Duke Source Term Reduction Strategies

David A Thompson, CHP
Manager, Fleet Radiation Protection/Chemistry

Agenda

- Background
- Forced Oxidation/Crud Burst Strategy
- Lithium pH Strategy
- Zinc Addition
- Fuel Cleaning
- Filtration Strategies
- Resin Overlays
- Results

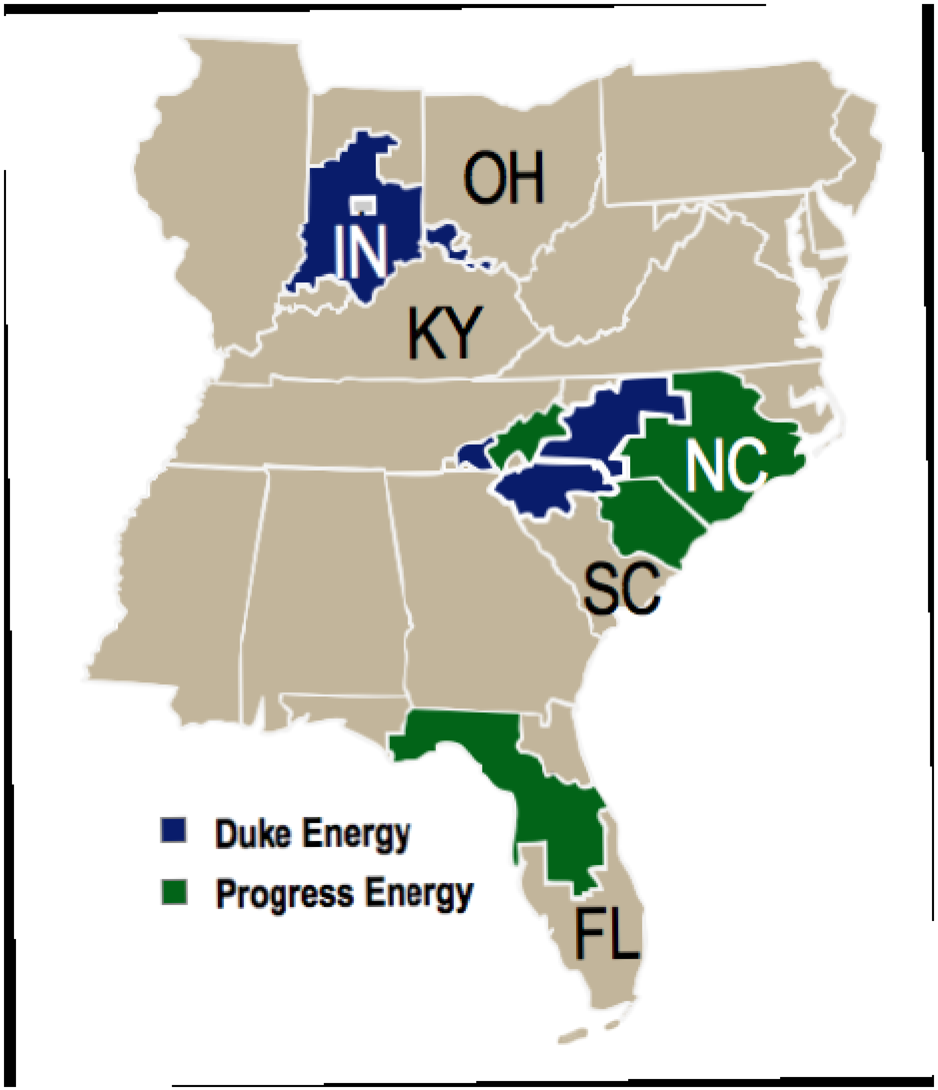
Background

- Duke Energy has 7 reactors at 3 sites in North and South Carolina
- Oconee: 3-Unit PWR located in NW South Carolina, on Lake Keowee. ~ 2-hours NE of Atlanta
  - B&W Design 4-RCPs, 2 OTSGs
  - ~900 MWg per unit
  - Commissioned between July 1973, and December 1974

Duke Energy®

Background (cont.)

- McGuire Nuclear Station, ~ 30 minutes N. of Charlotte, NC on Lake Norman
    - 4-Loop Westinghouse PWR, w/Ice Condenser Cnmt.
    - ~1200 MWg per Unit
    - Commissioned December 1981, and March 1984
- Catawba Nuclear Station, ~45 minutes SW of Charlotte, NC on lake Wylie
    - 4-Loop Westinghouse PWR, w/Ice Condenser Cnmt.
    - ~1200 MWg per Unit
    - Commissioned June 1985, and August 1986


OH
IN
KY
NC
SC
FL
Duke Energy
Progress Energy

Background (cont.)

- McGuire 1EOC16
  - Crud Burst Peak of 10.43 uCi/ml (2.6 uCi/ml Particulate)
  - Solubility following peroxide addition 68-80%
  - Significant Particulate Contamination during Steam generator Eddy Current testing
    - Contamination Control Issues
    - Dose Overages
    - Critical Path delays to manage the impact
  - Root Cause performed for impact drove several CAPRs
    - Ultrasonic Fuel Cleaning
    - Implement improved filtration program
    - Guidance developed for running, starting, and shutting down RCPs during Crud Burst
    - Eliminate Nickel based lubricants

Background (cont.)

- Steam Generator Replacements on 6 of 7 units
  - Catawba 1—RFO 9 (September 1996)
  - McGuire 1—RFO 11 (April 1997)
  - McGuire 2—RFO 11 (November 1997)
  - Oconee 1—RFO 21 (November 2003)
  - Oconee 2—RFO 20 (May 2004)
  - Oconee 3—RFO 21 (December 2004)
- Replacement S/G tubes are Inconel 690TT
- Catawba 2, original S/Gs are Inconel 600TT

Duke Energy®

Forced Oxidation Strategy

- McGuire/Catawba
  - Full inventory Crud Burst w/no RCPs running
  - Reactor vessel level is maintained above the flange
  - All RCPs are turned off
  - Peroxide is added, and clean-up is performed via the Decay Heat Removal System
- Oconee
  - Reduced inventory, with same clean-up strategy

Forced Oxidation Strategy (cont.)

- **Catawba 1**—last 3 shutdowns have been full system, no RCPs running (RHR pumps only)
- **Catawba 2**—last 3 shutdowns have been full system, no RCPs running (RHR pumps only)
- **McGuire 1**—RFO 17 – full system, 1 RCPs running; RFO 18 – full system, 1 RCPs running; RFO 19 – full system, 3 RCPs running; RFO 20 – full system, no RCPs running (RHR pumps only) RFO 21 – full system, no RCPs running (RHR only)
- **McGuire 2**—RFO 17 – full system, 2 RCPs running; RFO 18 – reduced inventory, no RCPs running (RHR only); RFO 19 – full system, no RCPs running (RHR only); RFO 20 – full system, no RCPs running (RHR only)
- **Oconee 1**—RFO 23 – full system, 2 RCPs running; RFO 24 – reduced inventory, RHR only; RFO 25 – reduced inventory, RHR only; RFO 26 – reduced inventory, RHR only
- **Oconee 2**—RFO 21 – full system, 2 RCPs running; RFO 22 – full system, 2 RCPs running; RFO 23 – reduced inventory, RHR only; RFO 24 – reduced inventory, RHR only; RFO 25 – reduced inventory, RHR only
- **Oconee 3**—RFO 22 – full system, 2 RCPs running; RFO 23 – reduced inventory, RHR only; RFO 24 – reduced inventory, RHR only; RFO 25 – reduced inventory, RHR only;

Forced Oxidation Strategy (cont.)

- Catawba—adds to CVCS charging flow downstream of VCT (normal chem add point)
- McGuire—adds to CVCS charging flow downstream of VCT (normal chem add point)
- Oconee—adds to CVCS between deborating demin outlet and letdown filters (upstream of letdown storage tank (VCT))

Forced Oxidation Strategy (Cont.)

- Theory behind strategy
  - Remove crud with-out redistributing throughout the Reactor Coolant System
  - RCPs off, so that sheer forces do not pull crud off the fuel
  - Use fuel cleaning machines to remove the crud from all reinsert assemblies prior to core reload
- Challenges to this strategy
  - Oconee does not fuel clean. Significant source term in SFPs during core offload/reload activities

Lithium/pH Strategy

- All units employ a constant pH, with maximum pH associated with boron limitations during cycle
  - Catawba 1—constant pH 7.15 at T_{ave} (began in cycle 15, March 2004)
  - Catawba 2—constant pH 7.20 at T_{ave} (began in cycle 14, October 2004)
  - McGuire 1—constant pH 7.15 at T_{ave} (began in cycle 17, April 2004)
  - McGuire 2—constant pH 7.15 at T_{ave} (began in cycle 17, April 2005)
  - Oconee 1—constant pH 7.10 at T_{ave} (began in cycle 21, April 2002)
  - Oconee 2—constant pH 7.10 at T_{ave} (began in cycle 20, November 2002)
  - Oconee 3—constant pH 7.10 at T_{ave} (began in cycle 21, June 2003)

Duke Energy®

Zinc Addition

- Zinc Addition is the desired strategy at all Duke Energy PWRs.
  - Catawba 1—began in cycle 17 (September 2007), target 10 ppb
  - Catawba 2—began in cycle 15 (January 2007), target 10 ppb
  - McGuire 1—began in cycle 18 (early 2006), target 10 ppb
  - McGuire 2—began in cycle 17 (fall 2005), target 10 ppb
  - Oconee—no zinc addition

Zinc Addition – Oconee

- Oconee SFPs have boraflex racks that are degrading
  - Silica concentrations are higher than fuel warranties support for 18-month cycle, with no zinc
  - Pursuing 24-month cycle, with more restrictive warranty requirements. (U2 Core Loaded Fall '11)
  - Zinc addition further reduces margin with respect to fuel warranties

Duke Energy®

Zinc Addition – Oconee

- Long Term Strategy
  - Pursuing Reverse osmosis units for each units BWST
    - License Amendment determined to be required late in project
    - Delayed 24-month fuel from being initiated following Spring '11 outage
  - Zinc Addition at risk for current Unit-2 cycle, due to delays in LAR approval
    - RO Unit not available to remove silica from BWST, impacting ability to dilute below 1.5 ppm

Fuel Cleaning

- Initially implemented as a CAPR from root cause associated with McGuire Steam generator crud
- Currently Core design group recommends cleaning of all reinserts and requires cleaning of high percentage (>90 reinsert assemblies, dependant on core design) to reduce CIPS risk
  - Catawba 1—began during RFO 15 (May 2005)
  - Catawba 2—began during RFO 14 (March 2006)
  - McGuire 1—began during RFO 17 (fall 2005)
  - McGuire 2—began during RFO 16 (March 2005)
  - Oconee—does not clean fuel
    - Core design is significantly less aggressive with respect to CIPS risk, as compared to Westinghouse units, even with 24-month fuel

Duke Energy®

Filter Strategies

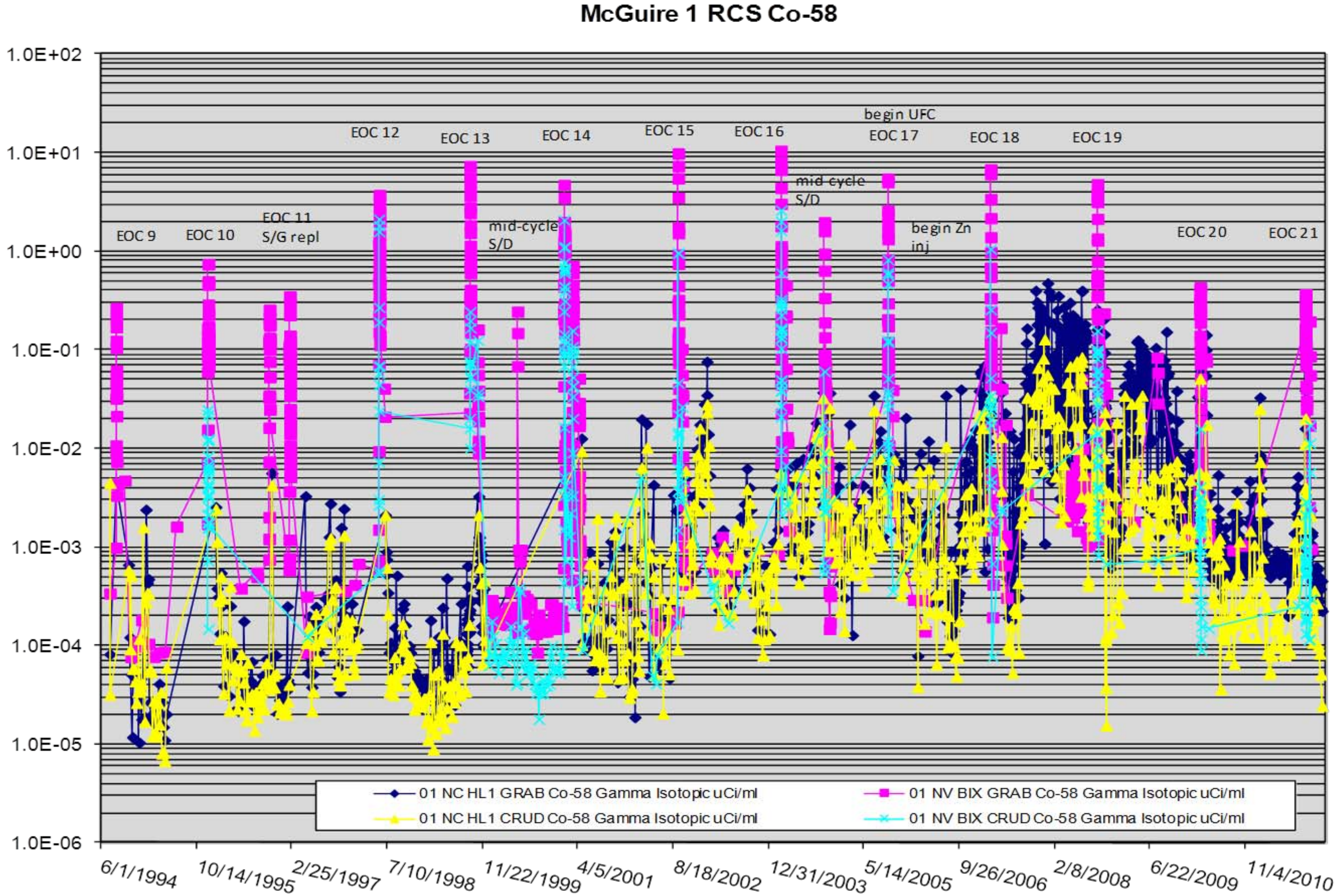
- McGuire
  - 0.1micron on-line, 1 micron standby
  - 0.1 micron during cool down
  - Both filters changed to 1.0 micron just prior to placing RHR in service (parallel flow during crud burst cleanup)
- Catawba
  - 0.1 micron on-line
  - 0.1 micron during outages. 1 micron as back-up
    - Prior to 2010, >10 filter changes post peroxide addition
- Oconee
  - 0.1 micron on-line
  - Historically increased to 5 micron prior shut-down through start-up
  - Spring '11 outage, went to a 1 micron filter during shut-down with opposite train loaded with a 5 micron filter. No filter changes during crud burst clean-up
  - Fall '11 outage 1 micron loaded on both trains of clean-up. Significant challenges with maintaining filter availability
  - 95+% solubility

Resin Overlays

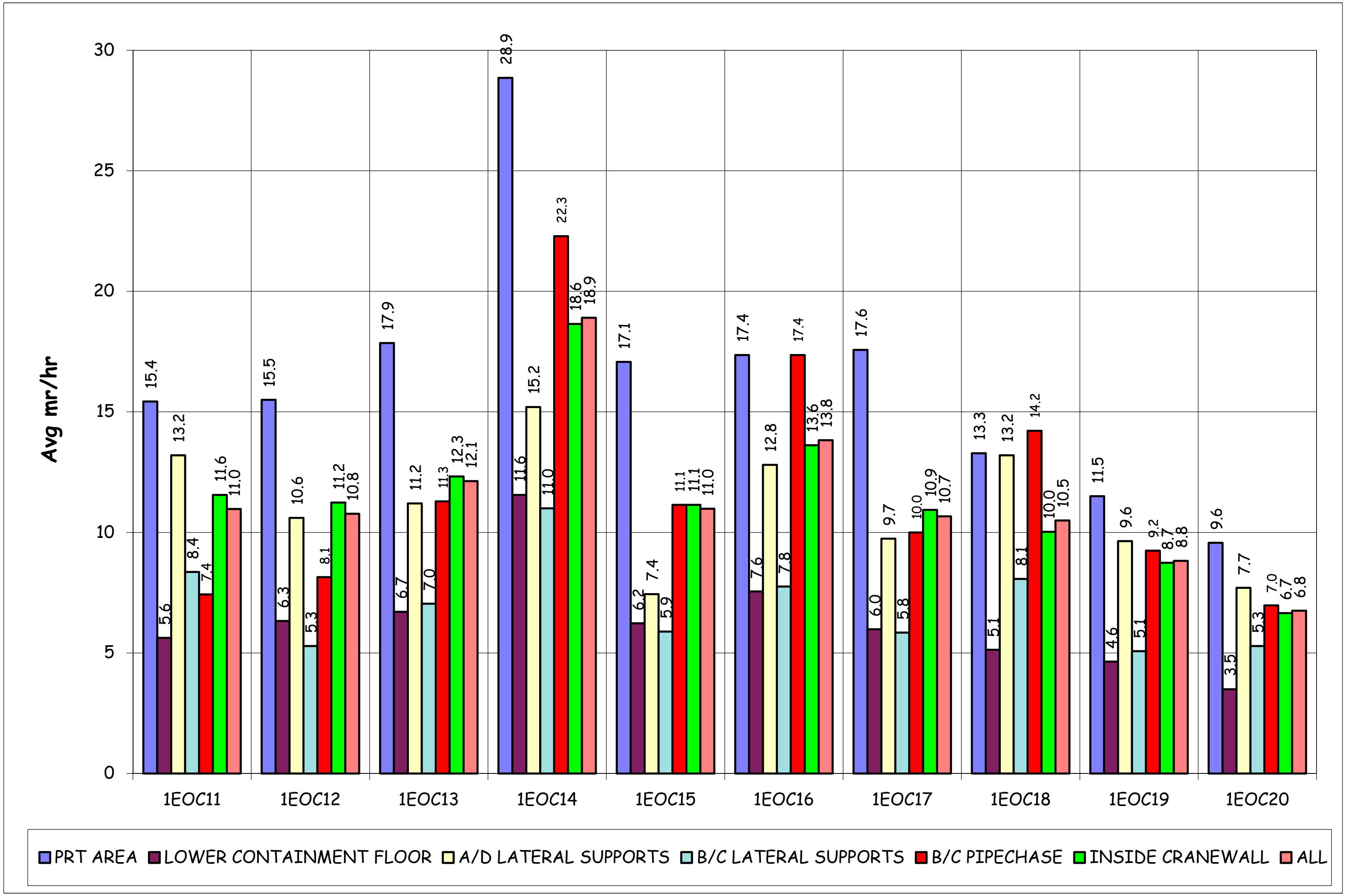
- Resin Overlay Pilot at Catawba this past year has shown benefit
  - Catawba—used 5 ft^3 anion and 5 ft^3 cation Purolite 5070 macroporous resin overlays in one CVCS demin on unit 2 during cycle 17 shutdown (September 2010) and on unit 1 during cycle 19 shutdown (April 2011)
    - Significant reduction in CVCS filter usage
  - McGuire—Delayed to 2012 due to issues with vendor resin (unrelated to Purolite)
  - Oconee—will add overlays during next primary resin bed change

Duke Energy®

Results – McGuire – 1



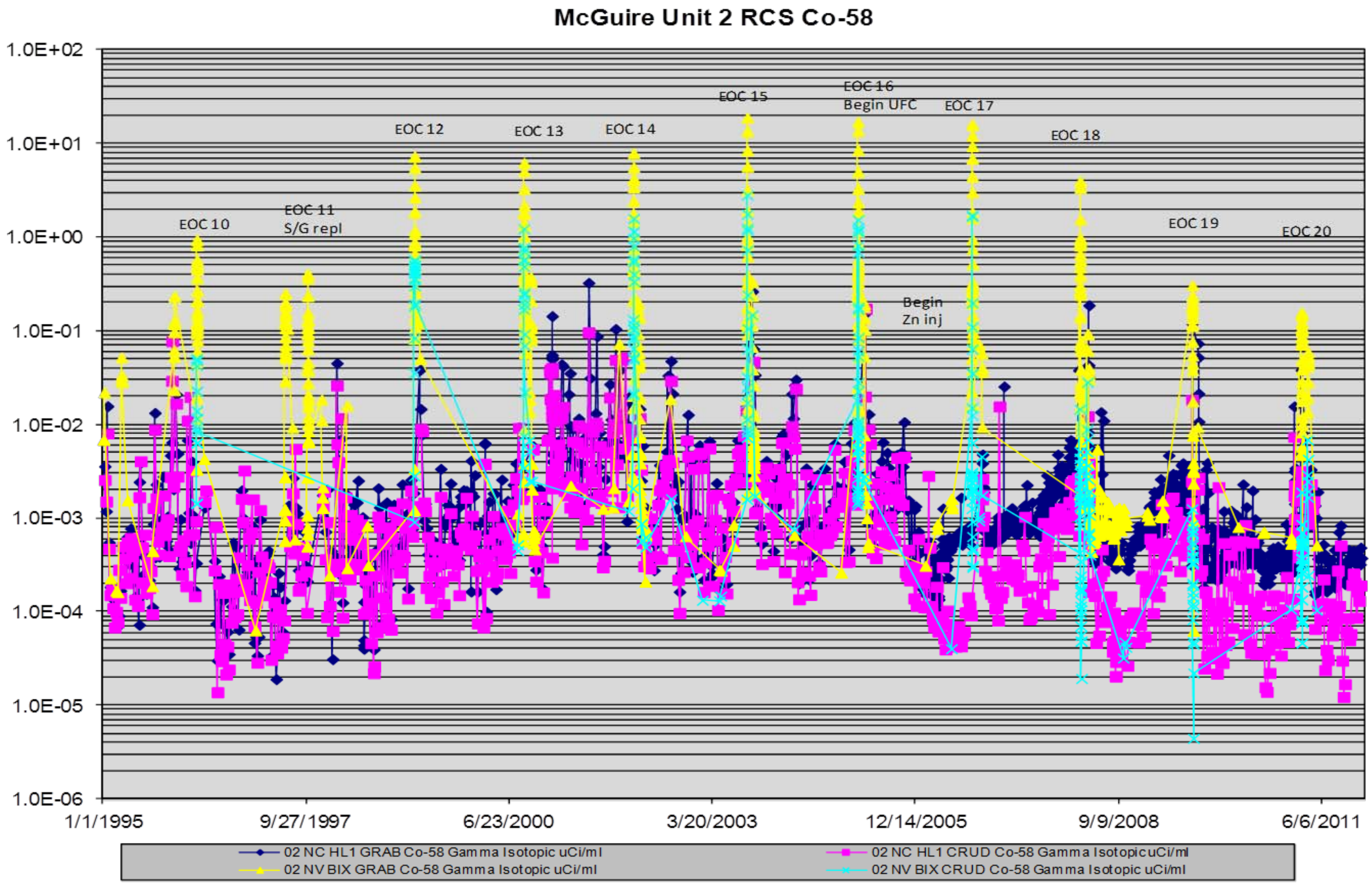
Results – McGuire – 1



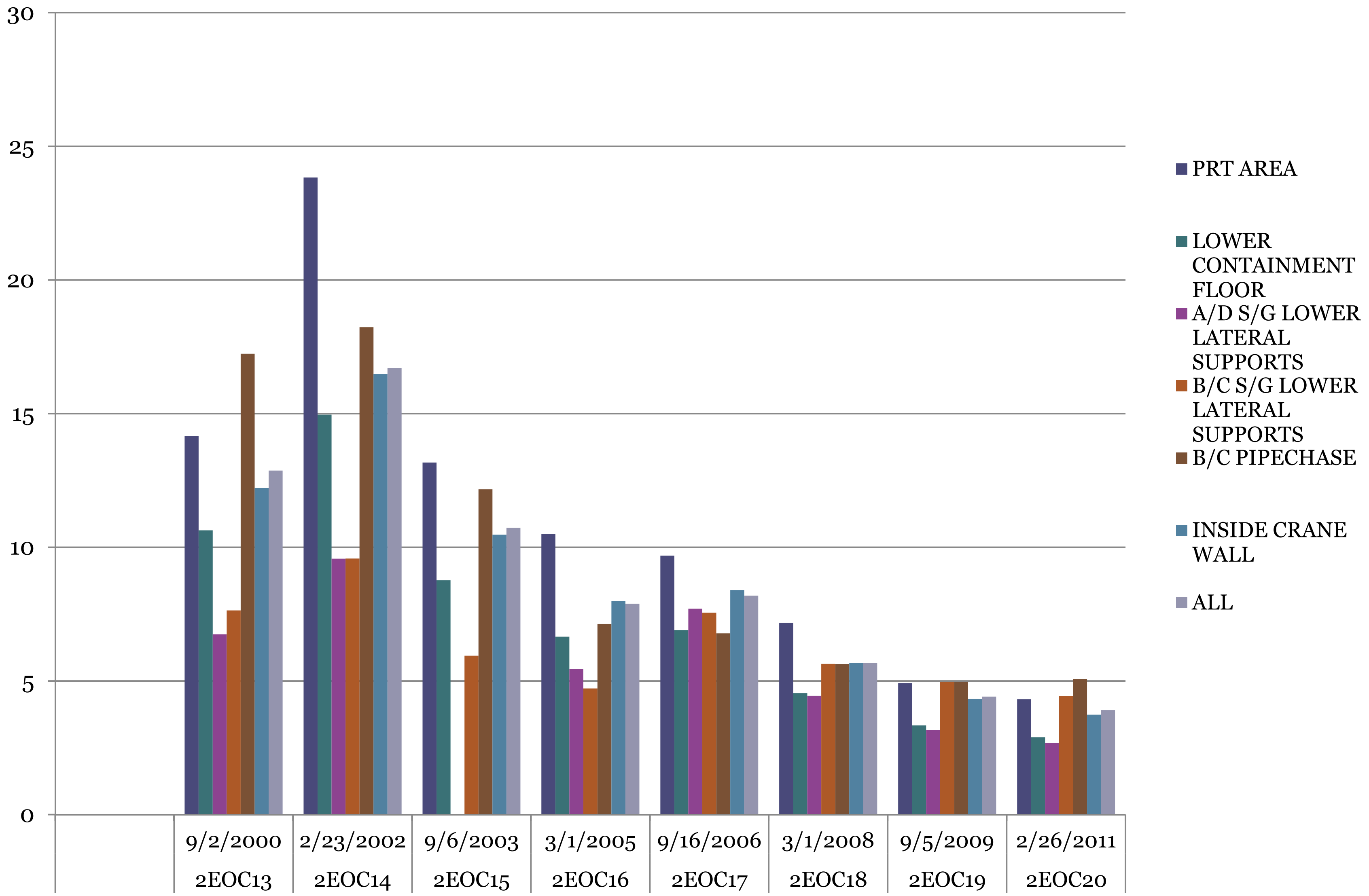
Results – McGuire – 1

- Greater than 3 cycles of zinc injection
  - -2%, -15%, -24% last 3 outages
  - -35% over last 3 cycles
- TLD/ED ratio over responding, compared to historical (Indicative of shift to Co-60 from Co-58)
- >Three (3) cycles of fuel cleaning
- Most recent crud burst peak of 0.29 uCi/ml
- Currently Top of 2nd Quartile in Dose performance

Results – McGuire – 2



Results – McGuire – 2

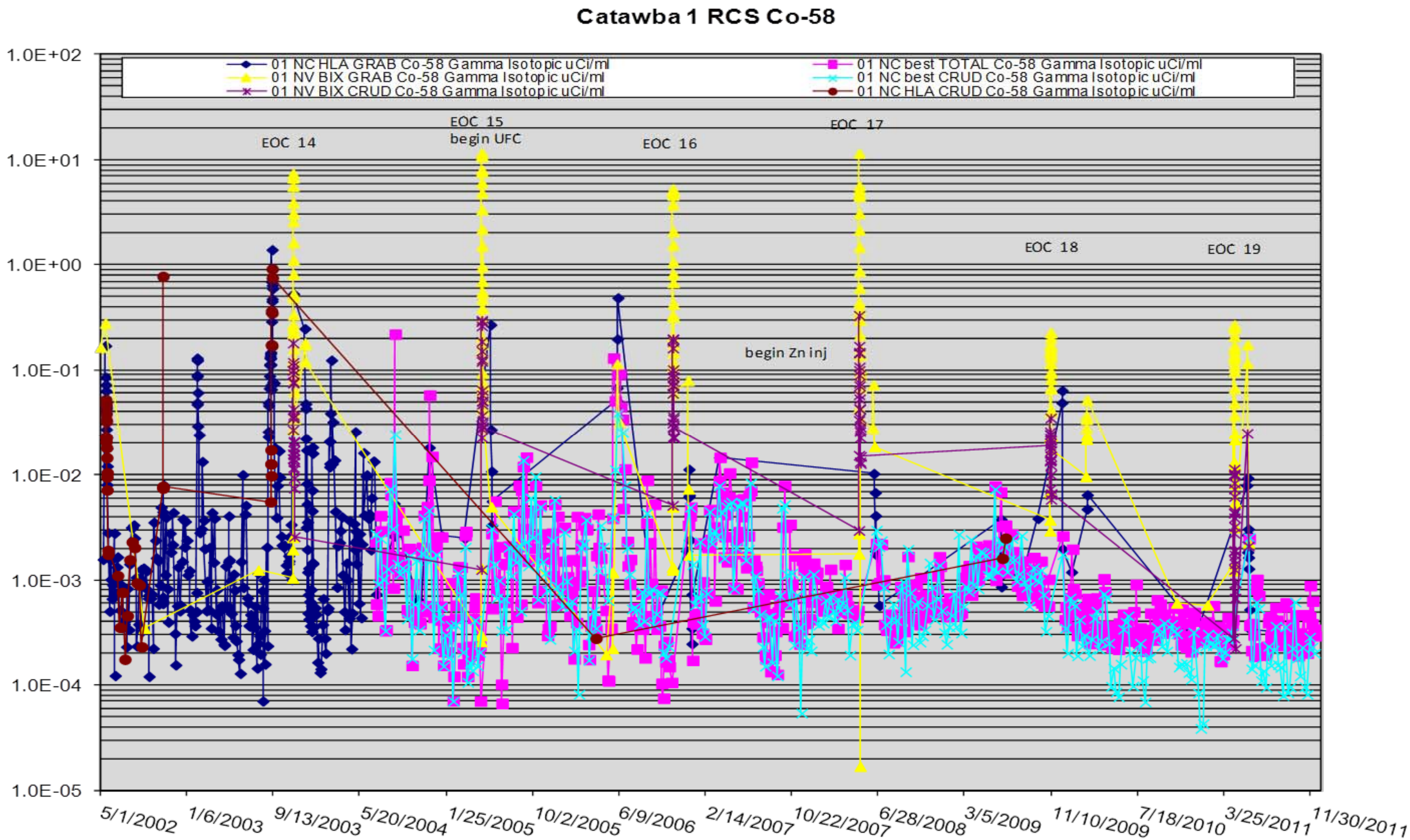


Results – McGuire – 2

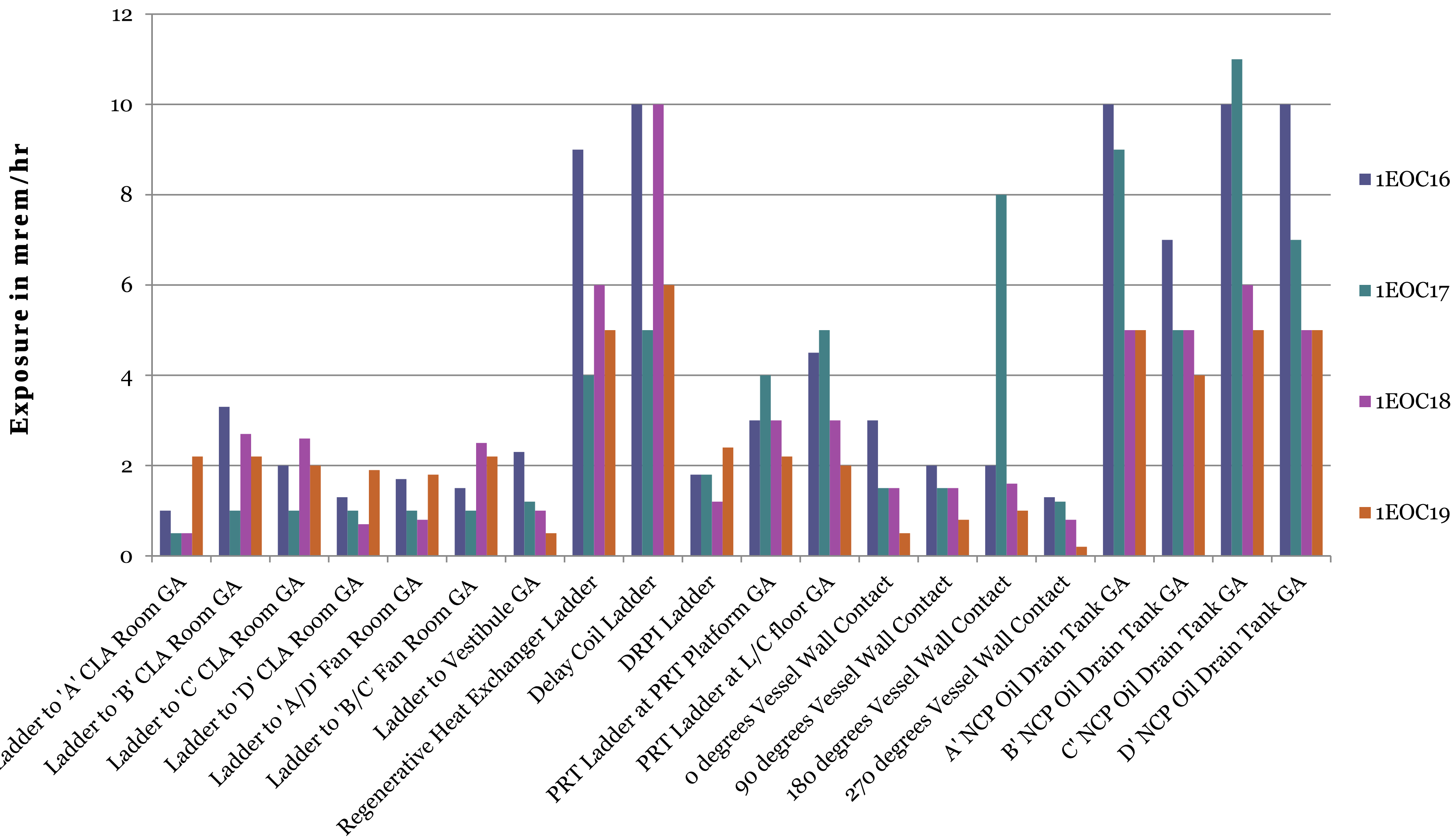
- Greater than three (3) cycles of zinc injection
  - -31%, -22%, -11% last three (3) outages
  - -55% base point dose rates over last 3 outages
- TLD/ED ratio over responding, compared to historical (Indicative of shift to Co-60 from Co-58)
  - Co-58/Co-60 scans show >90% Co-60 in high flow areas
- >Three (3) cycles of fuel cleaning
- Most recent crud burst peak of 0.16 uCi/ml
- Near Top Quartile Dose performance
  - Significant scope expansion associated with fuel transfer cart repairs

Duke Energy®

Catawba Unit – 1



Catawba Unit – 1



Catawba Unit – 1

- Three (3) Cycles of Zinc Addition
- ~15% decrease in GA dose rates, each of last 3 cycles. (~40% overall)
- >Three (3) Cycles of Fuel cleaning
- Forced Oxidation Crud Burst peak of ~0.26 uCi/ml
- Top Quartile Dose performance past 2 outages
    - Most recent outage ~40 days with a RCP pump replacement, and full scope S/G repairs

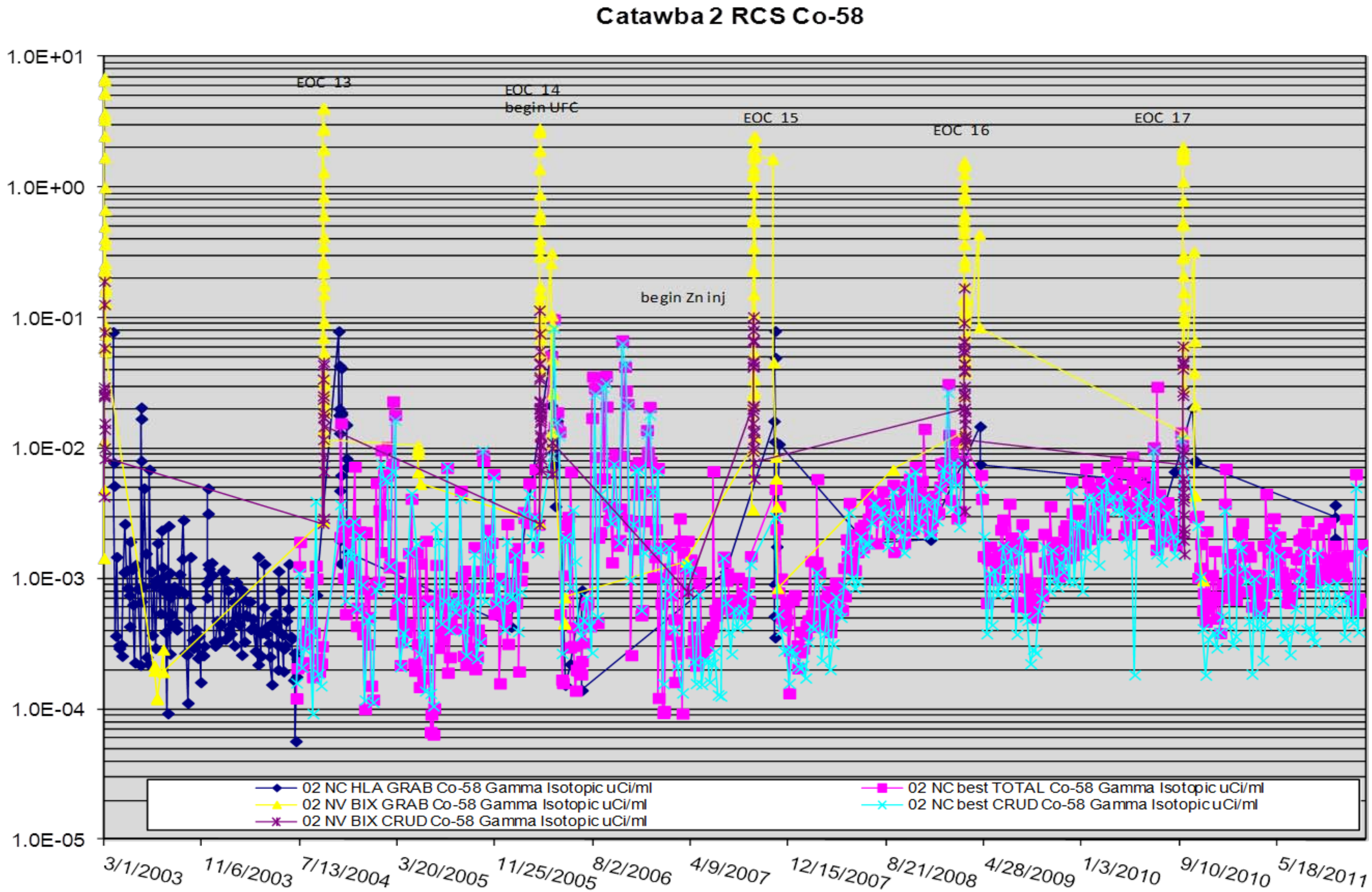
Duke Energy®

Results – Interim Summary

- Assumptions:
  - Iconel 690TT S/G Tubes
  - 3+ cycles of Zinc Addition
  - 3+ cycles of 100% Ultrasonic Fuel Cleaning
  - No focused fleet filtration strategy.
  - Full inventory forced oxidation, with all RCPs off
- Results
  - General Area Dose rates aligned with the Co-60 decay curve over past 3 cycles.
  - Forced oxidation Crud burst peaks at industry best levels (~0.25 uCi/ml)
  - Outage doses around industry top quartile performance.

Duke Energy®

Results – Catawba – 2



Results – Catawba – 2

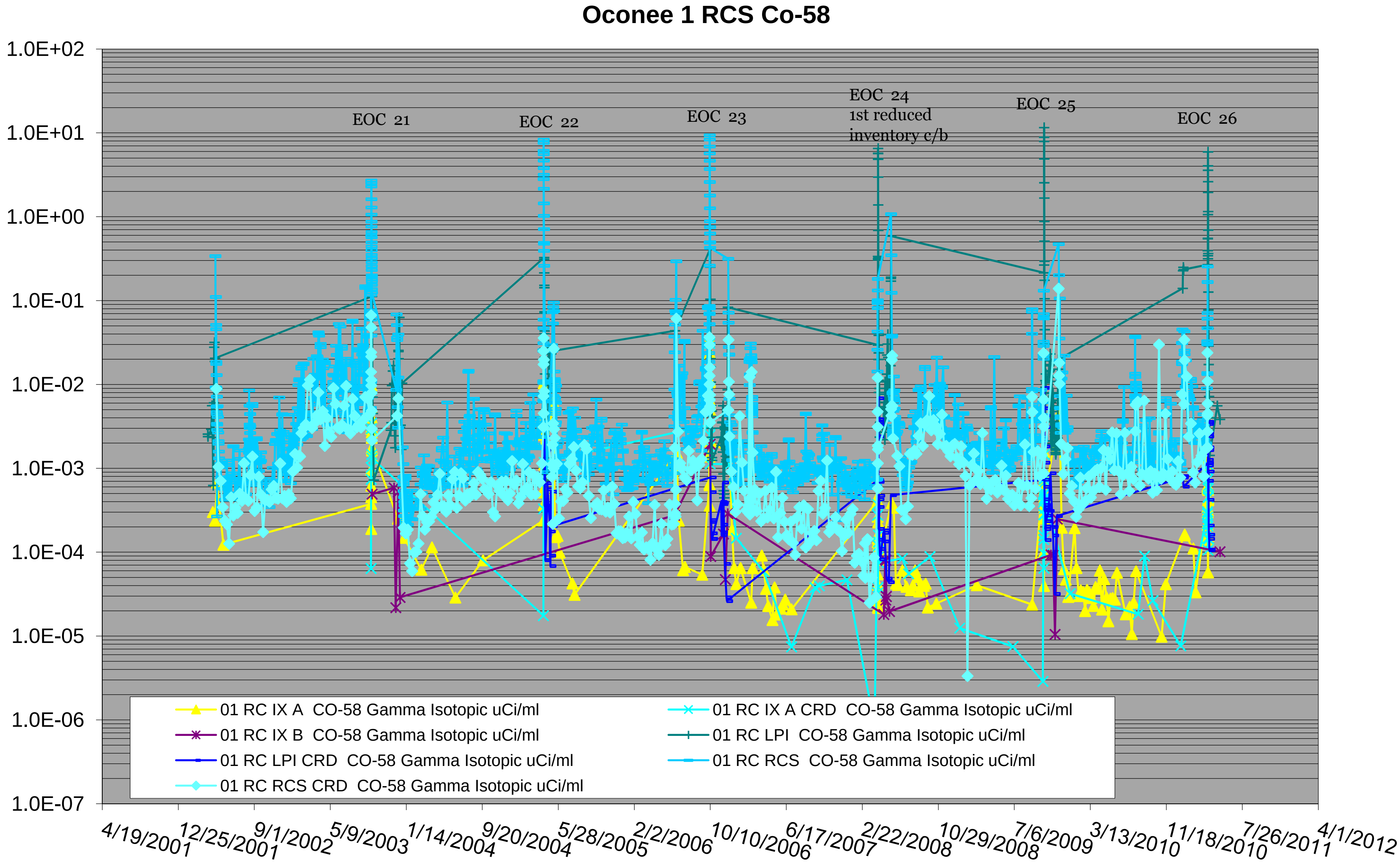
- Three (3) Cycles of Zinc Injection
  - 10% decline in dose rates each of last 2 cycles
  - 18% decline in dose rates over last 3 cycles
- >Three (3) Cycles of Fuel Cleaning
- Crud Burst peaks since start of UFC at 1.5-2.8 uCi/ml
- 3rd Quartile Dose Performance
- S/G Tubes only difference from MNS 1&2 and CNS 1 (Inconel 600TT, vs Iconel 690TT)
  - Gamma scan data not available

Duke Energy®

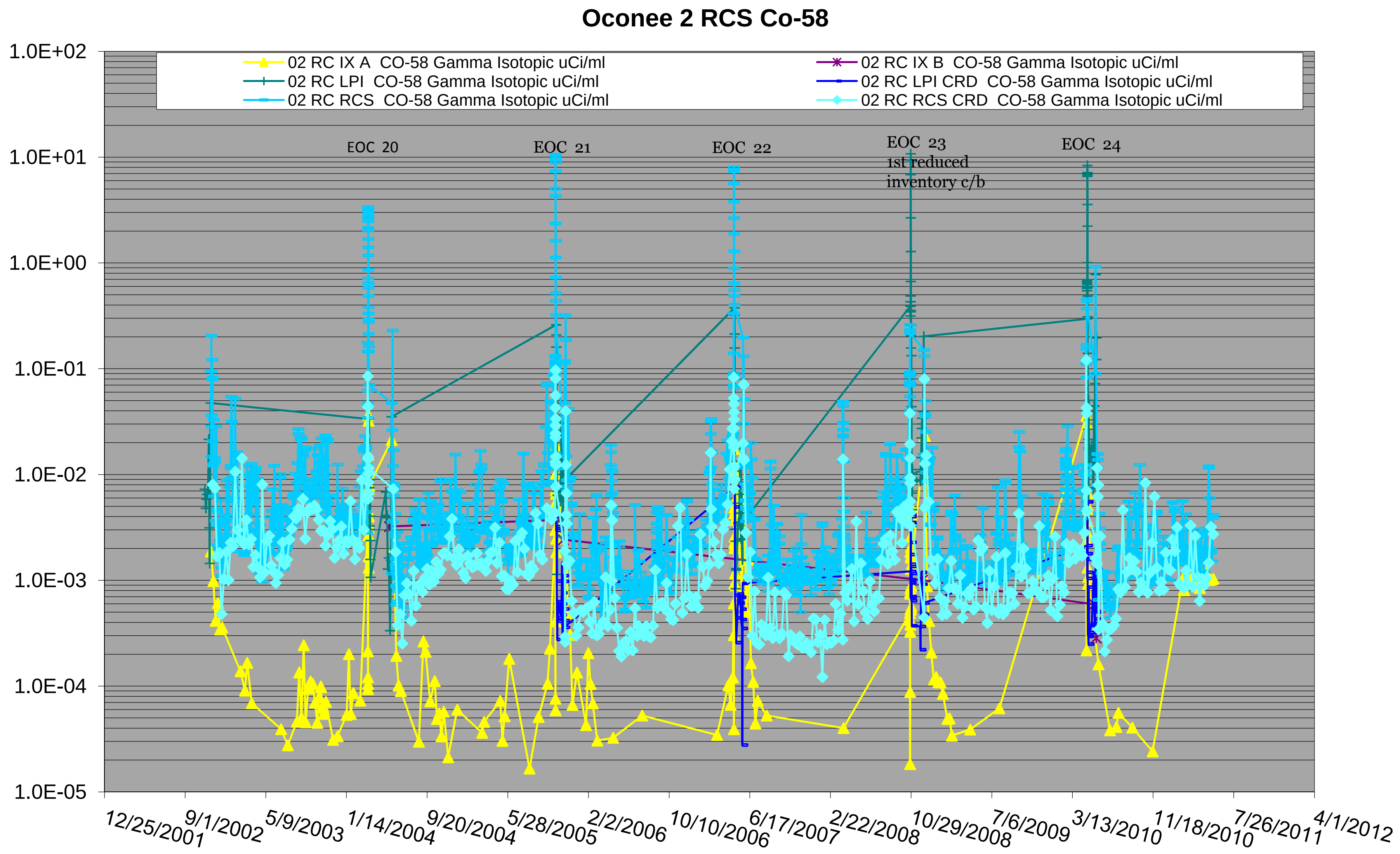
Results – Interim Summary

- Open Question
  - MNS and CNS have diverging ED/TLD ratios
    - MNS >1.0 ED/TLD ratio on both units
      - ED Correlation has been adjusted to bring MNS back below 1.0
    - CNS ~0.8 ED/TLD ratio on both units
  - MNS 1&2 and CNS 1 are behaving similarly with respect to chemistry parameters, but not with respect to ED/TLD ratio.

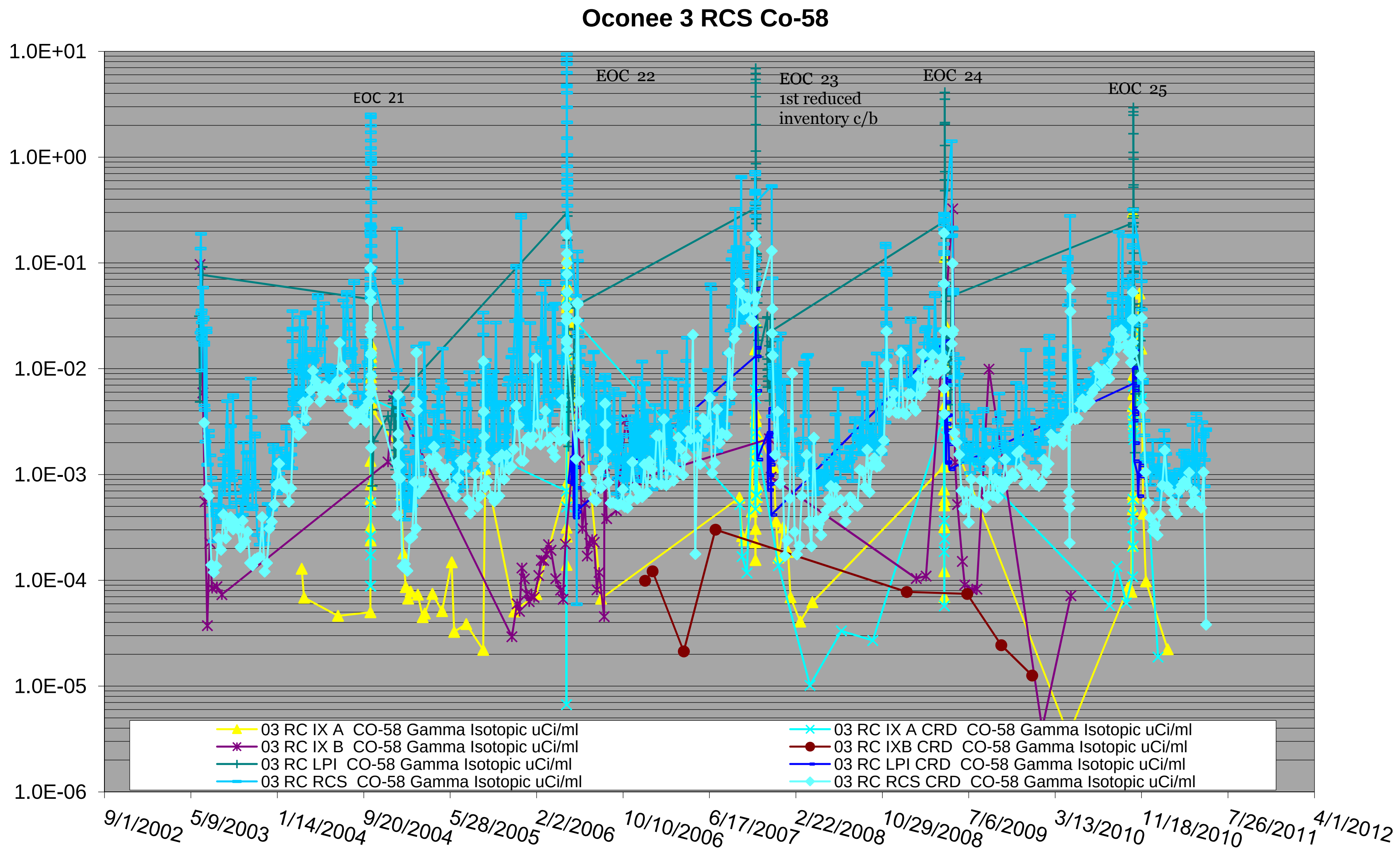
Results – Oconee – 1



Results – Oconee – 2



Results – Oconee – 3



Results - Oconee

- All Three (3) Units have predictable crud burst peaks and dose rates
  - 8 uCi/ml forced oxidation peak with reduced inventory crud burst
    - Mid-cycle forced outages reduce peak, but calculated curies removed remains unchanged
- Base scope outage is ~60 Rem – All 3 units
  - Bottom of second quartile performance best case scenario, if no major modifications or rework
- Unit-3 has additional challenges with particulate contamination associated with legacy operational strategies

McGuire – 1 CZT Results

	RY Surge Line	‘B’ SG Hot Leg	‘B’ SG Cold Leg	‘D’ SG Cold Leg	‘B’ SI Check Valve	‘D’ SI Check Valve	‘B’ X-over loop	‘D’ X-over loop	RHR Let-down Line
Co-58 (uCi/cm²)	2.04	5.66	3.61	15.6	3.11	4.30	10.3	1.76	8.07
Co-60 (uCi/cm²)	5.82	1.72	1.59	6.22	3.72	1.70	13.0	29.8	1.92
Co-58/ Co-60	0.35	3.29	2.27	2.51	0.84	2.53	0.80	0.06	4.20

Duke Energy®

McGuire – 1 CZT Results (cont.)

- Preliminary Thoughts for Discussion
  - High Flow regions have relatively high ratio of Co-58/Co-60. Indicative of Co-60 decaying
    - SG Hot/Cold Legs
    - Letdown piping
  - Lower flow areas have lower ratio
    - 'B' SI Check Valve
    - 'B' and 'D' Cross-over loops
      - 'D' SI Check valve more aligned with high flow areas. Why?
  - Pressurizer Surge line has ratio aligned with low flow regions

Duke Energy®

Duke Chemistry Source Term Reduction Strategy

QUESTIONS???