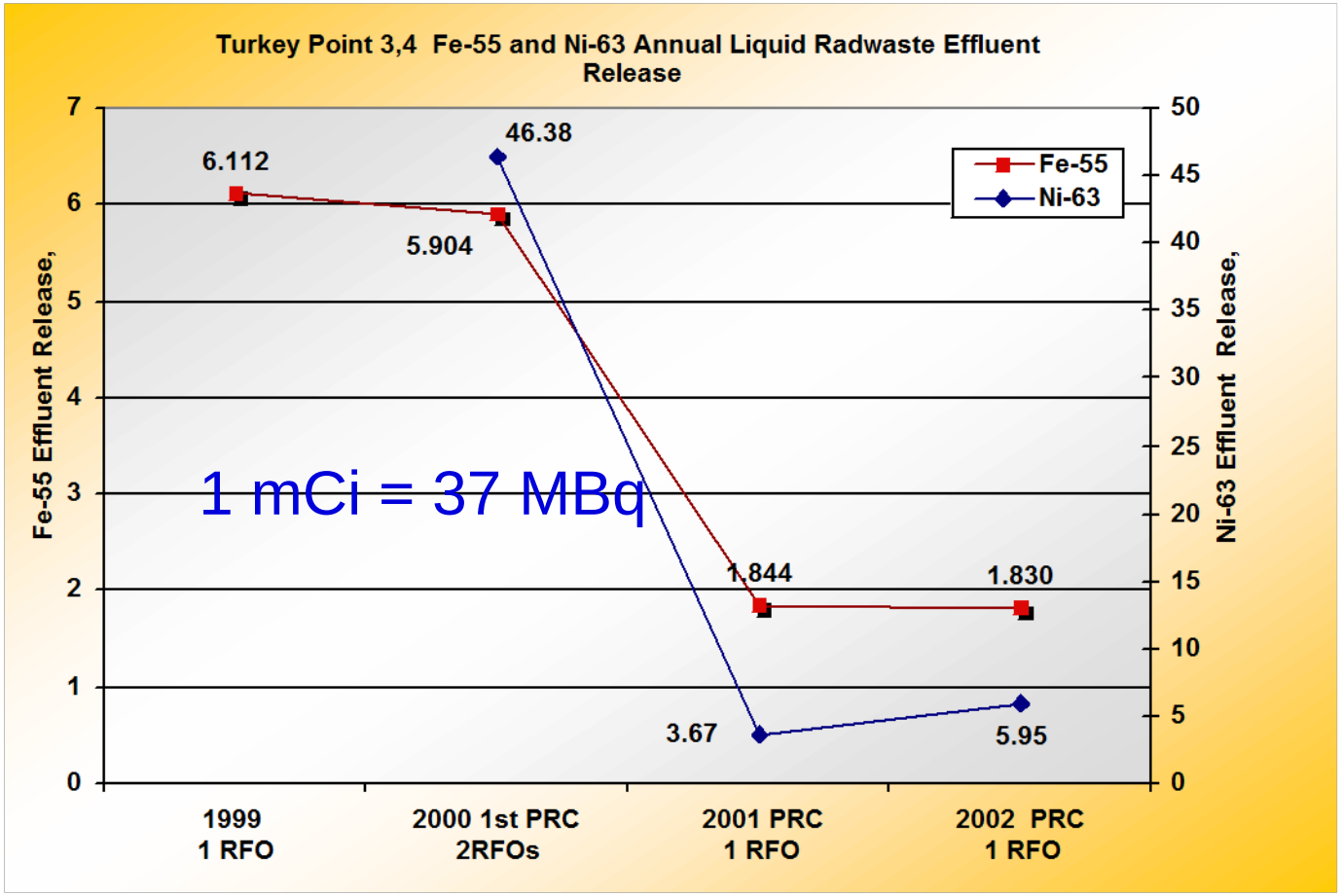
- **Before**
  - ~10 RCS Filters / Cycle
  - 5 to 200 R/hr Vessel Dose Rate
  - 1 R/hr = 10 mSv/hr
- **Now**
  - 1 RCS / Cycle
  - 6 um RCS Filter
  - 200 mR/hr Dose Rate

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

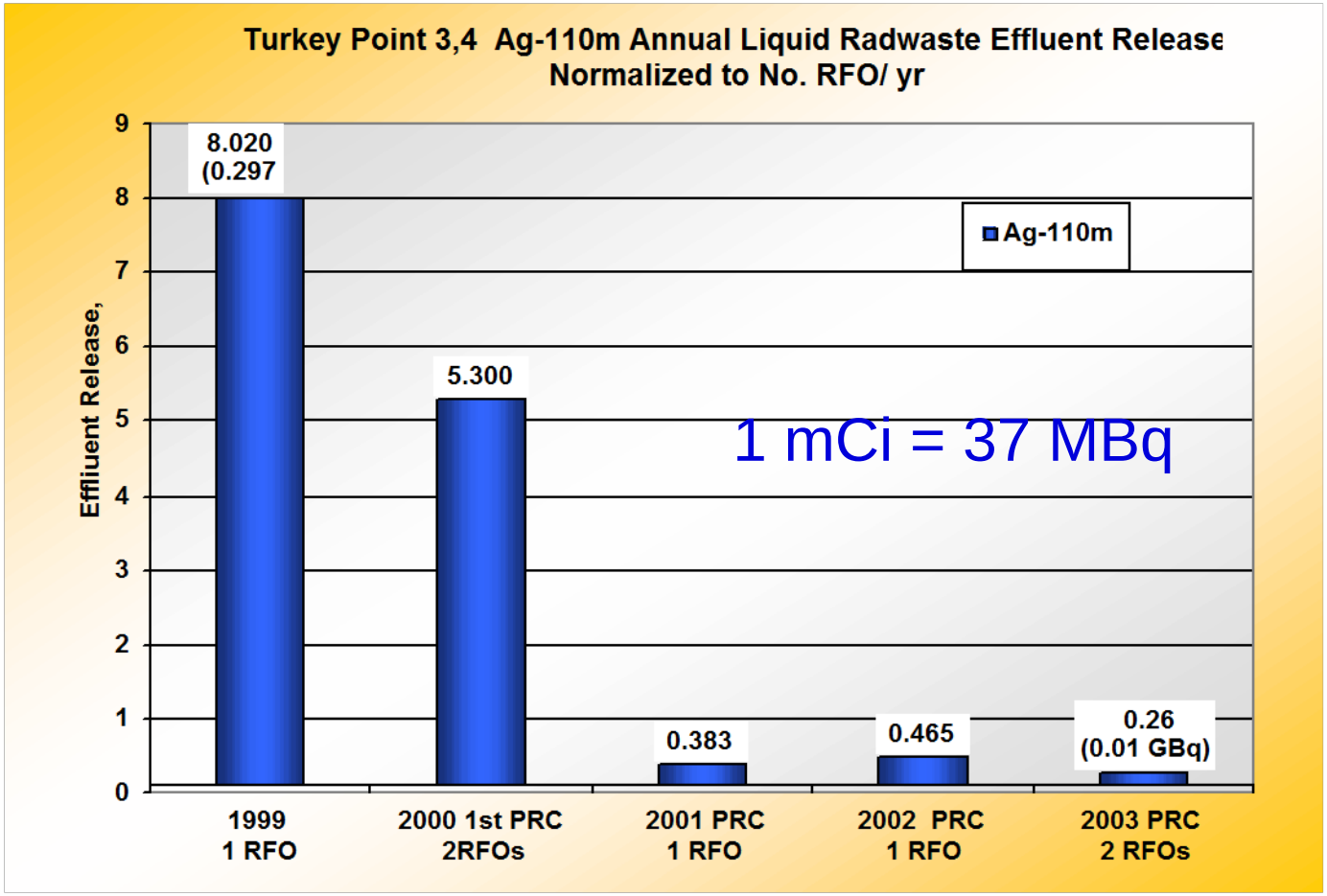
Liquid Radwaste Processing System:
Activated Carbon, Conventional Resins- No Ultra-filtration or Reverse Osmosis



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)

Summary (cont.)

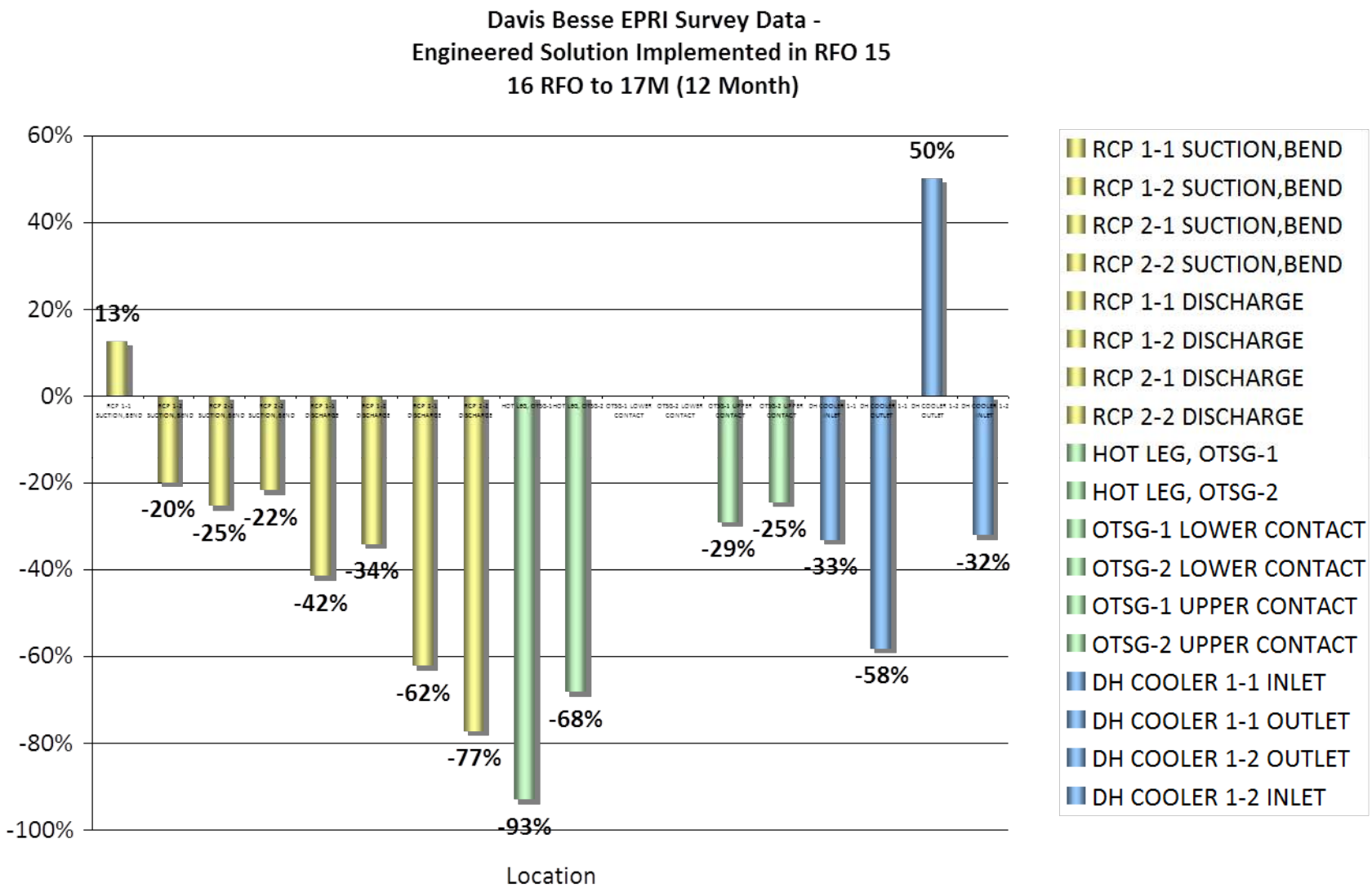
- - 61.5%
  - Reduction in number of High Radiation Area
- - 35%
  - Reduction in contract HP staff, $400,000 avoided costs every RFO.
- - 76%
  - Reduction in Hot Spots
- - 49 X (fold)
  - Reduction in annual effluent activity discharged for Co-58 and 15 fold for Co-60
- - 87.7 %
  - Reduction in Ni-63 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.

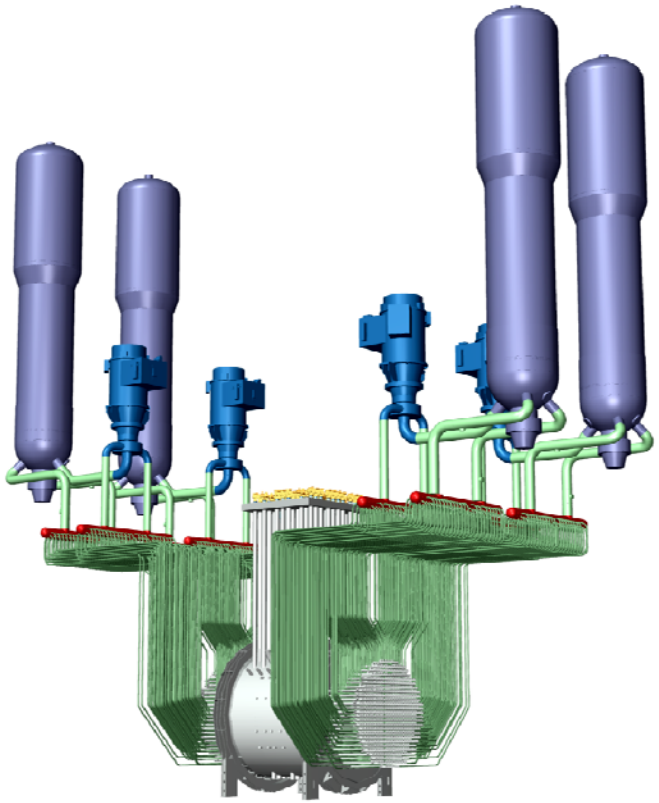
B&W Design

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

2011: Davis Besse- RVH Planned 128 REM; Actual 58 REM
RFO 16 to 17M - Two Core Rotations



CANDU's: Bruce Power Bruce A/B

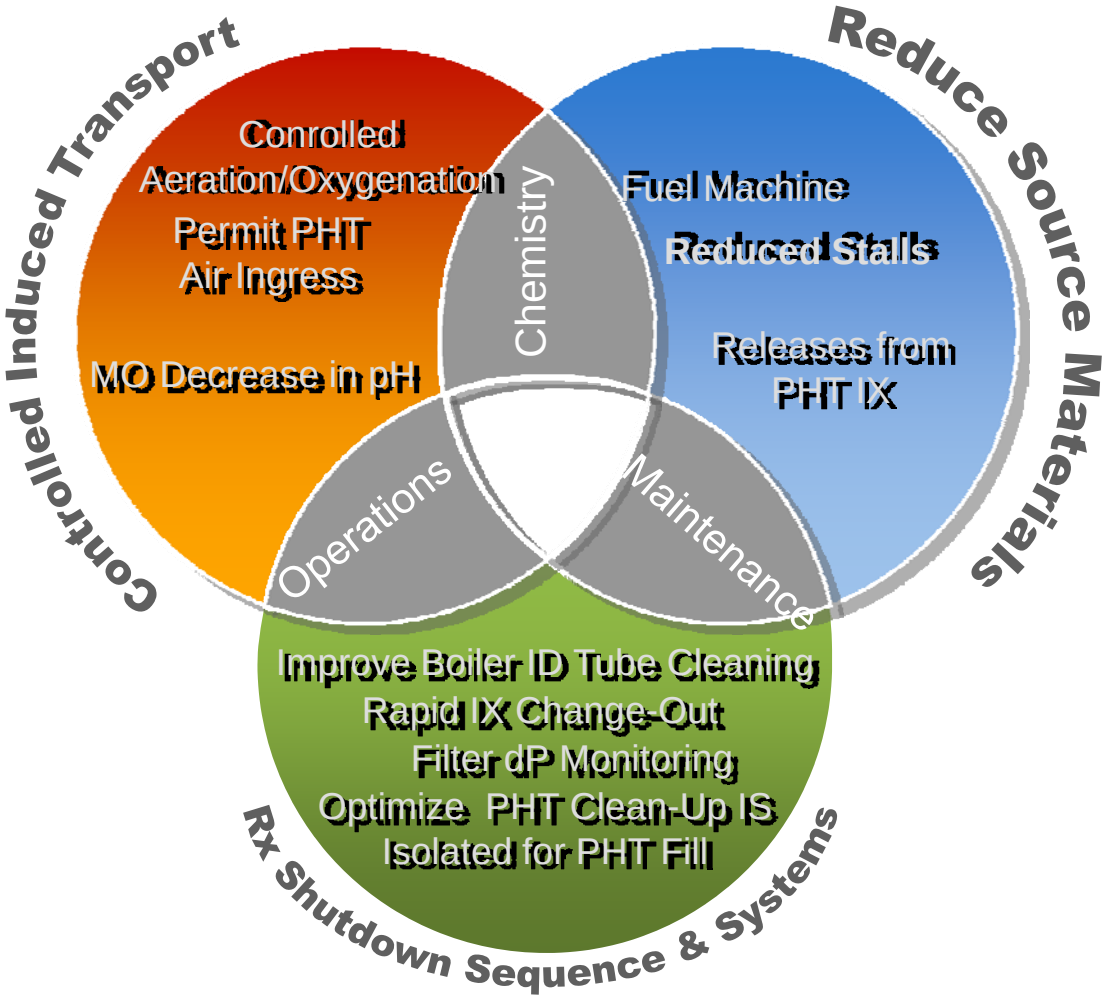


CANDU: BRUCE POWER

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

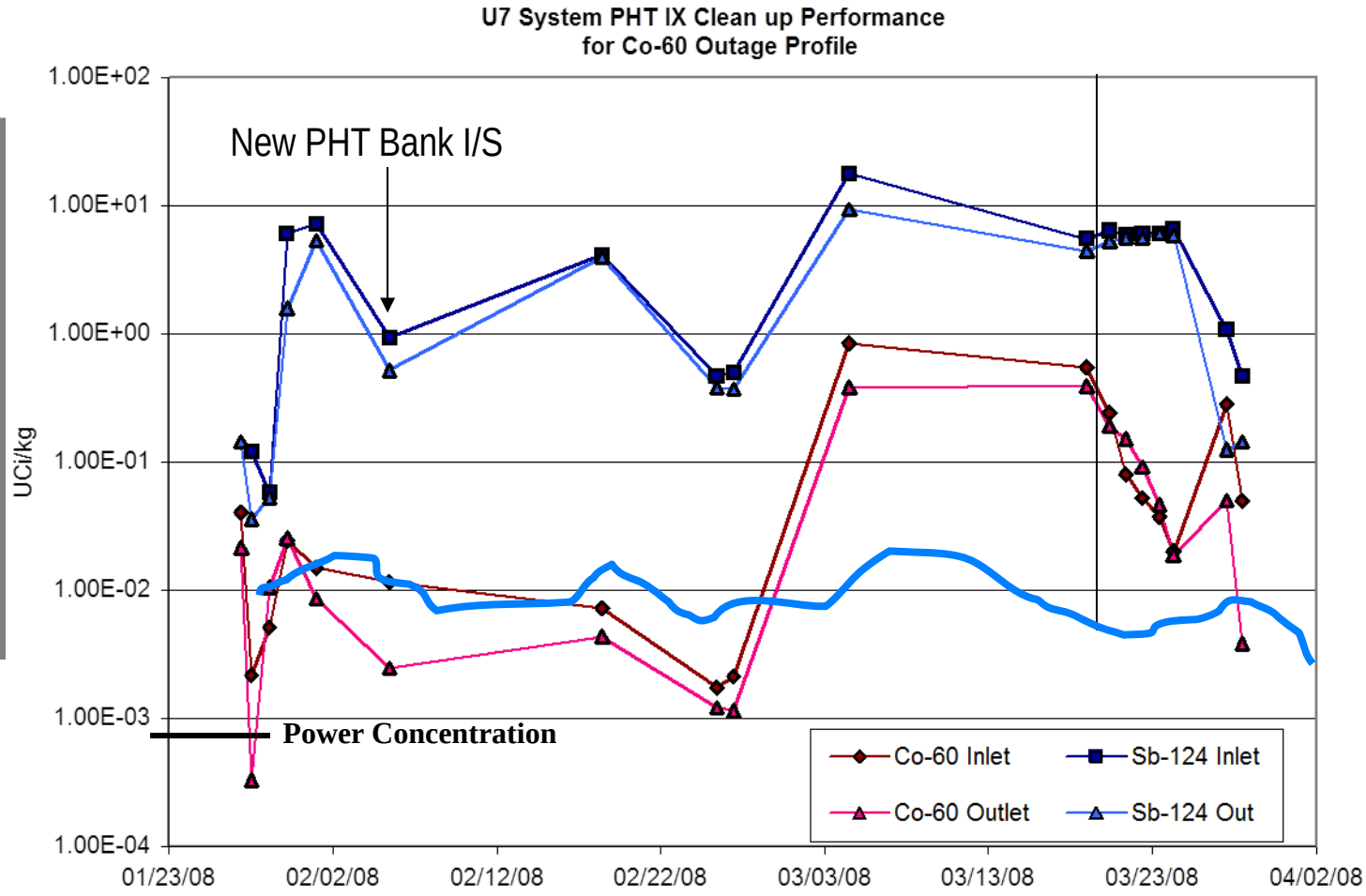
Ion Exchange Resin

Shows Almost No

Removal of

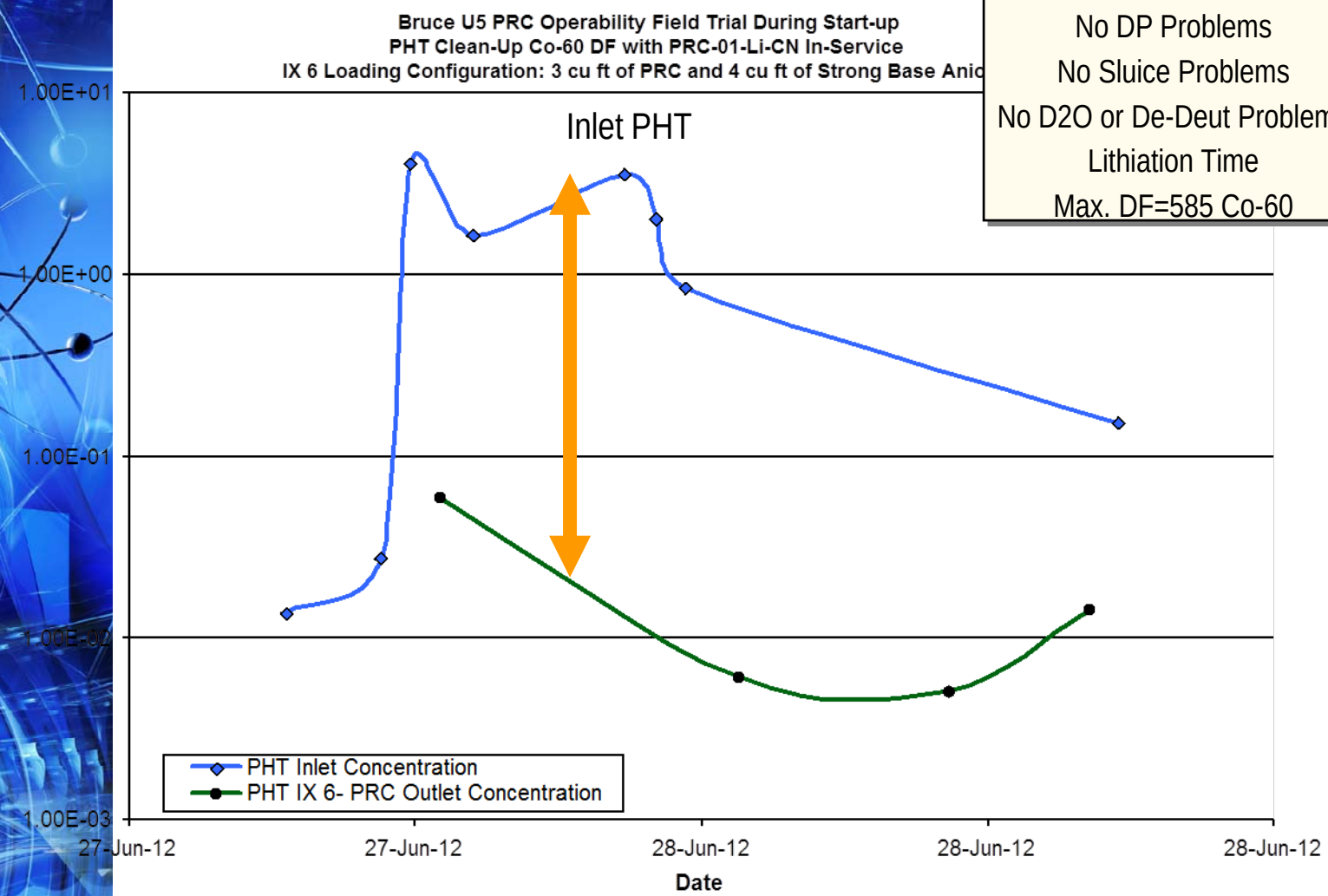
Co-60 or Sb-124

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

BWR

Monticello R22 to R23 Results

PRC Use R22 RFO, Cycle, R23

April 2007

- **-28%**
  - <u>Decline in BRAC Points</u>
  - 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%**
  - <u>Decline in A Recirc Suction</u>
  - 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

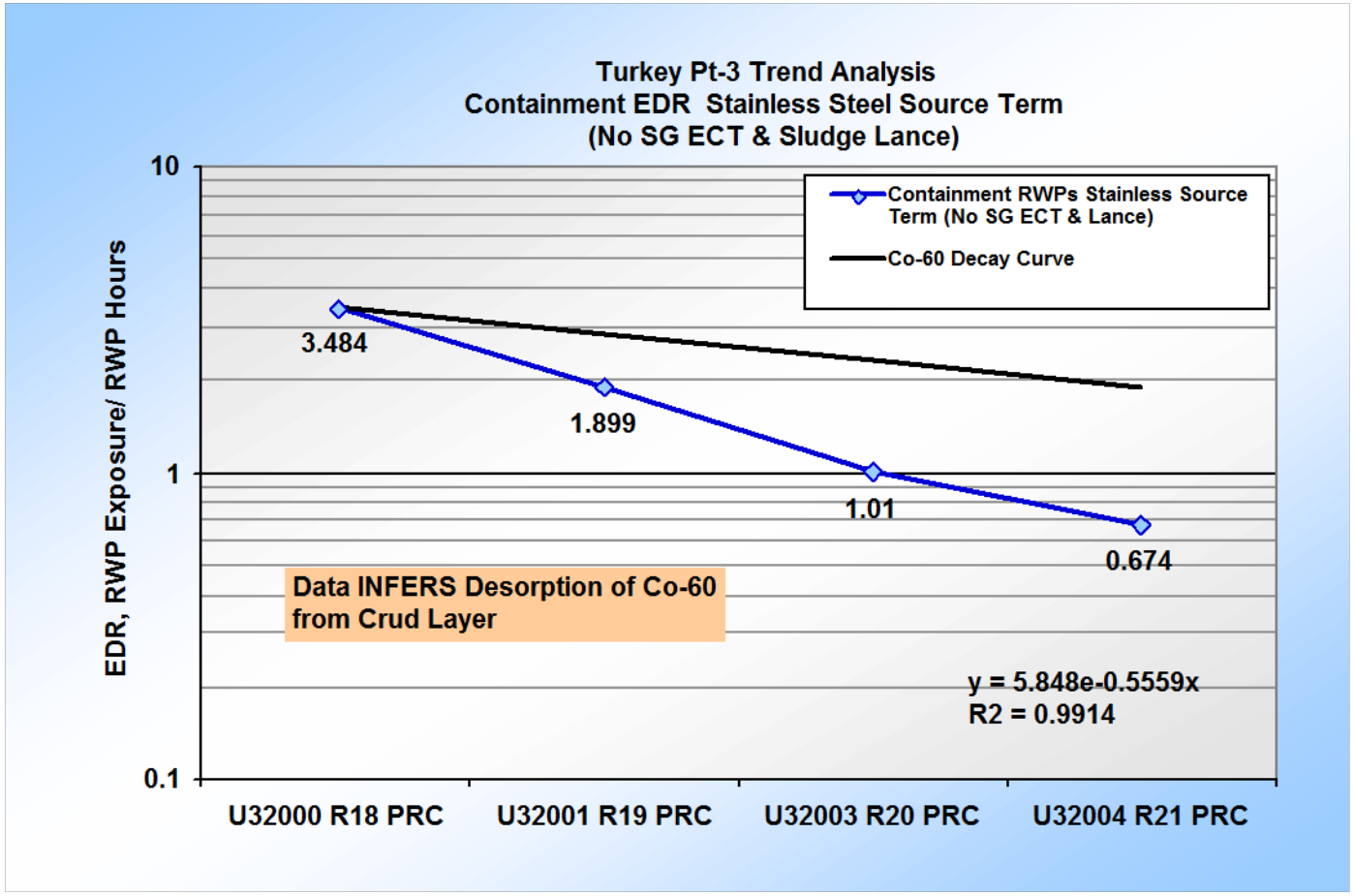
BWRs

- Application on RWCU
  - 100% time
  - Refueling
- Expanding to Flush in CPS
- Expanding to On-Line Portion of CPS

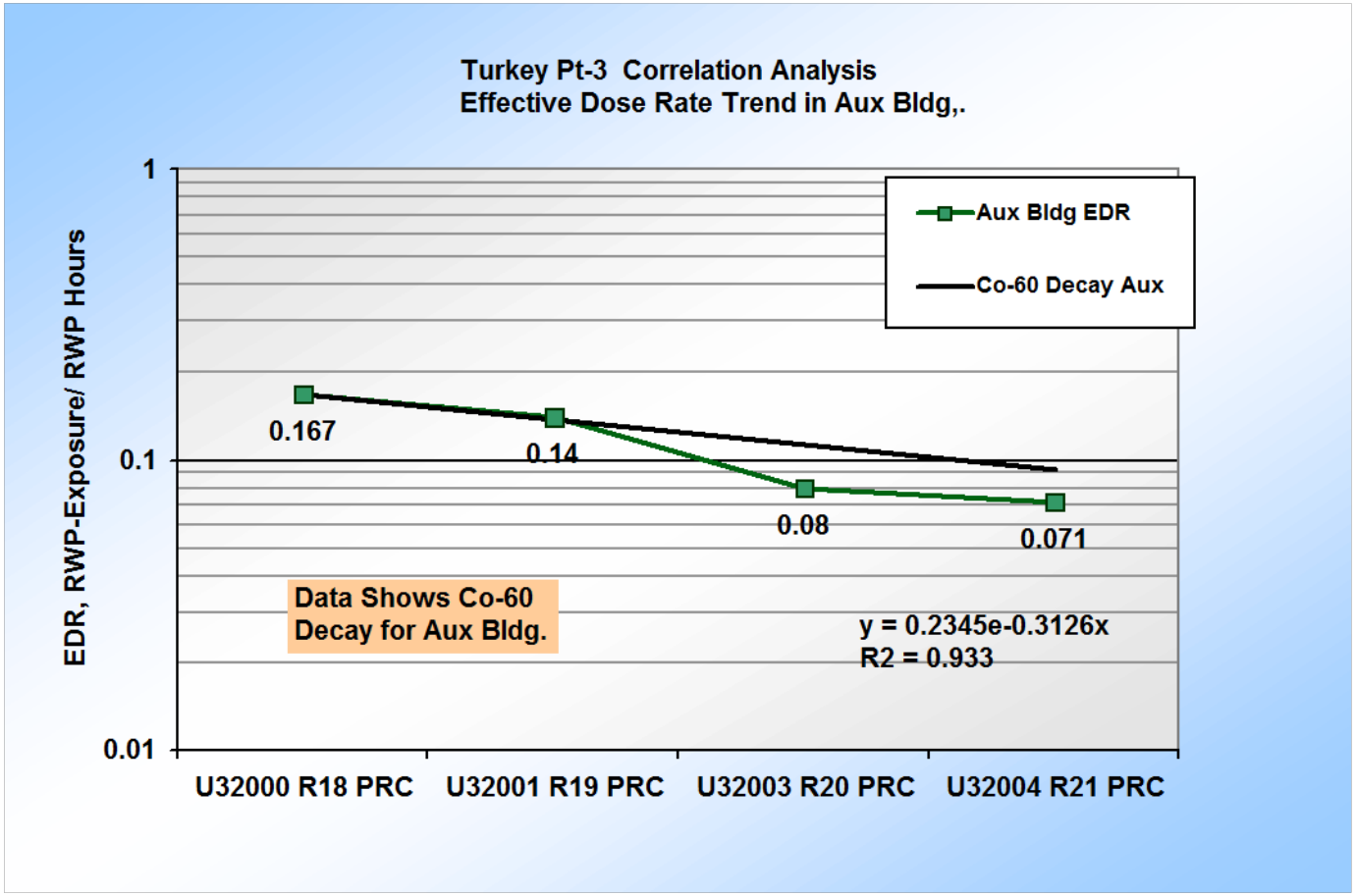
Questions?

Turkey Pt-3
Effective Dose Rate: Containment Stainless Steel Source Term

1 mrem = 100 uSv



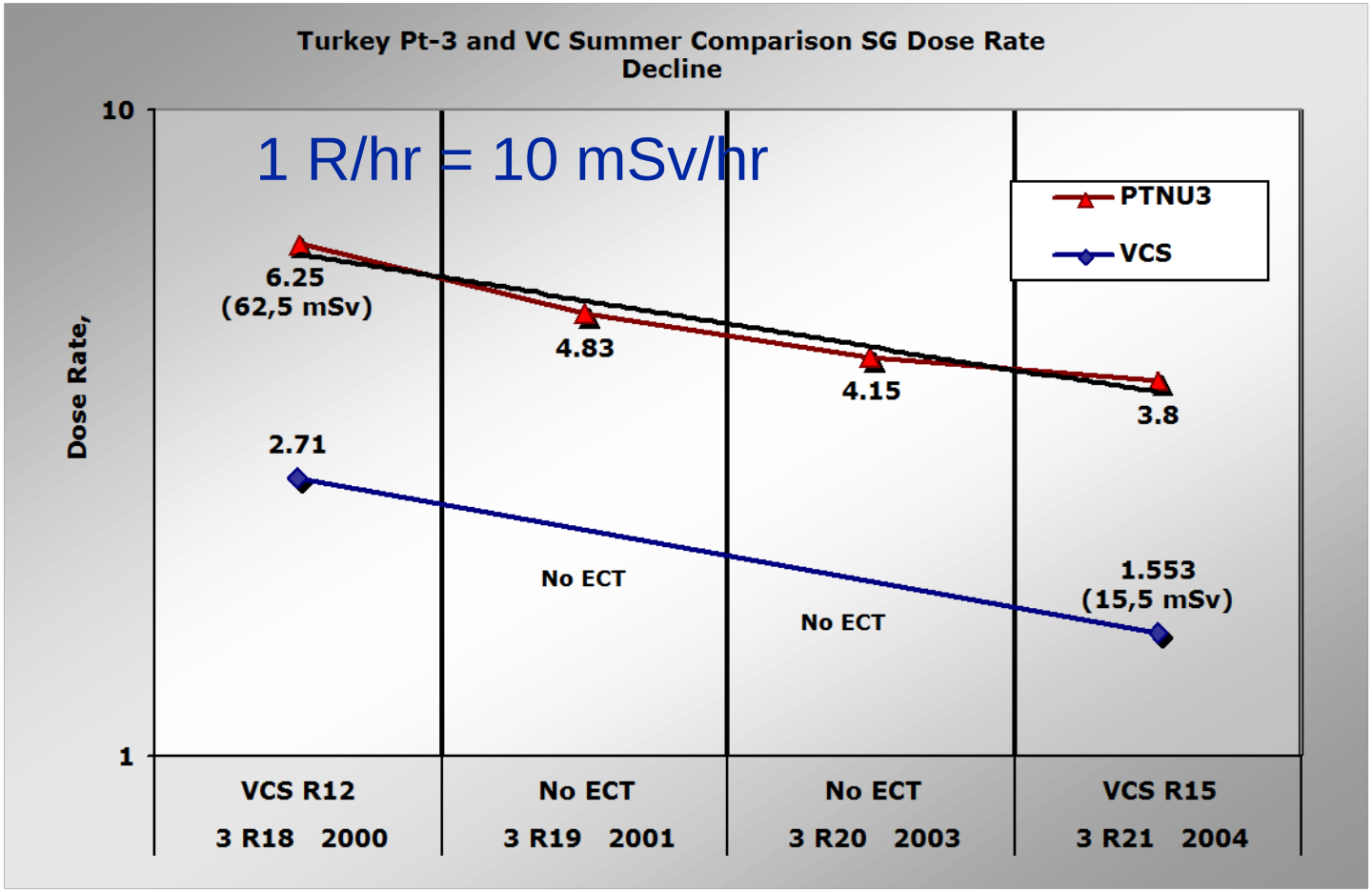
Turkey Pt-3
EDR Auxiliary Bldg RWPs
Show Co-60 Decay Rate



Benchmark Turkey Pt-3 & VC Summer

Avg. Channel Head Dose Rates Declining at Co-60 Decay Rate

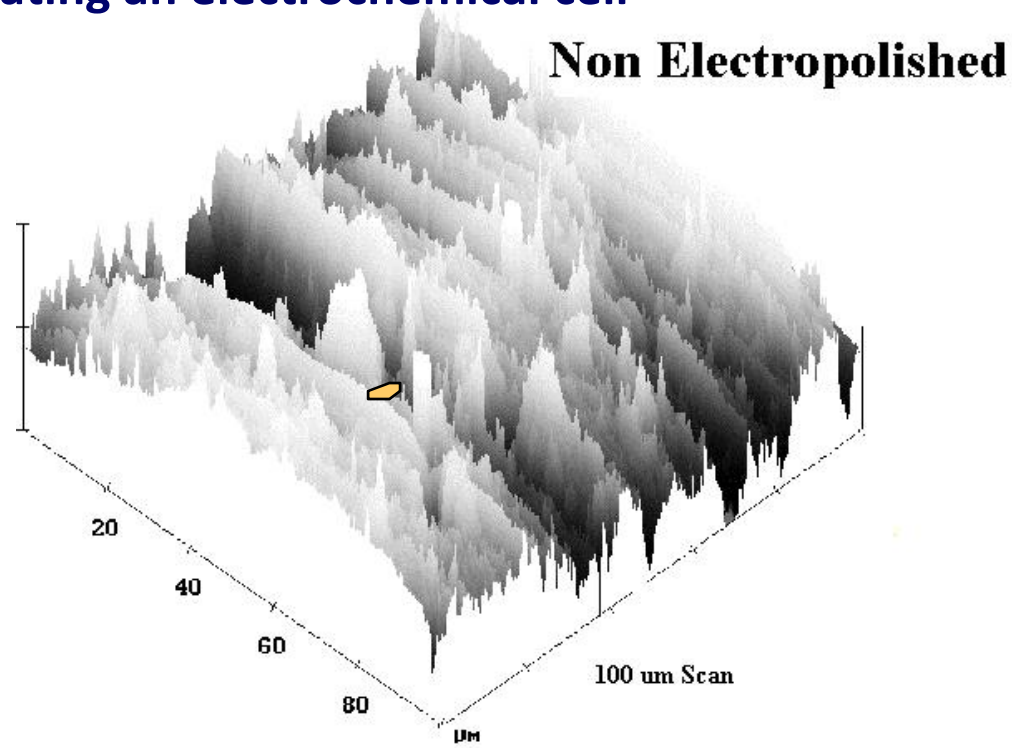
17-21 EFPY Inconel 600TT vs. 3-7 EFPY Inconel 690



Surface Profile Stainless Steel

(J.Underwood Browns Ferry Photo)

- Colloids attach to surface under shutdown conditions if not mitigated
- Significant surface area for deposition
- Colloids can induce corrosion under specific conditions by creating an electrochemical cell



PWR Operating Experience Data with PRC-1 Solution

1 Bq =1 disintegration per second= 2.7×10^{-11} Ci

Amount of Radioactivity		Radiation Dose	
1 µCi	37 kBq	0.1 mrem	1 µSv
27 µCi	1 kBq	1 mrem	10 µSv
1 mCi	37 MBq	10 mrem	100 µSv, 0.1 mSv
27 mCi	1 GBq	100 mrem	1 mSv
1 Ci	37 GBq	1 REM	10 mSv
27 Ci	1 TBq	10 REM	0.1 Sv

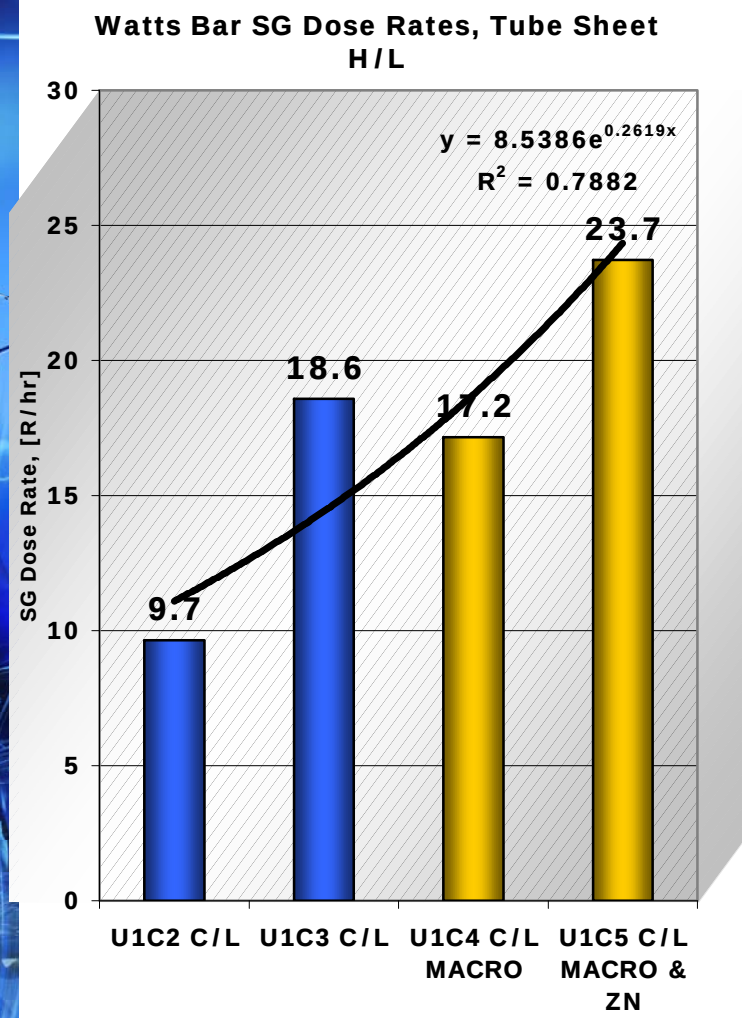
1 US Gallon/ Minute (GPM) = 3.785 L/Minute

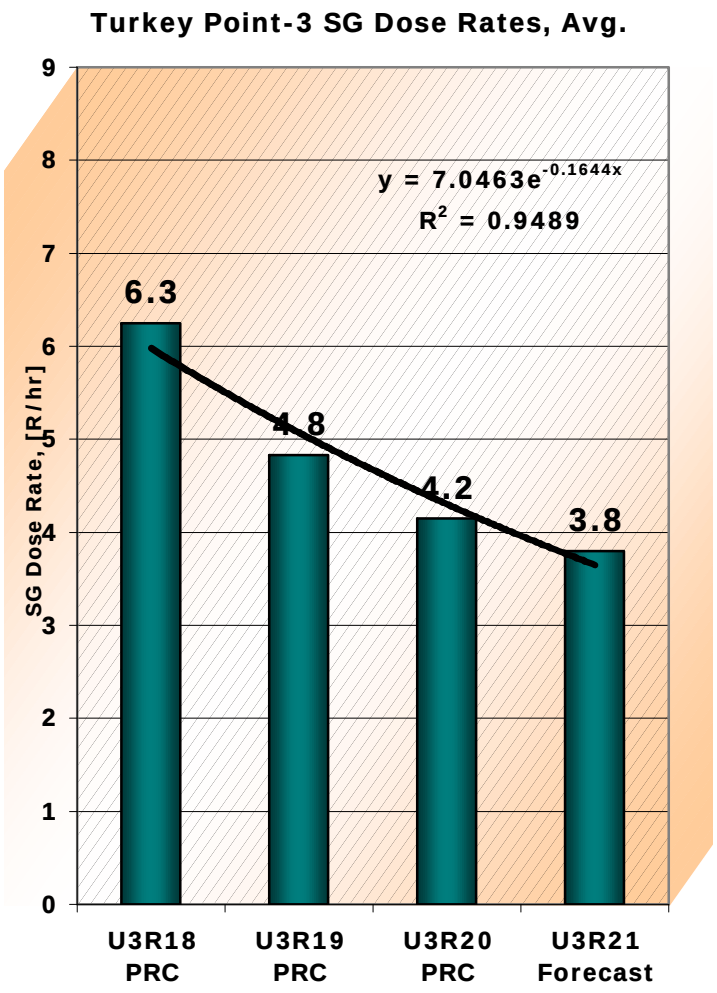
Correct Science & Sequence, Yields Results

Correct with PRC-01 Integrated Solution

Wrong with Purolite A501P Anion Macroporous Resins

1 R/hr = 10 mSv/hr





How Do We Know It's Working?

By Using Trend Analysis RFO to RFO

- **Chemistry Parameters**
  - At Power Co-58 and Co-60 trend… Declining?
  - Shutdown Core Release… Declining?
- **RP Measurements-Everything Declining?**
  - Dose Rates and Effective Dose Rate
  - Personnel Contamination Events (PCE)'s
  - Discrete Radioactive Particles
  - Smearable Contamination Levels
- **Low Level Waste and Liquid Effluent Activity**
  - Less Low Level Waste
  - Less Curies

CRUD
(ref: ANT International presentation)

- **Corrosion Products Released from System Surfaces**
  - Ionic Forms
  - Particles
  - Colloids (Agglomerating to Particles Given Time)
  - Co-deposited Ions/Colloids/Particles
- **Particles and Colloids Deposit on Surfaces by**
  - Gravity (big particles) in Low Flow Areas
  - Crud Diffusion and Ion Exchange In Oxide Films
  - Surface Charge Attraction
  - Precipitation at over-saturation due to boiling

CRUD Oxide Forms
(ref: ANT International presentation)

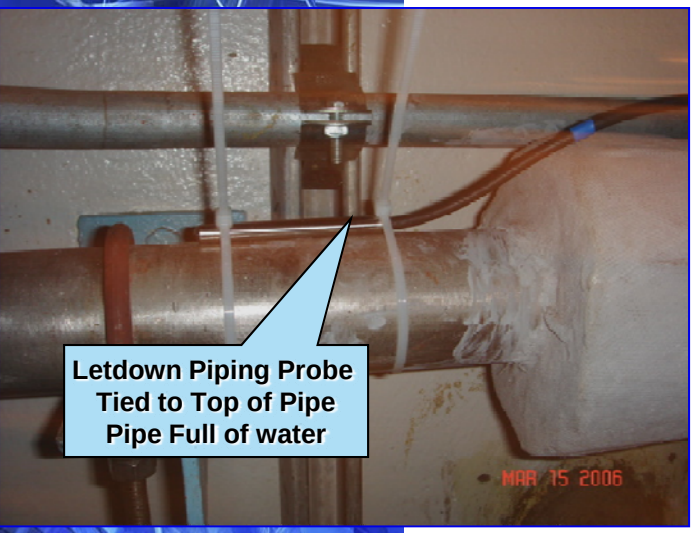
- **Elemental Nickel**
  - Possible to Obtain PWR/VVER at high Hydrogen Concentrations
  - (Also, hydrogen pick-up facilitated in nickel base materials and zirconium alloy cladding)
- **Hematite Fe_2O_3**
  - Formed at more oxidizing conditions
  - Present in BWRS at NWC at sufficient iron input
- **Magnetite Fe_3O_4**

- **Chromium oxide Cr_2O_3**
  - Insoluble in reducing conditions- Soluble in oxidizing?
- **Mono Oxides NiO, CoO, ZnO**
  - Present in PWRs
  - Probably Present in BWRs

Canberra Inspector CZT Data Acquisition

Paul Skinner, Turkey Pt 3,4 Chemistry Supervisor

P1: Letdown Piping Before Demineralizer After Non Regenerative HX, 2 inch Sch 40 Stainless Steel (austenitic) CZT Probe, 60 mm3, 6 inch Long



P2: Letdown Piping After Demineralizer Insulated Piping, Dose Rate: 0.334 mR/hr

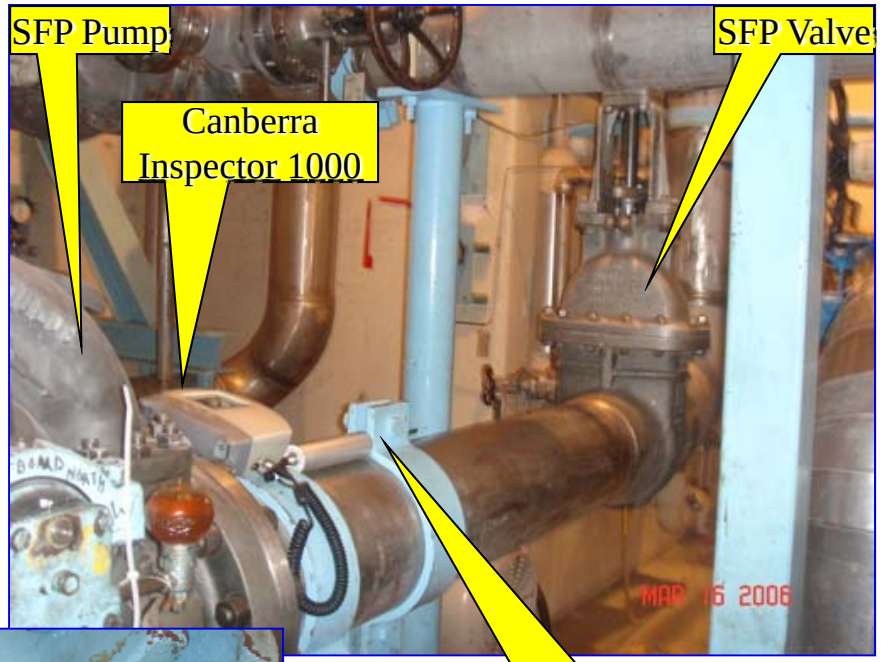
10,000 s. acquire time
Data Showed No pipe wall deposition

P4: Spent Fuel Pool Purification From Pool Before Pump on Piping

Frank Rihls, Chem. Technician

Spent Fuel Pool Piping, Before Pump

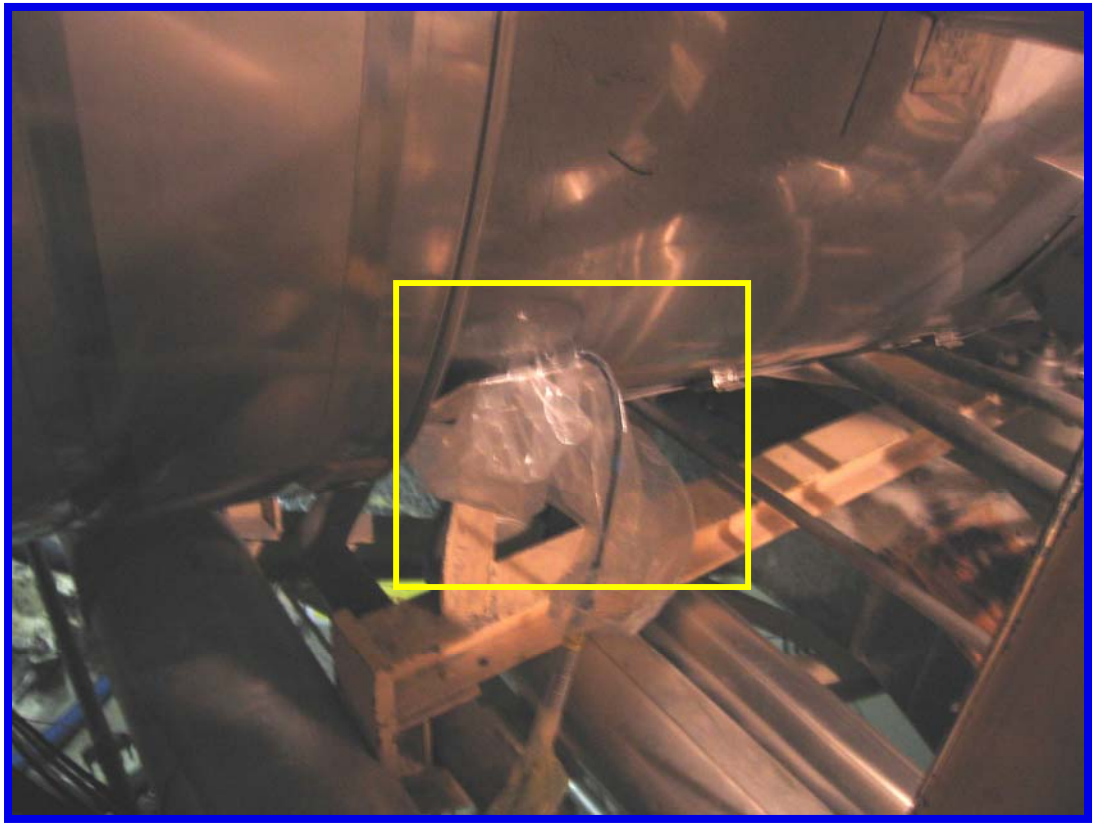
Dose Rate 4.35 mR/hr



CZT Probe
Location
Dose Rate 4.3 mR/hr

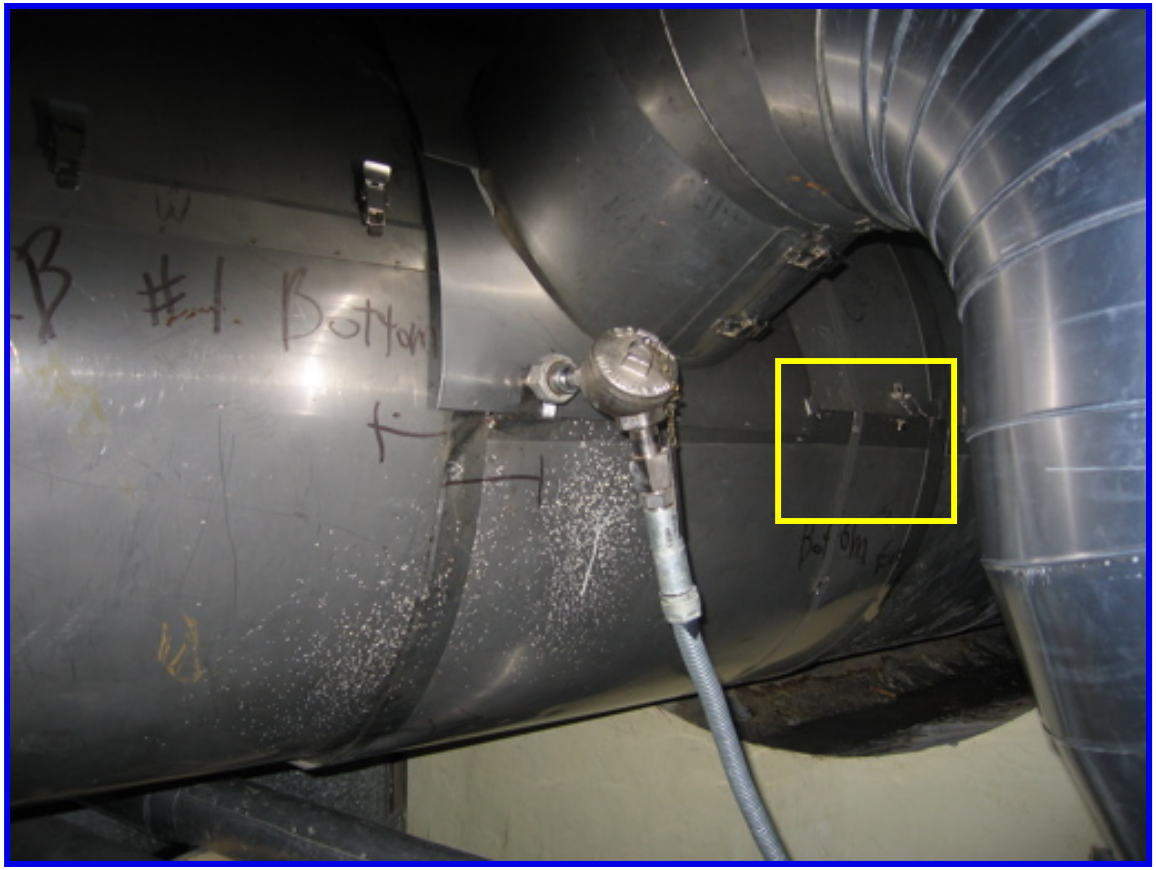
Containment: B Hot Let Piping

Reflective Insulation
Dose Rate Contact = 60 mR/hr



B Cold Leg Piping
Probe Was Placed in Box

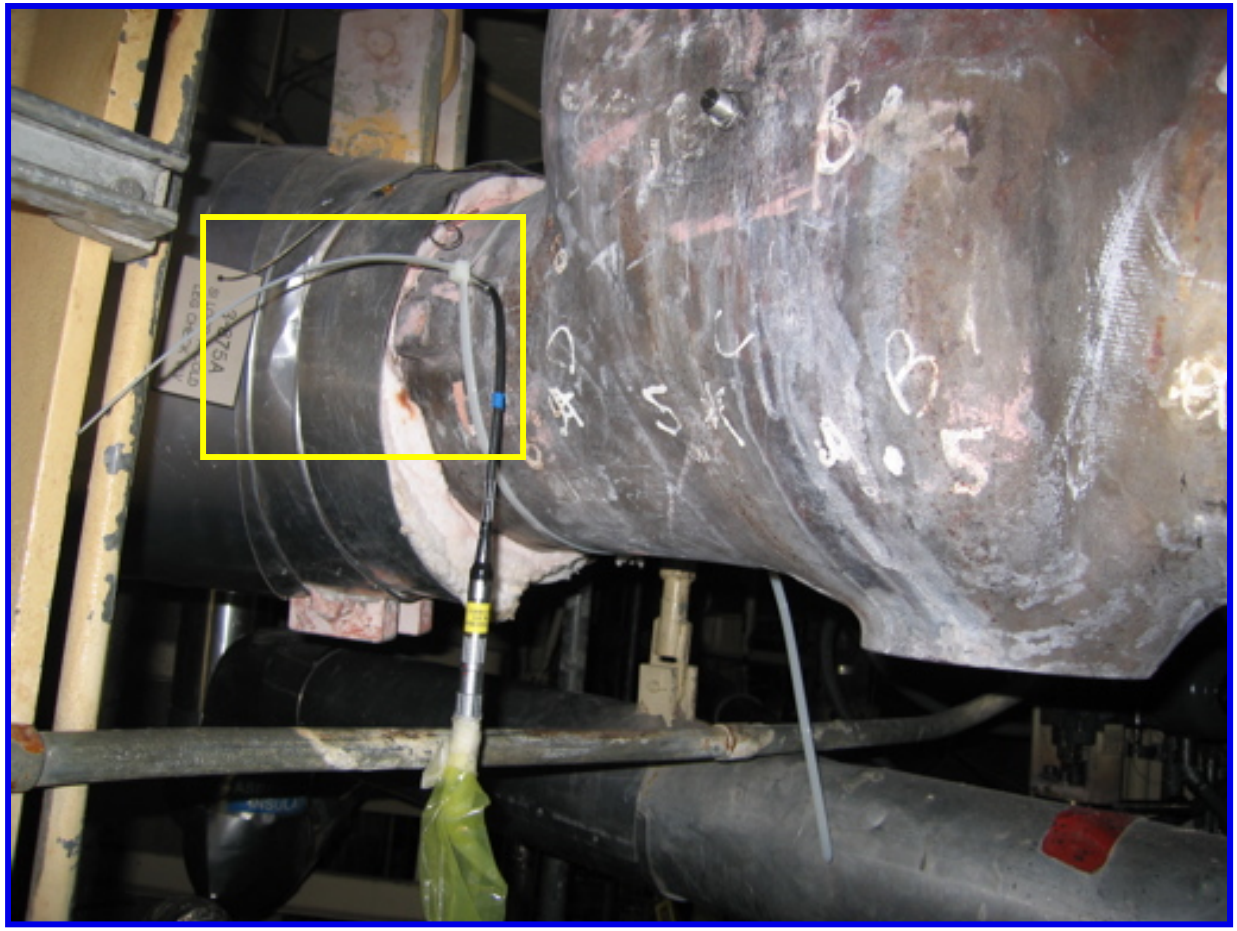
Dose Rate: 44 mR/hr Contact



875 A Safety Injection Check Valve

No Insulation On pipe

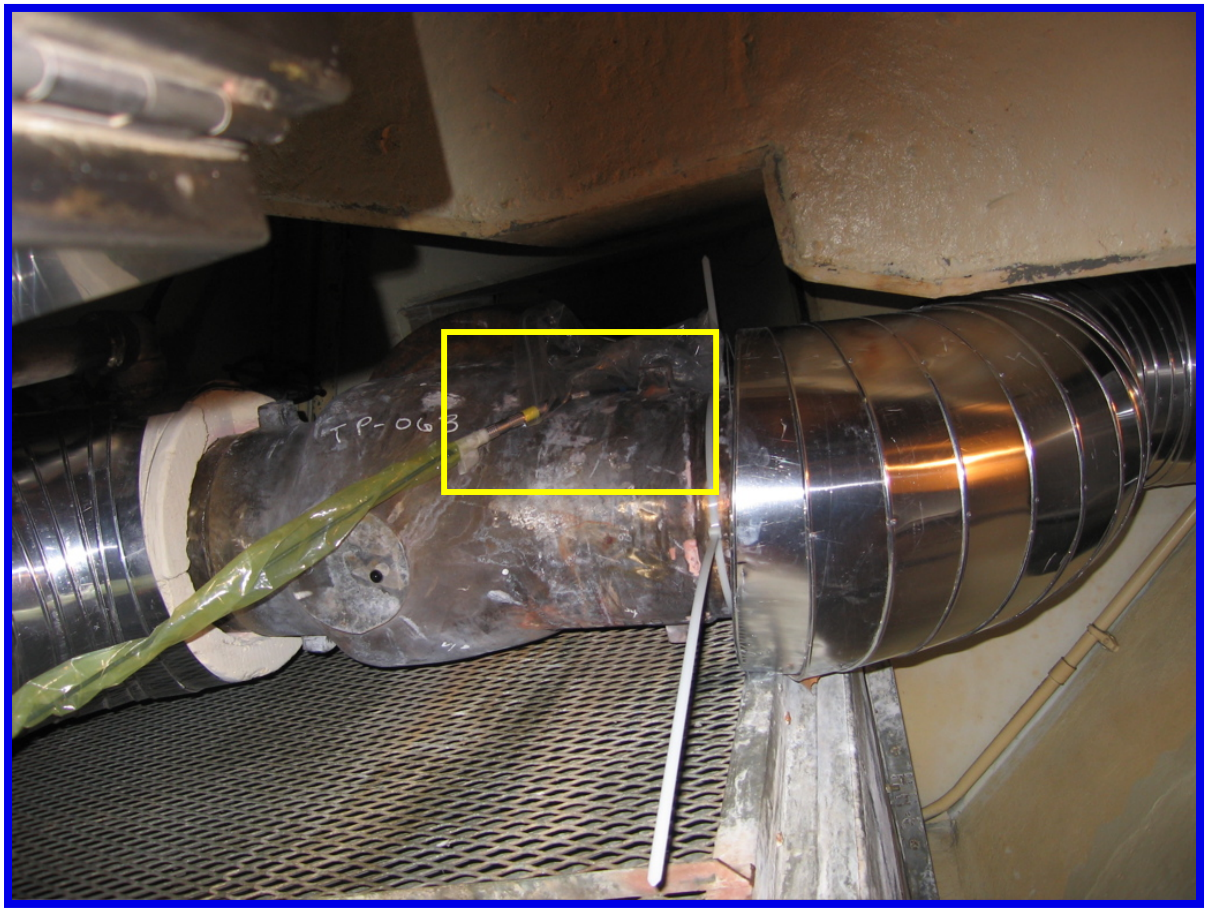
Dose Rate Contact: 150 mR/hr Contact



875 B Safety Injection Check Valve
No Insulation On pipe
Dose Rate Contact: 160 mR/hr Contact, 30 cm 80 mR/hr

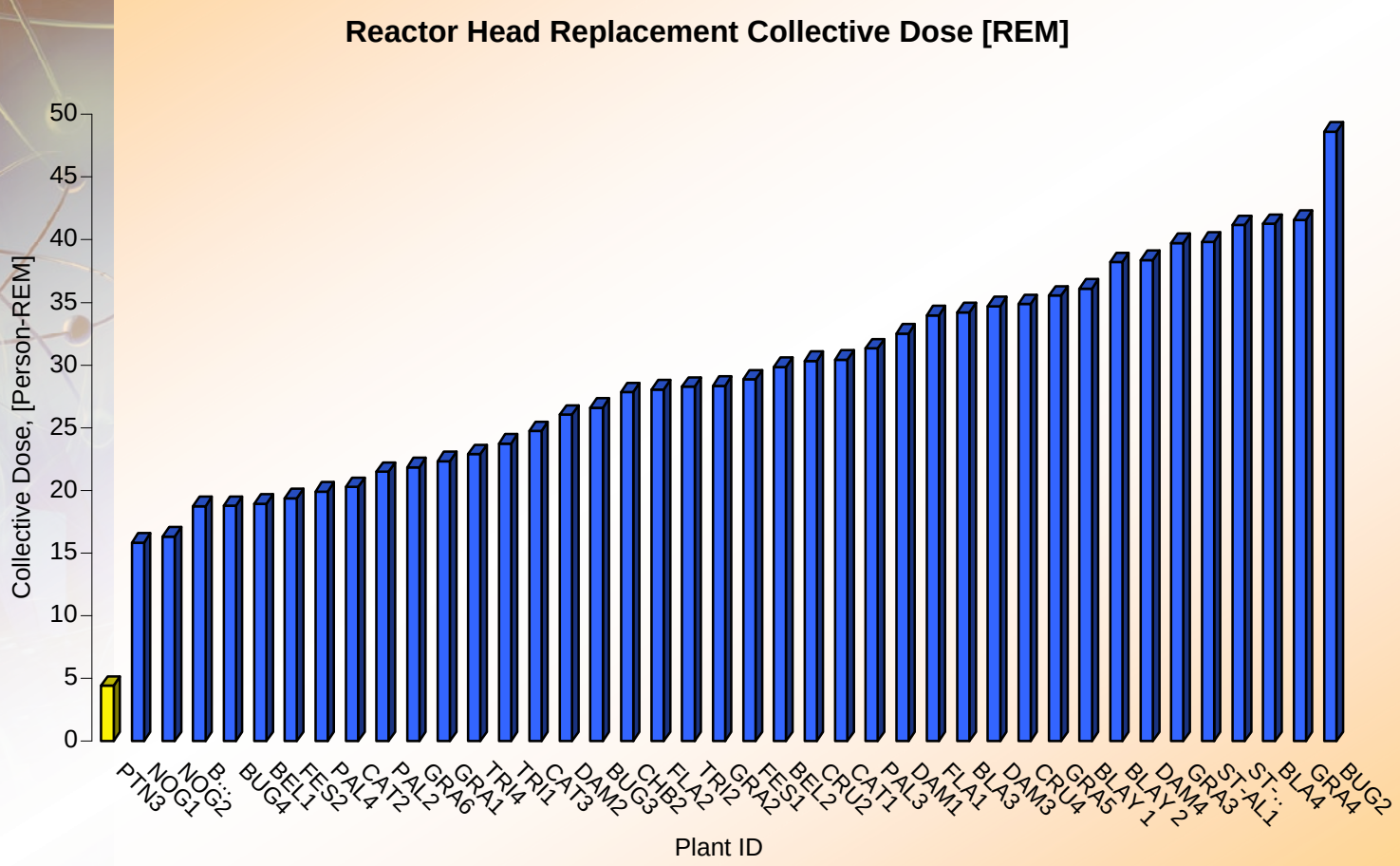
875 C Safety Injection Check Valve

Dose Rate = 150 mR/hr Contact
(9 feet elevated)



Turkey Pt-3 Rx. Head Replacement Project
World Record Low Dose = 5.923 REM (59.2 mSV)

World Record- RVH Replacement Low Dose 5.923 REM



* Does not include mishap dose for RVH project

Thank You….

…Questions?

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