US PWR and BWR Experience in Reducing Critical Path, by Reducing Radiation Source Term

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Presentation Outline

- "Ideas that Inspire" TED Talks Website
- Focus On the "Right" Problem For Radiation Source Term
  - Challenge the Status Quo
- Value of Reducing Radiation Source Term
  - BWR Bad Case Study
  - PWR Good Case Study
- Results & Return on Investment
  - Opportunities Reduce Critical Path
  - Dose Reduction

TED Talks:“ Ideas Worth Spreading”
Simon Simek, On Inspired Leadership

- **TED is a nonprofit devoted to Ideas Worth Spreading.**
  - New Knowledge to Inspire Us.
  - TED.com talks 18 min or less
- **“Leaders” versus “Those Who Lead”**
  - Leaders hold a position of power and authority
  - Those Who Lead, Inspire Us. We follow those who lead, not because we have to but because we want to.
  - Those who start with “Why”, Inspire those around them and find others who Inspire them.
  - Those who challenge “Status Quo” or “Accepted Condition” produce better results.

TED Talk: Femtosecond Photography of Scattered Packet of Light – Photon 3:52

Here's What I Believe…

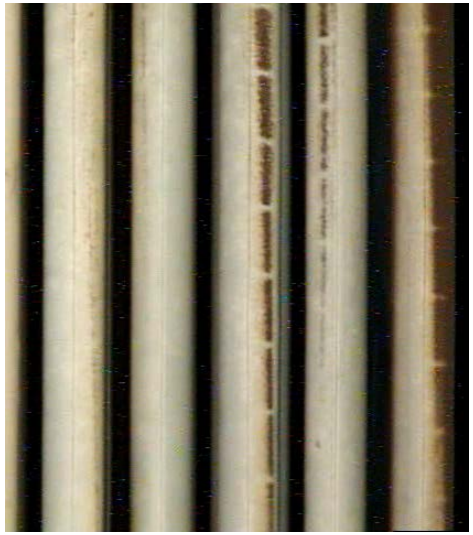
- I believe in challenging "Status Quo" or Accepted State …
  - because there are risks associated with complexity, uncertainty and foremost, complacency.
- Ted Talks Have Clarified that "New Knowledge" Inspires Me
- I believe in Diverse Scientific Collaboration,
  - Because many inspired minds, Can Manage Complexity, Uncertainty, and Complacency
- "New Knowledge" on How to Reduce and Sustain Low Dose Rates

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 The Solution Required a "Challenge to the Status Quo"**
- **New Engineered Solution and New Invention**

Nuclear Fuel --Before

Nuclear Fuel -After



What is/was the "Status Quo" to Controlling Source Term

- **Belief… if we:**
  - **Control Cycle Chemistry**
  - **Control Cycle Corrosion Rates**
    - **Elevate pH**
    - **Inject Zinc to Reduce Corrosion Rates**
    - **Remove/Replace Materials with Lower Corrosion Rate Materials, or No Stellite**
  - **Use Ion Exchange Resin and Small Size RCS Filters, 0.1 um for Coolant Purification**
- **Then Source Term will Decline**
- **Well…. That just didn't happen**

Challenge to "Status Quo"

What we learned, about Reducing Source Term:

- **You do NOT need to elevate pH**
  - **and risk increase in Primary Stress Corrosion Cracking**
- **You do NOT need to inject zinc,**
  - **and increase risk of fuel failures**
  - **and risk increasing CRUD trap dose rates e.g. elbow, valve, pump, HX**
  - **and providing no mitigation of crack growth**
- **You do NOT need to replace materials for lower general corrosion rate,**
  - **it causes no harm, just expensive**
  - **There is value in replacement of materials for crack initation and growth, but that's not source term action.**
- **If you understand the problem, then you can solve Solve Source Term problem.**

We Learned 1 More Thing….
…. You Cannot Be Complacent in Rx Operations

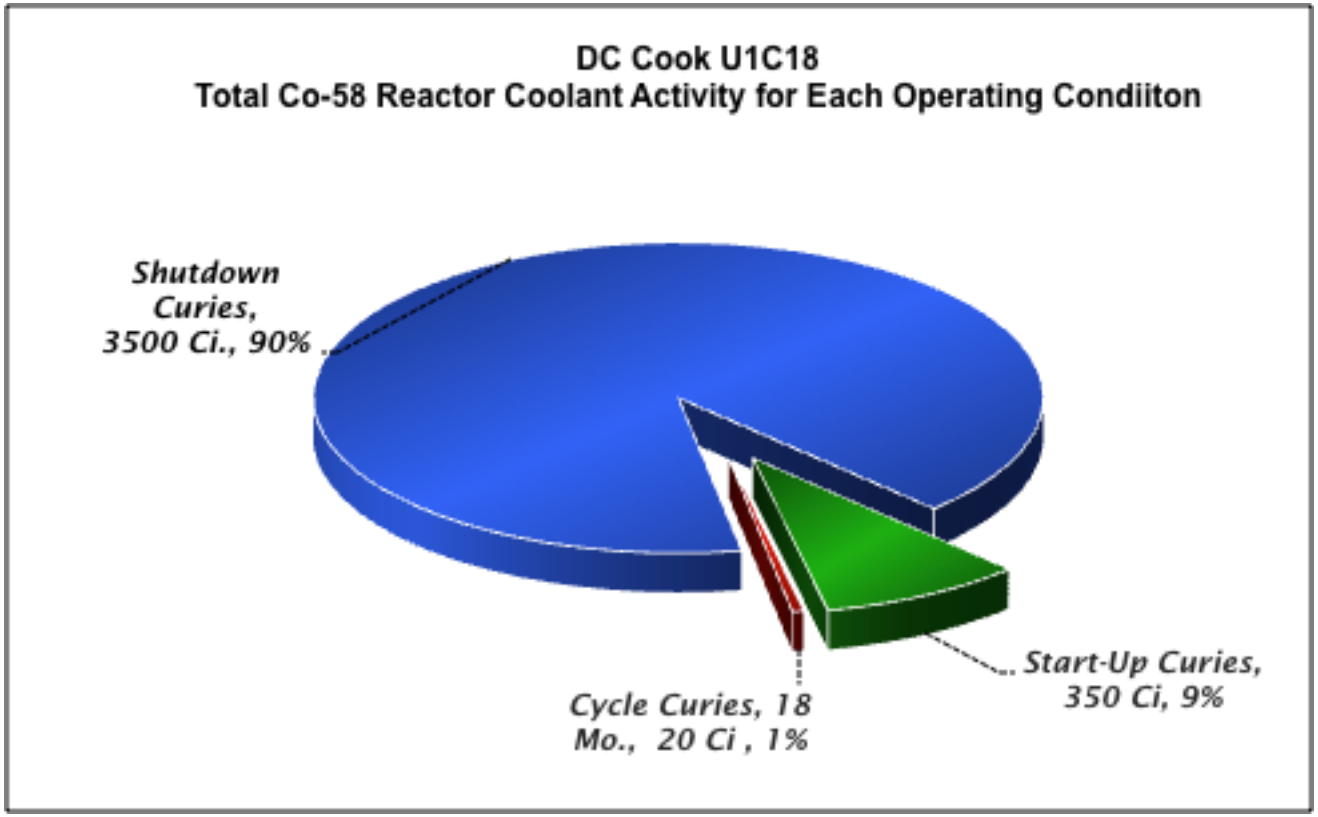
- **BWR Refueling Outage 2013**
  - **Failed at Shutdown to Maintain Reactor Water Clean-Up (RWCU) Filter Demineralizers in Service**
  - **Cavitated RWCU Pump**
  - **Deposited Activity Everywhere**
  - **Very High Smearable Contamination, and Dose Rates**
  - **Worse… Created Opportunity to Make Source Term Conditions Really Bad through operational mistakes**
- **Watch This…**

Vented RHR Heat Exchanger Through The Nuclear Core

We Learned 1 More Thing….
…. You Cannot Be Complacent in Rx Operations

- **Result on Cavity Dose Rates:**
  - 1- 2 mR/hr, 0.01 mSv- 0.02 mSv/hr
  - 300- 400 mR/hr, 3-4 mSv/hr
  - 300% increase
- **Final Cavity Decontamination**
  - Added 16 hours of Critical Path Time
  - 7 REM of Additional Outage Exposure
- **Engineered Solution Includes:**
  - Right Technology
  - Applied the Right Way
    - Right Operational Sequence

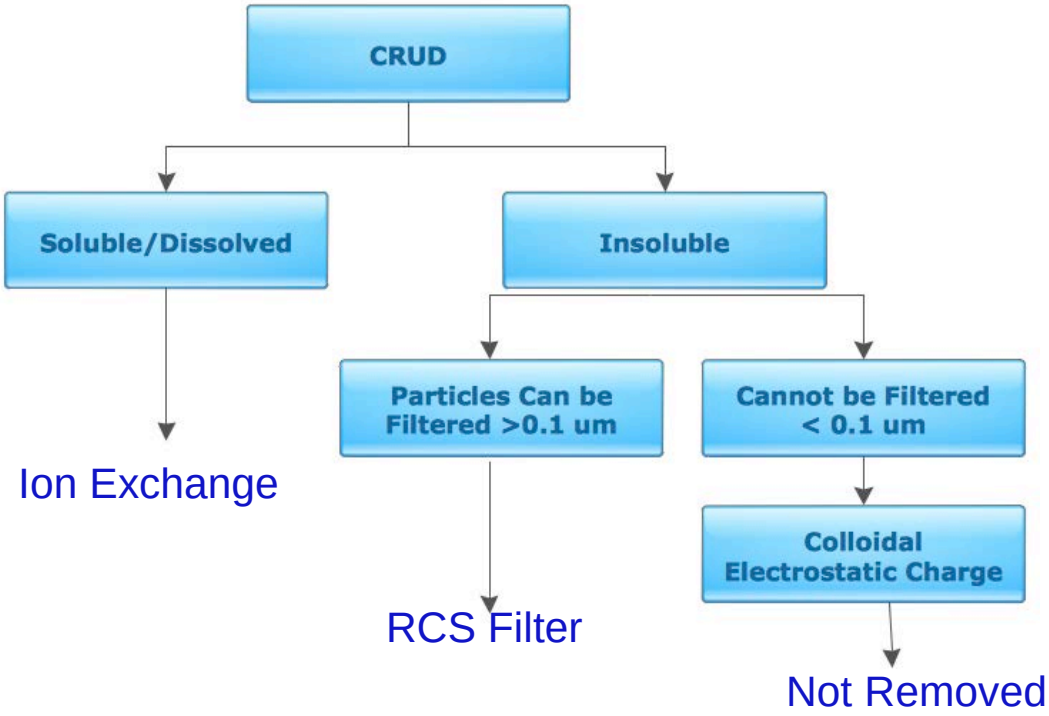
To Reduce Source Term, You Must Manage Cold Shutdown Transport of CRUD



Shutdown CRUD Composition Is Hard to Define and Variable….

…. But Easy to Removal from Coolant

- **If… you know what your doing**



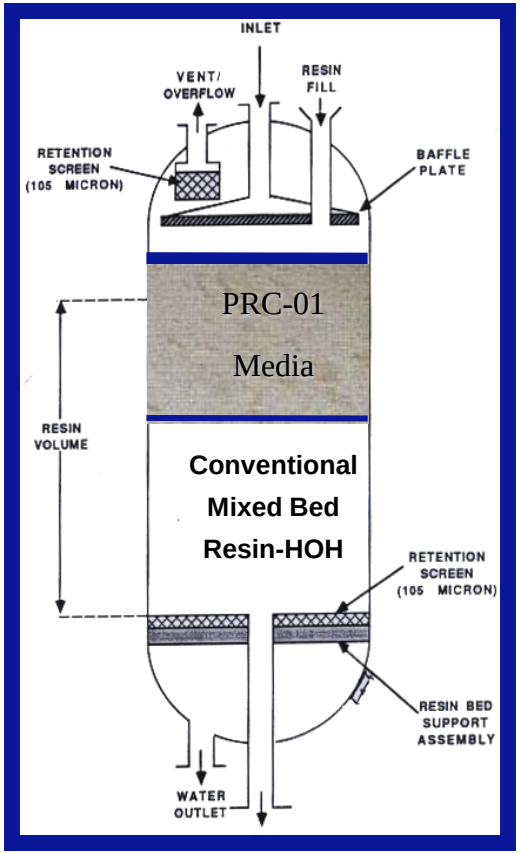
- **The Invention of PRC-01M Resin Combines All 3, Ion Exchange, Filtration and Colloid Polymer Filtration into 1 Technology Advancement**

Collaboration

- Los Alamos National Laboratory (LANL) Scientists
  - Acquired a New Chemical Separation Science, known as "Polymer Filtration"
  - Engineered that Science Into a Product That Can be Used in Nuclear Power Plant Purification Systems
    - BWR: Reactor Water Clean-Up, Condensate Polishers
    - PWR: Chemical and Volume Control System Demineralizers
- Partnered with NPP to Evaluate and Implement Engineered Solution
  - PRC-01M Resins Developed by LANL in Chemical and Volume Control System During Shutdown
  - Team Worked to Improve Shutdown Process

Benchmark: Technology Innovation

Used Correctly, Key to Success



PWR/BWR
Deep Bed Vessel

- **Two Part Engineered Solution:**
  - **Shutdown/Start-Up Protocol**
  - **New Technology, PRC-01M**
- **PWR**
  - **Deep Bed Demineralizers**
- **BWR**
  - **RWCU Filter/Demineralizers**
  - **Condensate Polishers Deep Beds**

NPE Engineered Solution at USA, Mexico and Canada

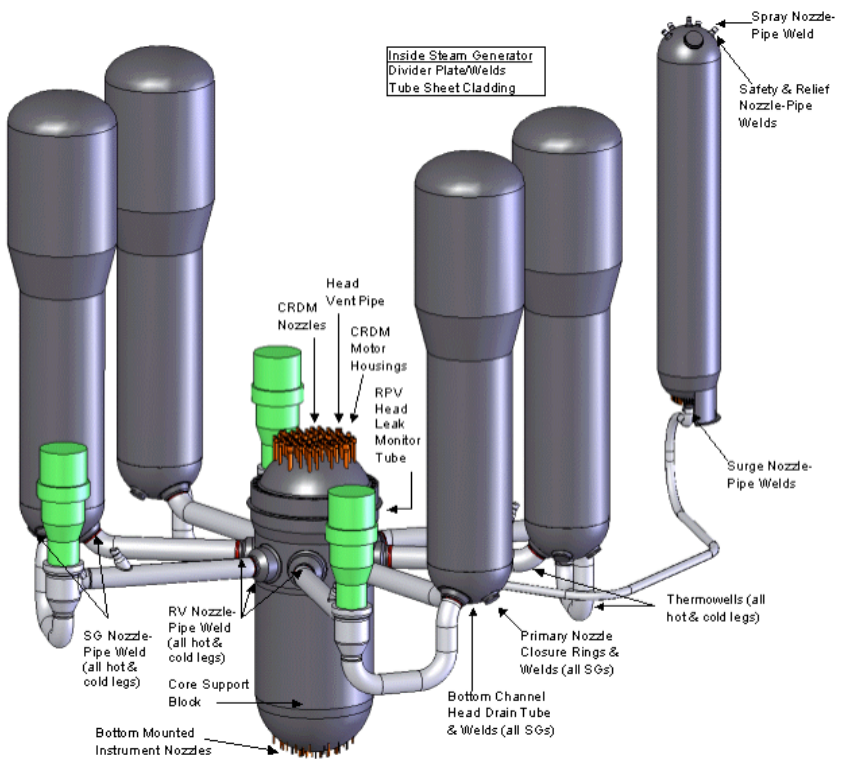
PWR …120+ Refueling Outages

BWR …. 35+ Refueling Outages

PWR Case Study

How Source Term Reduction Reduced Outage Critical Path TIme

Turkey Point-3,4



FPL 1st Integration 13 years Ago

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

Pat-San

PRC-01

Turkey Point-3,4
Source Term Approach

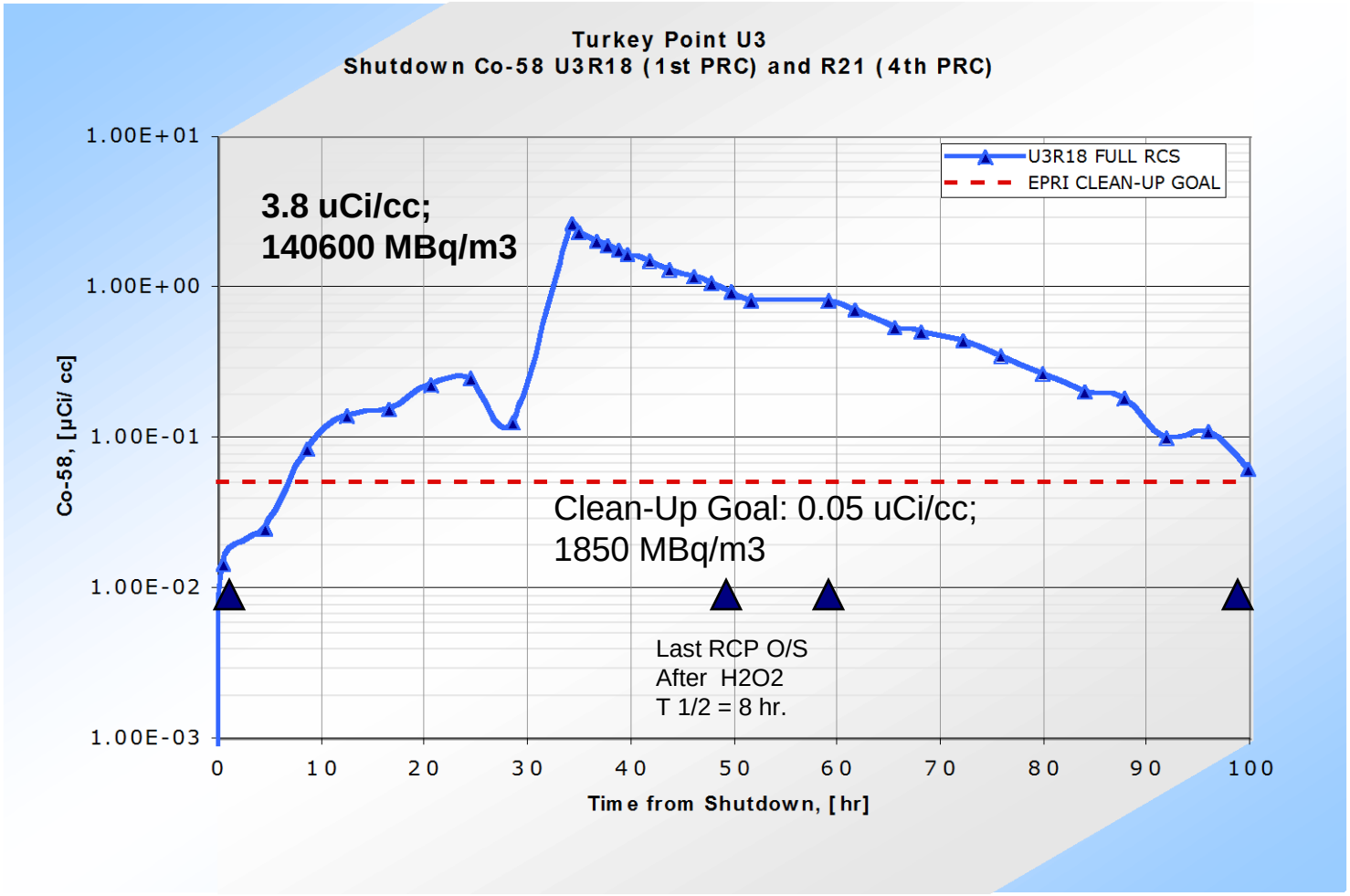
- **Turkey Point 3,4:**
  - **Yes: U3R18 Chemistry pH(t) = 6.9 Modified**
  - **Yes: PRC-01 Media Technology**
  - **No: Zinc, No Fuel Cleaning, No Elevated pH 7.2 to 7.4**
  - **Fuel Duty: Middle Fuel Duty**
  - **13 to 18 EFPY SG, Inconel 600 TT**

FPL Turkey Pt-3R18 (1st PRC)

RCS Shutdown Co-58

100 hrs to Clean-Up Goal

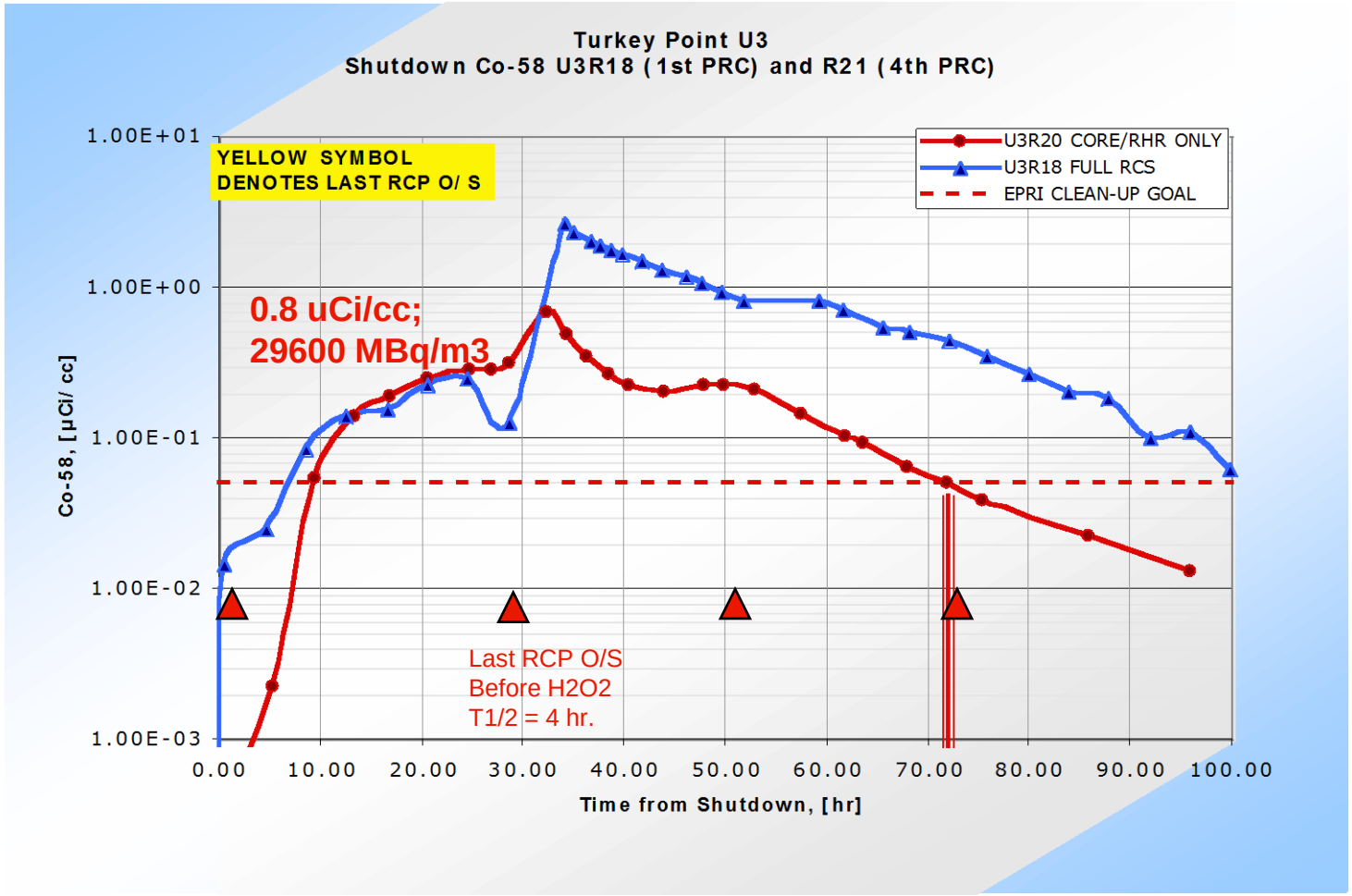
1 E-3 uCi/cc = 37 Bq/ cc



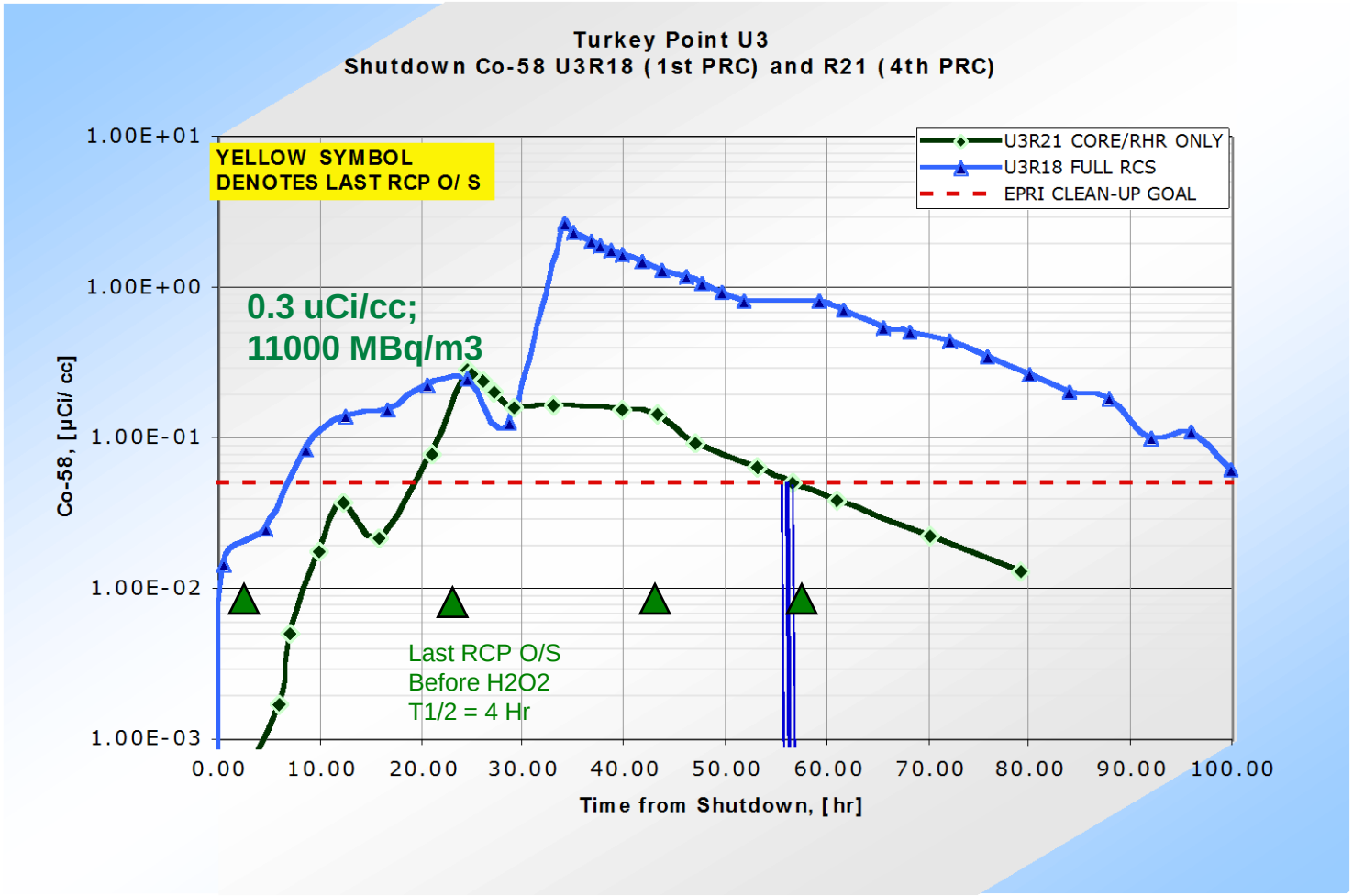
FPL Turkey Pt-3 R20 (3rd PRC)

Shutdown Co-58

70 Hours to Clean-Up Goal



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



Turkey Point-3, 4 Critical Path Savings by Reducing Radiation Source Term

- Sustained Results
- Critical Path Reduced by 30 Hours EVERY Refueling out
  - $30,000 USD/ Critical Path Hour
  - $900,000 USD/ Every Outage
  - Unit 3: 3R21, 3R22, 3R23, 3R24, 3R25
  - Unit 4: 4R21, 4R22, 4R23, 4R24, 4R25
- Total Critical Path Savings: $9.0 Million
  - And Still Benefits Accruing
- Return on Investment: 6.42 to 1
- But…. Did Dose Rates and Outage Exposure go Down?

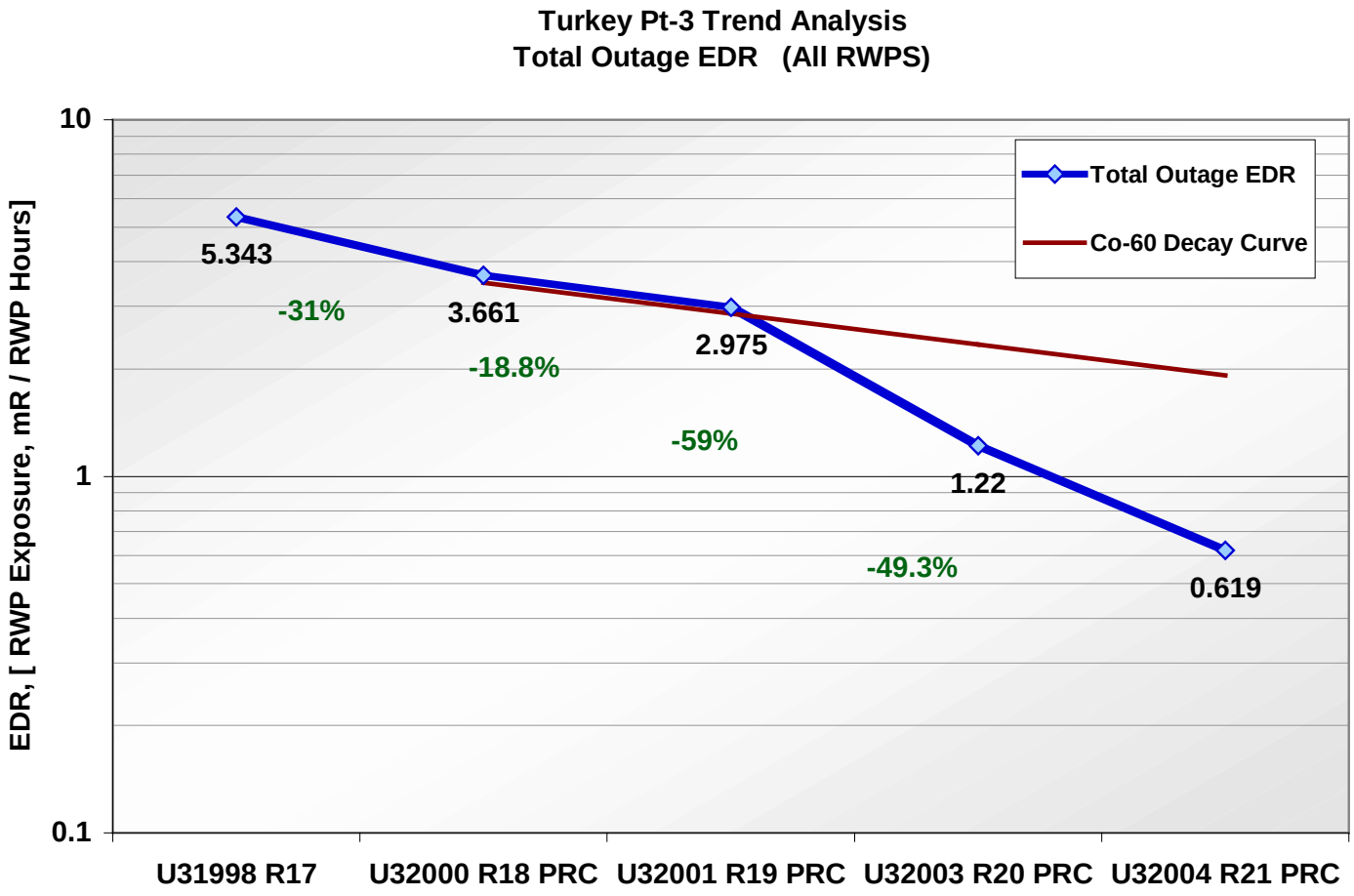
Effective Dose Rate Trending

- **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**

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



Turkey Point-3,4
Summary (cont.)

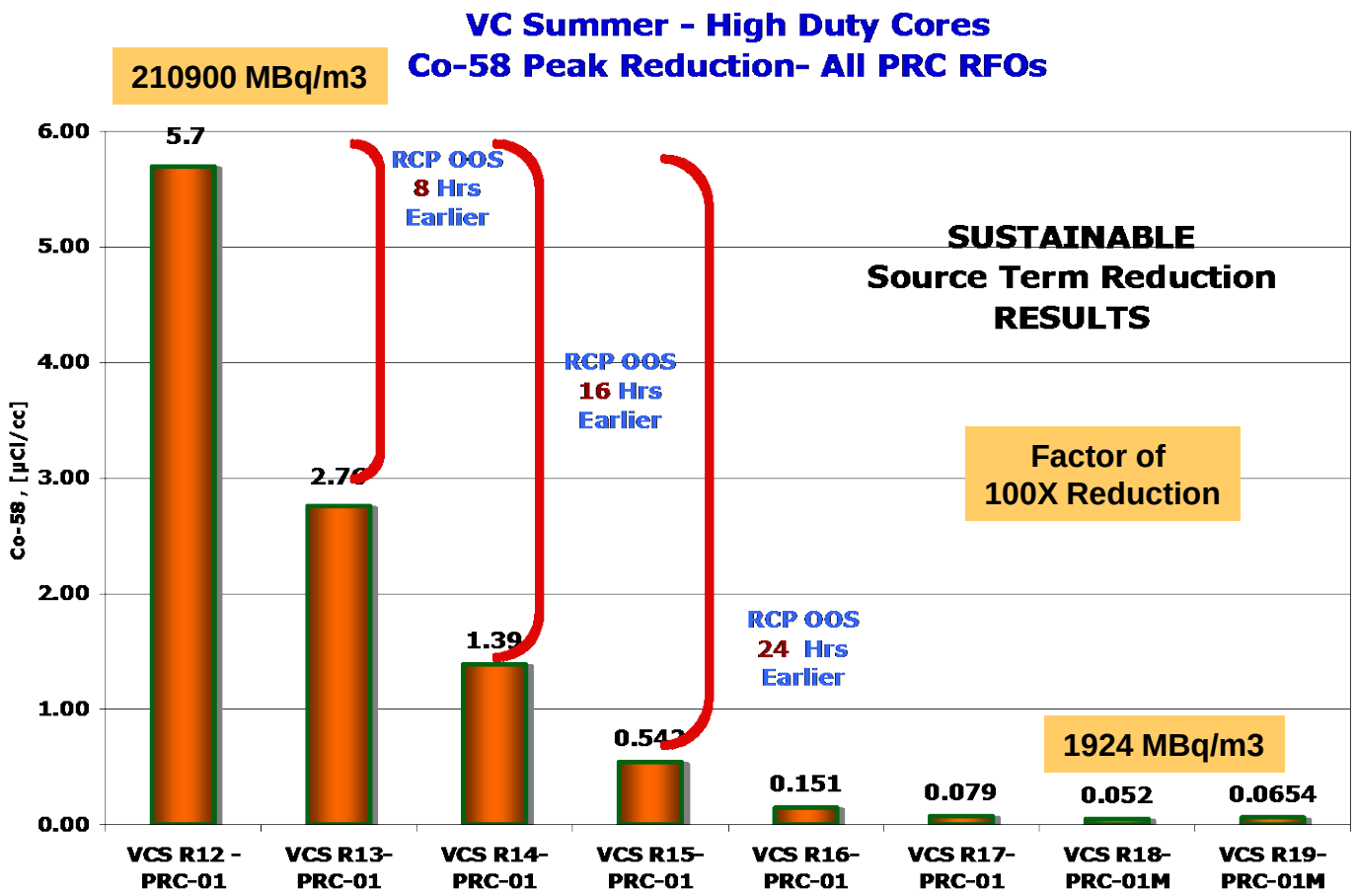
- **- 60.0%**
  - **Reduction in number of High Radiation Area**
- **- 35%**
  - **Reduction in contract HP staff, $400,000 avoided costs every RFO.**
- **- 76%**
  - **Reduction in Hot Spots**
- **- 49 X (fold)**
  - **Reduction in annual effluent activity discharged for Co-58 and 15 fold for Co-60**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

Can Results Be Duplicated at Other Stations?

- **The Source Term Problem is Never Really Solved, if you cannot duplicate results**
- **Results Follow for:**
  - **PWR: 3 Loop, VC Summer**
  - **PWR: 4 Loop Ice Condense, DC Cook-1,2**
  - **BWR: Monticello**
  - **BWR: Vermont Yankee**
  - **BWR: Peach Bottom-2,3**

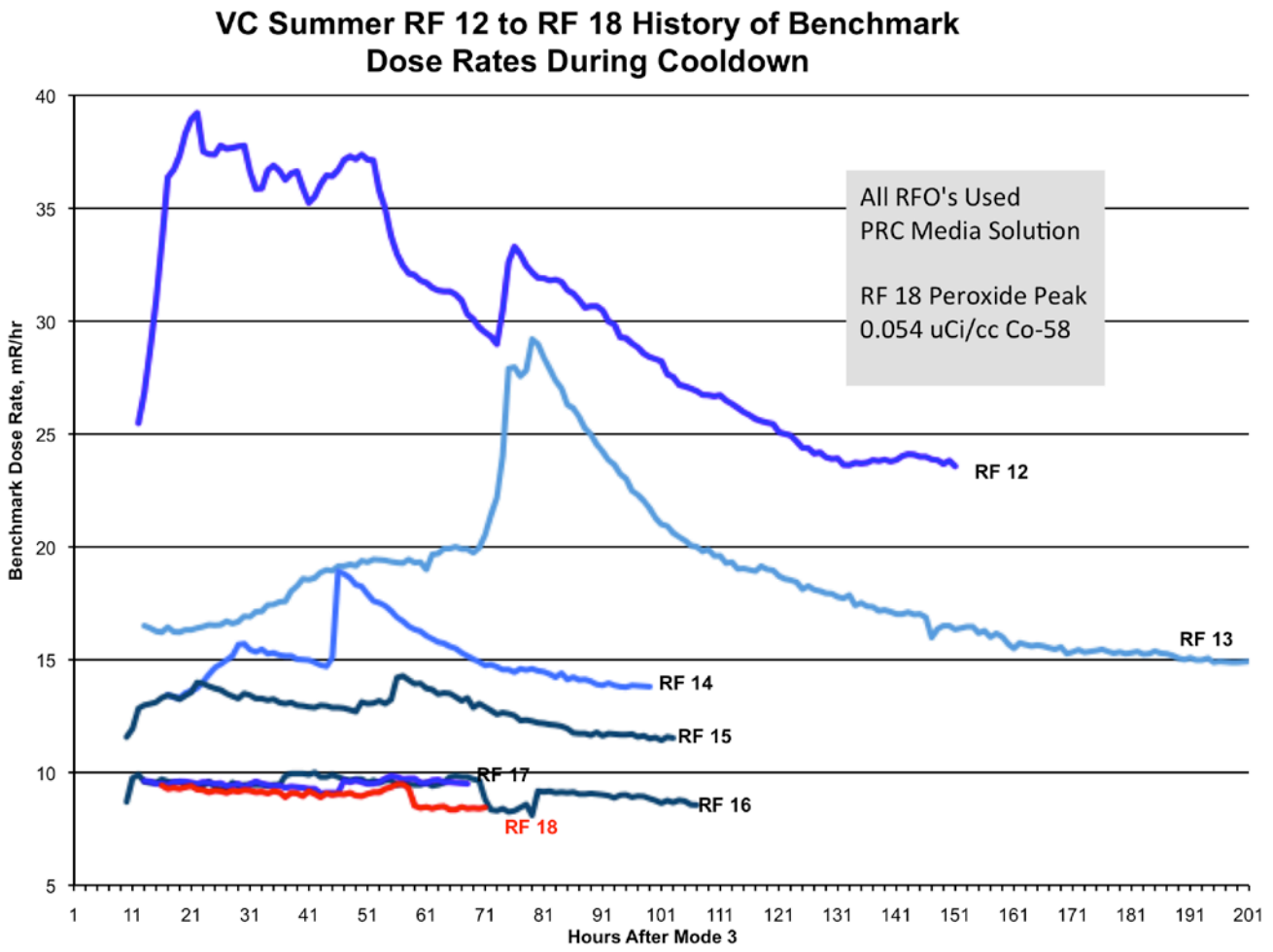
Duplicated at VC Summer



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

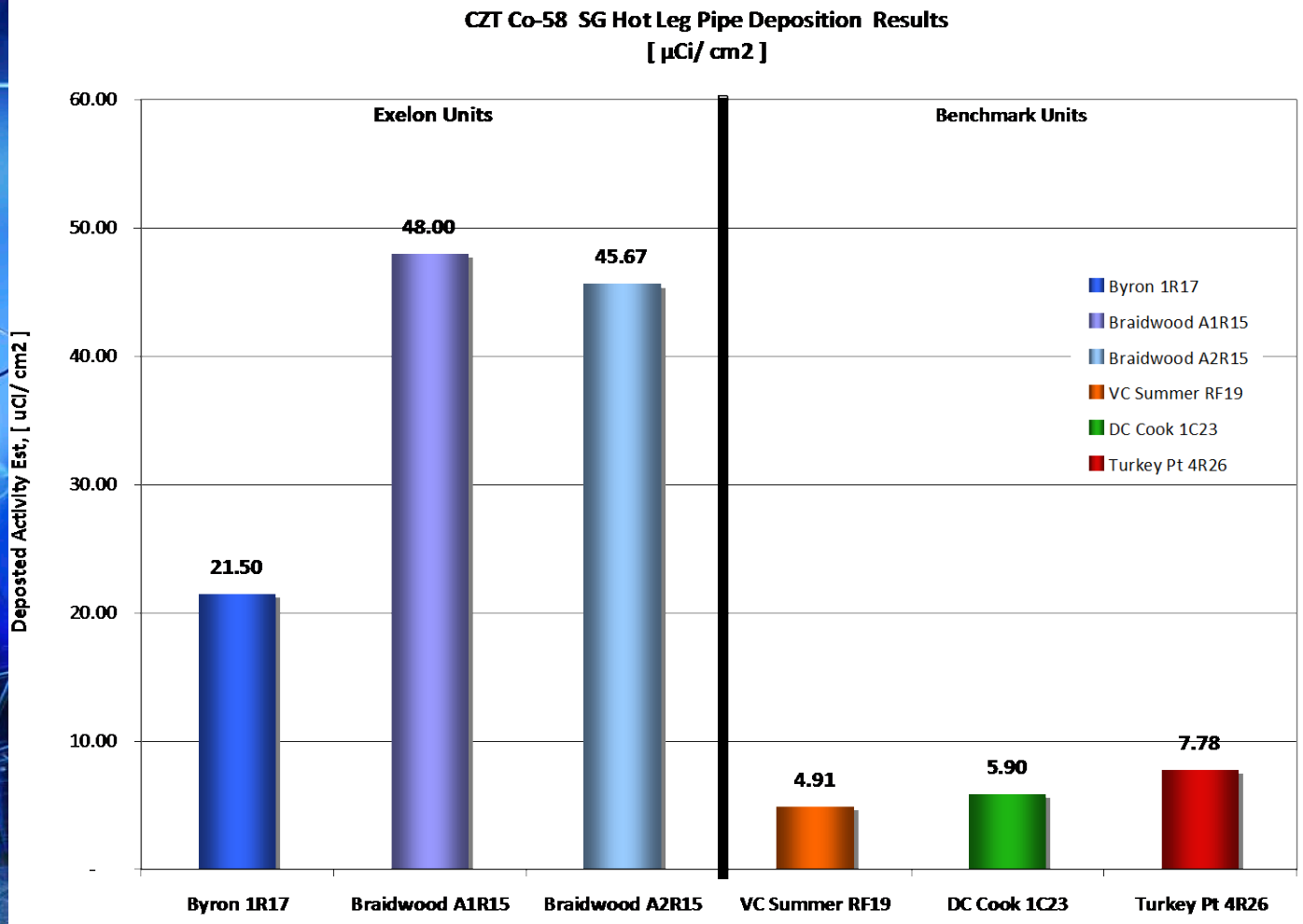
Duplicated at VC Summer- 30 hours

Critical Path Savings from Source Term Reduction



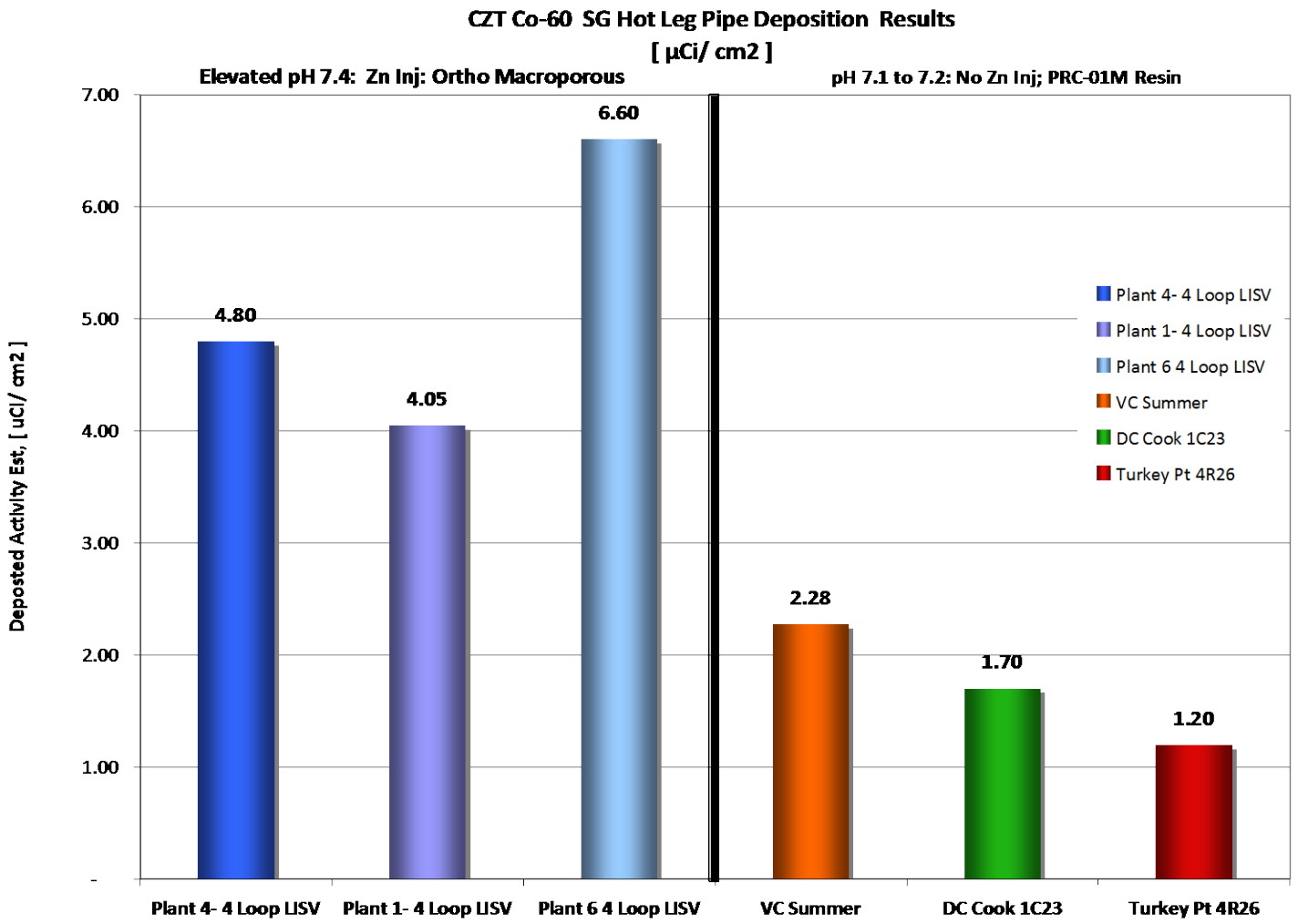
CZT Results - Benchmarks

Co-58 SG Hot Leg Piping Deposited Activity



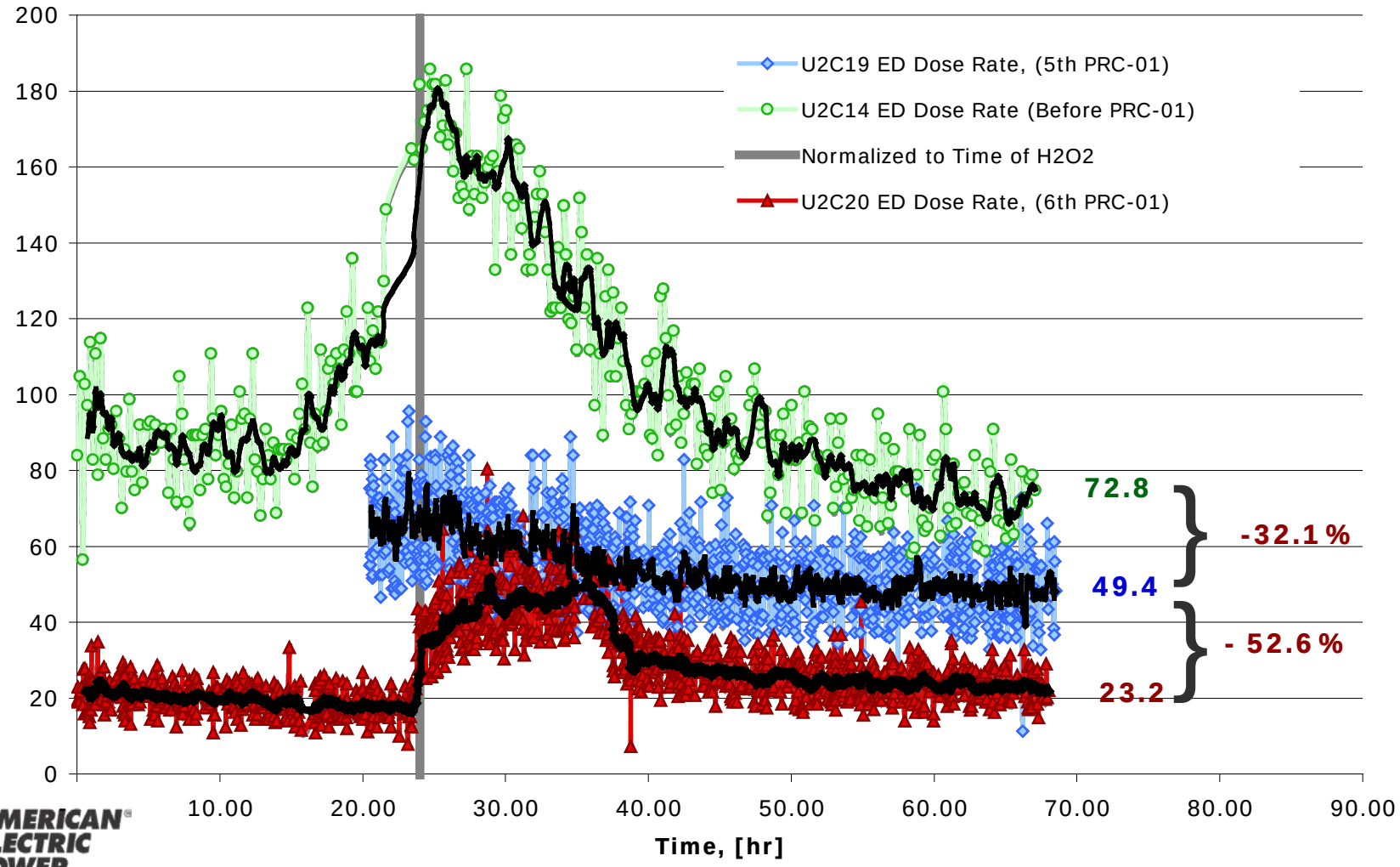
CZT Results - Benchmarks

Co-60 SG Hot Leg Piping Deposited Activity



Effective Source Term Results

Achieved Through Implemented Proprietary 2 Part Engineered Solution



AEP AMERICAN ELECTRIC POWER

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

Peach Bottom 2, 3

- 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

Summarizing "Why" Reduce Source Term 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)

Summarizing "Why" Reduce Source Term Initiative Value Proposition

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

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

Here's What I Believe…

- I believe in Radiation Protection
  - as my Professional, and Ethical responsibility for health and safety of Nuclear Power Plant workers.
  - I am one of them.
- I believe ALARA
  - As an important guiding directive, because we don't know everything about radiation health effects

Why Reduce Radiation Exposure? New Research

- It is Not Just Cancer Induction Risk Anymore
- Radiation Induced Cardio Vascular Damage from Low Dose Ionizing Radiation
- Lens of Eye Damage