

Source Term Challenges At LaSalle Station

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Rev. 2

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Overview

LaSalle Unit 2 is recognized as one of the highest source term plants in the world. Additionally, the unit has experienced chronic fuel failures which compounds the source term issue and challenges nuclear safety as one barrier to the public is degraded. This requires aggressive and broad based actions to mitigate risk in the areas of radiological and nuclear safety.

Unit 2 is in the 4th Quartile in CRE with a 2-year rolling average of 247.3 rem and 0 INPO points. With the current strategy and work scope Unit 2 can not achieve full points and 1st Quartile until after 2022. With the completion of the L2R16 CRE reduction initiatives we are projected to achieve full points and 1st Quartile performance in 2019.

LaSalle Cobalt Information

Cobalt Check-in Assessment Information:

Based on industry data for soluble Co-60 for BWR 5/6 units; out of the eleven sites, Unit 1 was ranked 6th and Unit 2 was in 11th place. For reference, soluble Co-60 is the driving force for incorporation into piping films.

BWR 5/6 Sorted by Soluble Co-60 Levels			
	Most Recent RCI Co-60 Sol	Soluble Co-60 Rank	CRE Quartile (1Q2015 -New)
Clinton	2.18E-05	1	1
Grand Gulf	5.53E-05	2	2
River Bend	8.48E-05	3	2
Laguna Verde 2	1.00E-04	4	N/A
Cofrentes	1.60E-04	5	N/A
LaSalle 1	1.80E-04	6	3
Perry	2.22E-04	7	4
Liebstadt (KKL)	2.95E-04	8	N/A
Laguna Verde 1	3.26E-04	9	N/A
Nine Mile Point 2	3.38E-04	10	4
LaSalle 2	9.00E-04	11	4

Unit 2 Source Term Analysis

Based on the Unit 2 performance diverging in CEI and CRE from Unit 1 the Station commissioned four studies:

- **Root cause report (RCR)** to determine the cause for the increased cobalt activity in Unit 2 (compared to Unit 1) (May 2015)
- **Blue Ribbon Panel** review of our Dose Excellence Plan (May 2015)
 - The panel included source term reduction industry experts from INPO, EPRI, Duke, Southern Company, Corporate RP and Chemistry
- **EPRI/Finetech** study (June 2015)
- **ALARA BWROG Assessment** (June 2015)

Summary of Unit 2 Root Cause Analysis (RCR)

The fuel crud mass present consists of two layers - a dense and adherent (tenacious) to the fuel oxide/cladding inner layer, and a porous and loosely adhered outer layer.

The RCR concluded that the elevated cobalt levels in Unit 2 is caused by a less tenacious crud mass (comprised of low zinc to iron ratio) inventory containing a significant amount of activated corrosion products around the beginning of L2C12.

The timing of the following plant events and transients on Unit 2 relative to the presence of the large crud mass exacerbated the current condition on Unit 2:

- L2C12 channel distortion testing
- Later replacements of the OEM CRB's and #23 FW heaters (compared to U1)
- Timing of online Noble Metal (OLNC) applications relative to Zn/Fe
- Plant transients (i.e. forced outages & reactor scrams)

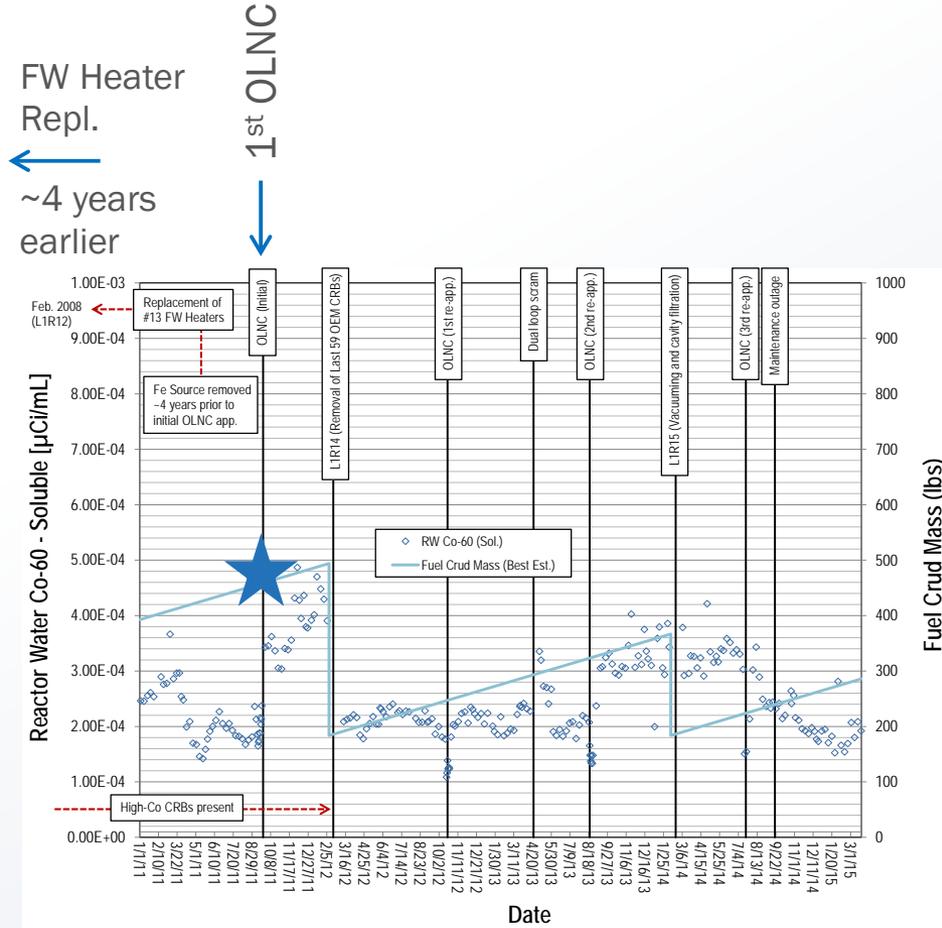
Summary of Unit 2 Root Cause Analysis

- The increasing cobalt levels on Unit 2 is due to the lack of a tenacious crud layer on the fuel, which results in redistribution of the crud into the coolant as recirculation flow is increased and other transients/events occur.

Relative magnitude of legacy Co-60 sources (projected to upcoming L2R16 refueling outage):

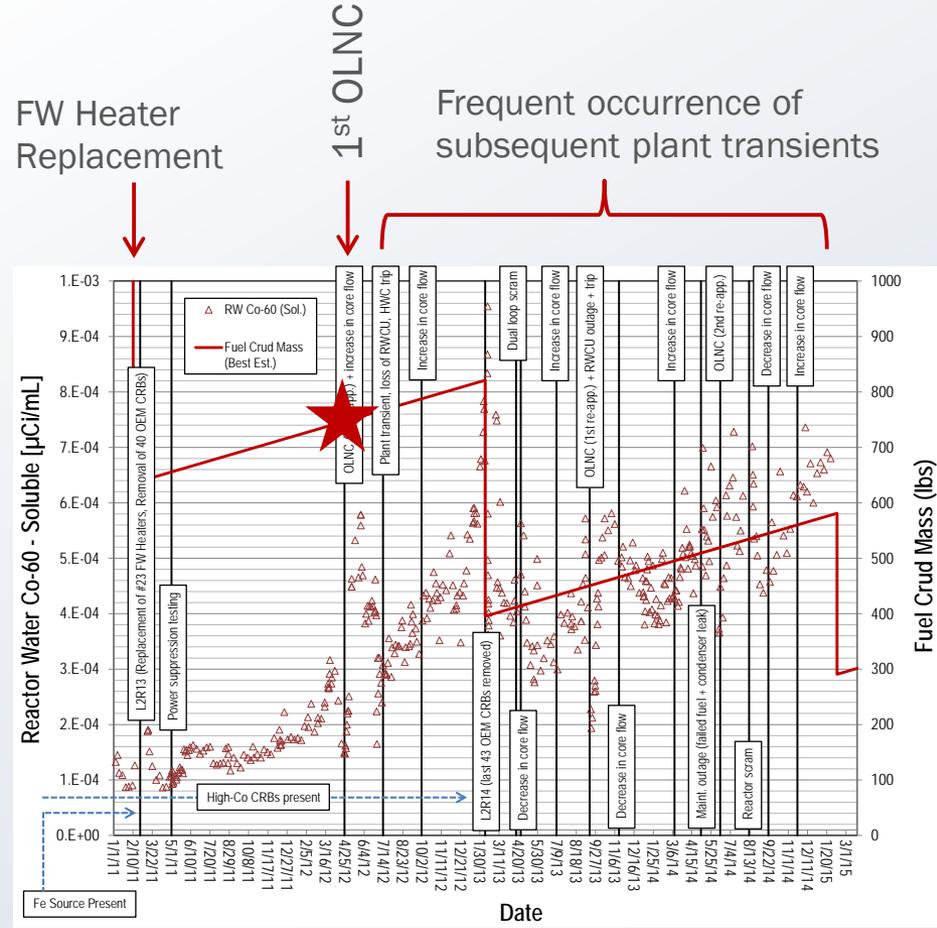
- Fuel crud – 73,200 Ci (>90%)
- Crud accumulated in low flow areas/Guide tubes – >400 Ci (< 1 %)
- Corrosion films on recirculation piping – 67 Ci (~0.1%)

Co-60, Fuel Crud Mass and Event Timeline



Unit 1

★ Denotes total crud mass of ~450 lbs and Zn/Fe ratio of 7

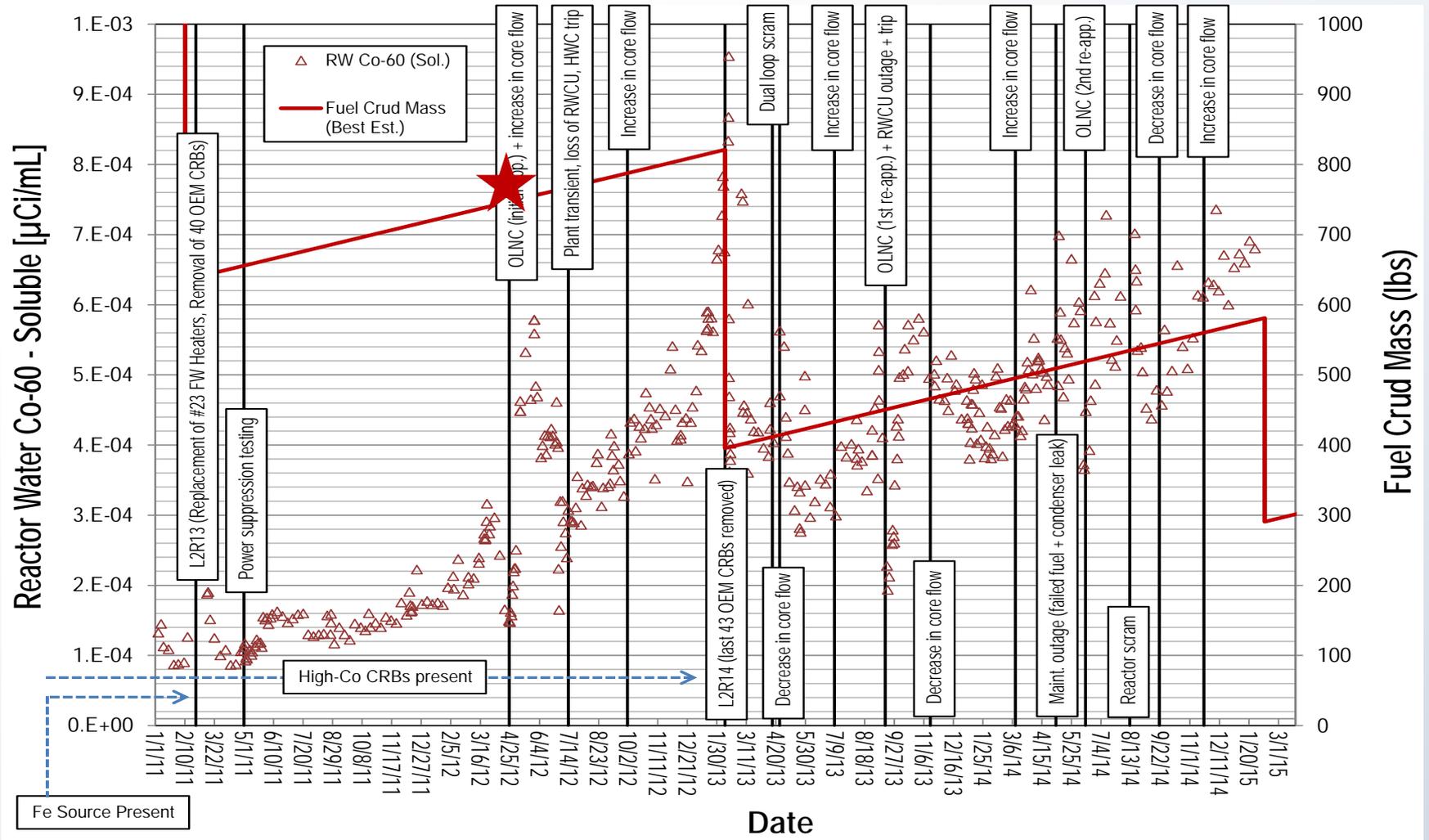


Unit 2

★ Denotes total crud mass of ~740 lbs and Zn/Fe ratio of 0.5



Unit 2 Timeline - Zoomed View



Recommended Actions

Below are the top L2R16 source term reduction actions:

- Fuel cleaning
- Vacuum reactor vessel to include bottom head region
- Vacuum guide tubes
- Chemical decontamination of both RR loops, RWCU and RHR
- Vacuum 100% of the suppression pool
- 2B33-F067B valve (RR discharge) repair/replacement (Contingency)

Fuel Cleaning

This is the most significant source term reduction action:

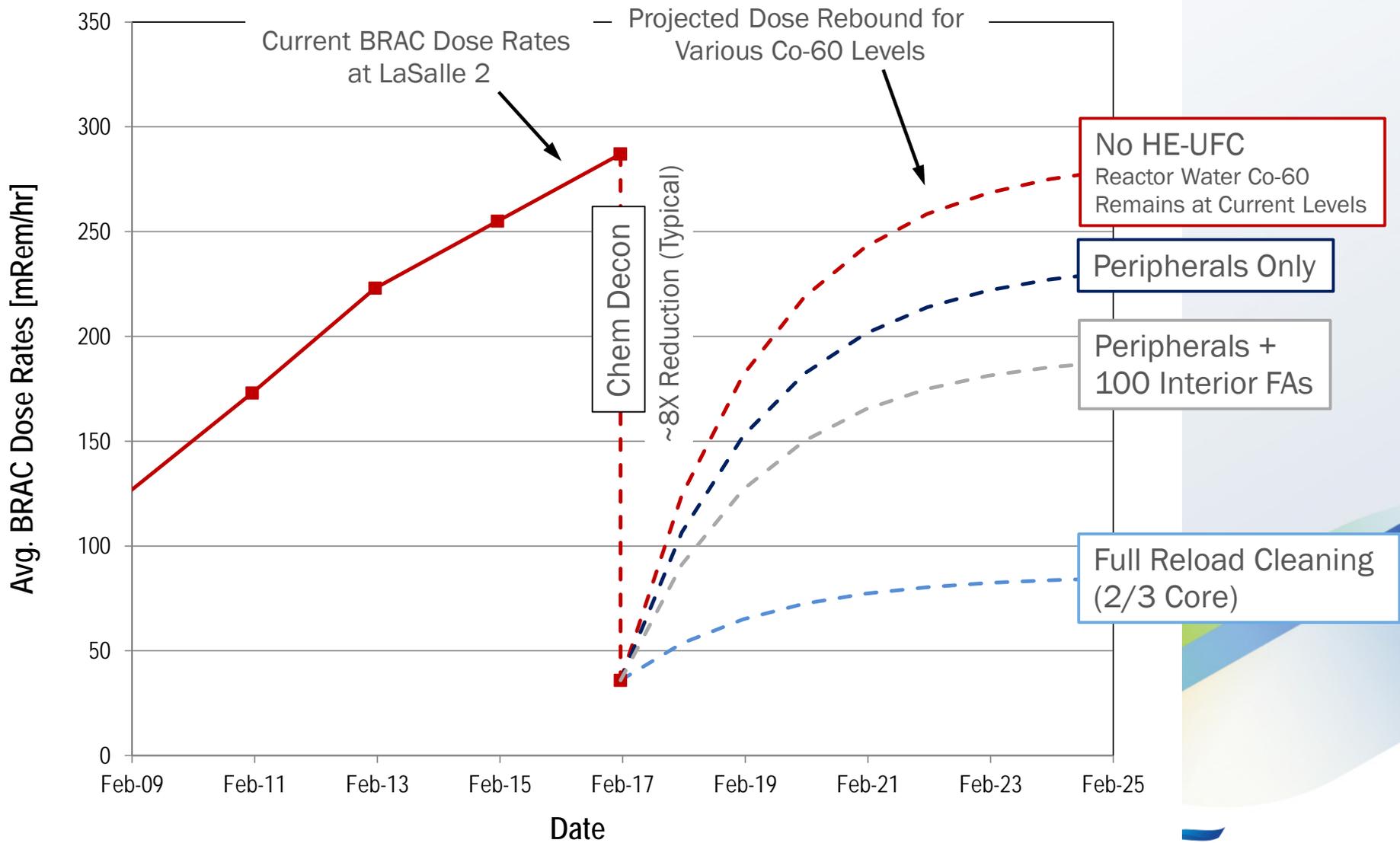
- Fuel crud is by far the largest source of legacy Co
 - It is estimated that ~480 lbs of crud will be present on fuel in Unit 2 during the next refueling outage (L2R16 in February 2017).
 - This crud is expected to contain primarily Fe and Zn oxides/spinels, but also approximately 73,200 Ci of activity (primarily Co-60).
- Fuel is also the largest surface area facilitating exchange of Co-60 with reactor water and subsequently ex-core surfaces.
 - If not removed, 39,300 Ci of Co-60 will be left on reload fuel and may be redistributed to new fuel and other plant surfaces.
- High Efficiency Ultrasonic Fuel Cleaning (HE-UFC) will be used to clean reload fuel assemblies:
 - > 90% of reload fuel crud can be removed by cleaning the 1st and 2nd burn bundles
 - OPEX indicates a 2x - 10x reduction in reactor water Co-60 levels expected

Fuel Cleaning

Expected Results

- Cleaning time – Cleaning can be completed during fuel shuffling or during defuel window (if core is offloaded to the pool). Time to clean is 3 minutes per bundle.
- Activity Removal – Projected to remove 234 lbs of crud and 35,400 Ci. In comparison, RWCU removes ~ 480 Ci per cycle.
- Estimated Dose Savings – ~ 69 rem (over 5 years)
- Impact on Reactor Water Co-60 – Soluble Co-60 expected to decrease from $8.49\text{E-}4$ to $9\text{E-}5$ uCi/gm with all recommended actions completed.
- Foreign Material Removal – Removal of foreign objects from lower tie plate / debris filter (reduces risk of future fuel failures)

Fuel Cleaning - Expected Results (cont'd)



Fuel Cleaning

- Pilot cleaning completed at LaSalle in July 2016 to verify anticipated HE-UFC results
- Activity removal as expected
- No fuel integrity issues



Before HE-UFC



After HE-UFC



Reactor Vessel and Guide Tube Vacuuming

Rx Vessel Vacuuming:

- Remove several hundred Curies
- Soluble cobalt 60 to $9E-5$ uCi/gm with all recommended actions completed
- Contributes to fuel defect reduction

Guide Tube Vacuuming :

The guide tube vacuuming in L2R16 will remove legacy crud from the guide tubes, thus eliminating an inventory of crud for redistribution. Additionally, the removal of crud from the guide tubes will improve system performance which has been noted as problematic.

This is a fully viable method to remove legacy crud, improve CRD performance and prevent migration of crud during plant transients

- Estimated cost:
 - Guide Tubes: \$1.4M (~88 hours x \$16k/hr)
- Remove approximately 400 Curies

Estimated Dose Savings for both – ~24 rem

Chemical Decontamination

Summary

Perform chemical decontamination on Unit 2 RR piping (which requires reapplication of noble metal on RR piping) for legacy source term removal and for immediate CRE reduction during scheduled RR work in L2R16.

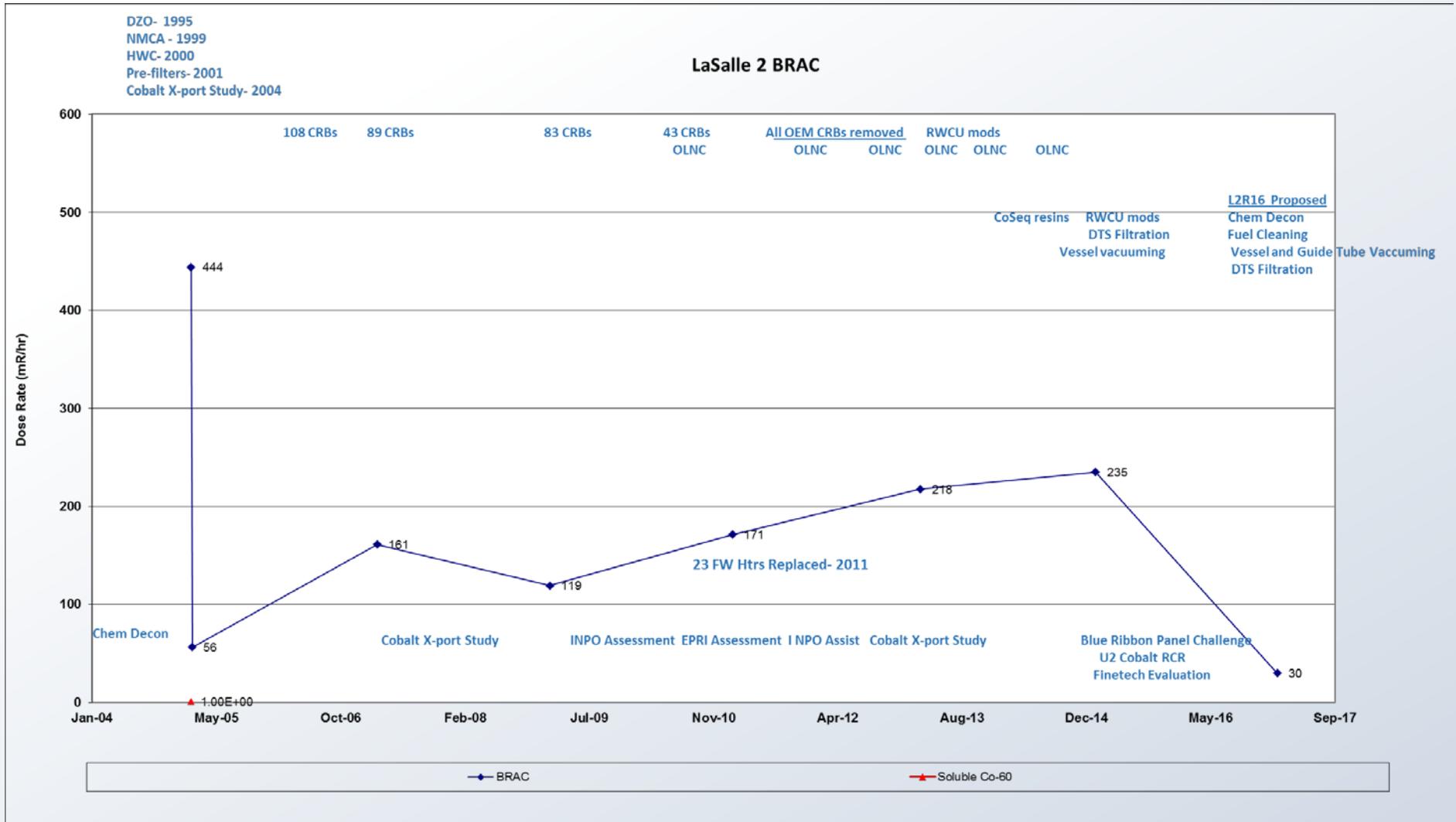
- Scope; RR, RWCU piping and RHR
- Provides an immediate major dose reduction benefit in L2R16
- Both RR motors will be replaced in L2R16 versus over two outages to maximize benefit from the chem decon and to achieve 1st quartile performance two years sooner
- We do not anticipate a rapid recontamination of piping due to vacuuming and fuel cleaning – sustained impact

Chemical Decontamination

Expected Results:

- Estimated time for actual decon ~7 days
 - Project duration will be ~17 days
- Projected to remove 100 Curies
- Estimated Dose Savings – ~ 329 rem (over 5 years)
- Positive impact on RR work activities: RR motors, seals and 2B33-F067B valve replacements
 - Positive impact on all other activities requiring 740' drywell access

Unit 2 BRAC Projection



Suppression Pool Vacuuming

Vacuumping 100% of the suppression pool will result in removal of a large quantity of source term and elimination of a potential source of foreign material.

- Preparatory surveys were performed during L2R15.
- Eliminates a potential source of foreign material resulting in improved fuel reliability.
- Eliminates a source of crud for distribution within the plant.

2B33-F067B Repair/Replacement (Contingency)

Summary

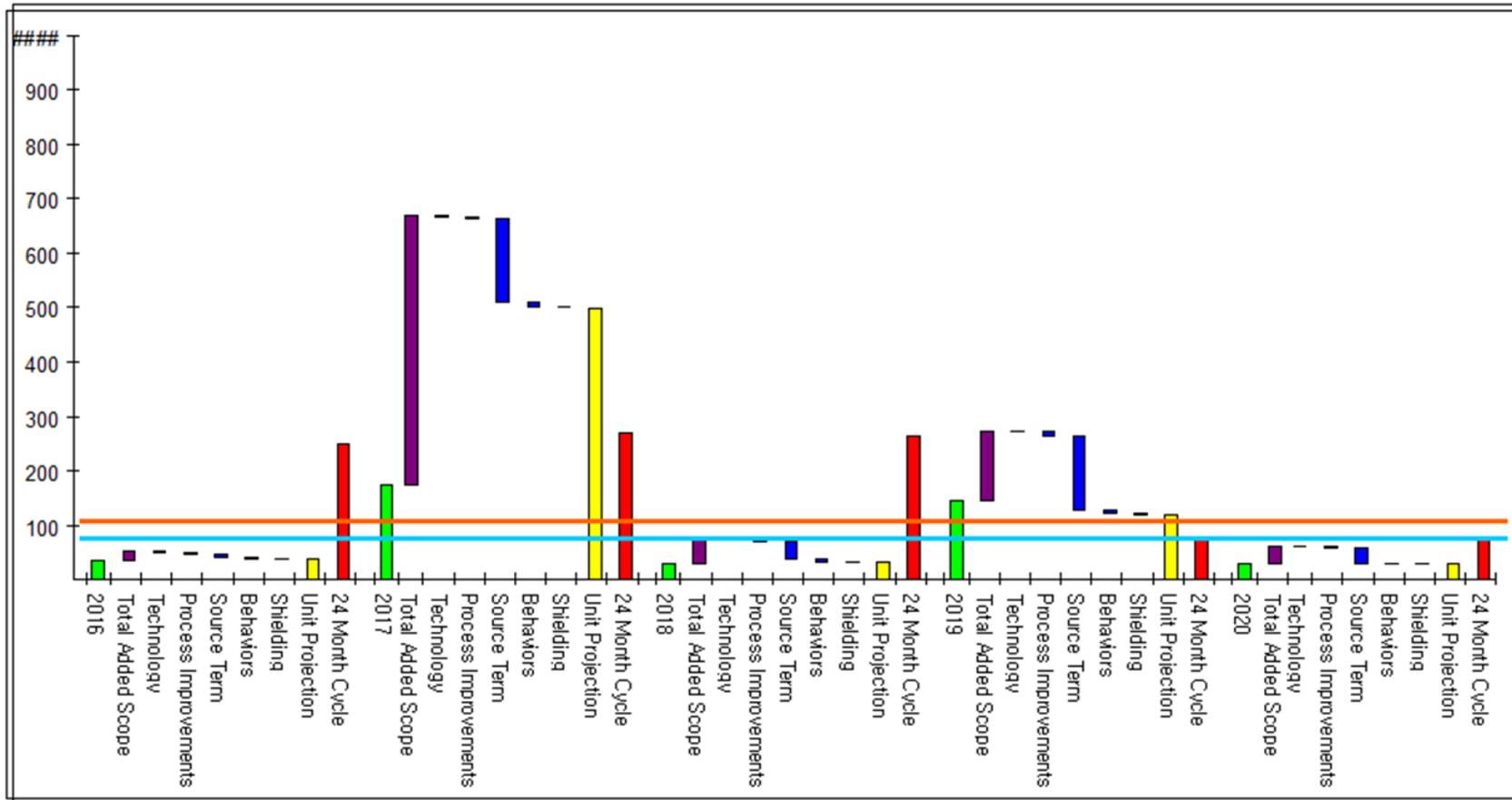
The Root Cause Report for the L2C15 fuel failures details that debris capable of causing fuel failures comes from either legacy debris within the vessel and/or from a known major source of debris to the vessel – the 2B33-F067B (RR discharge) valve.

- Material condition issues warrants the repair/replacement of the 2B33-F067B valve. The repair/replacement will improve equipment reliability and reduce elemental cobalt inputs to the reactor vessel.
- A boroscope inspection of the valve body will be performed early in L2R16 to determine repair scope

CRE Waterfall- Projection With All Proposed Initiatives

Exposure Waterfall

LASALLE - UNIT 2



Full INPO Points = 110 Rem

Top Quartile = 80 Rem

Summary

The L2R16 source term reduction initiatives will reduce foreign material concerns, reduce legacy cobalt and will allow us to achieve and maintain 1st Quartile CEI and CRE Performance:

An outage duration of ~33 days will be required to accomplish the following:

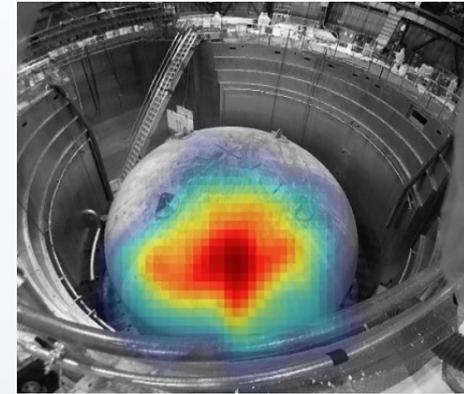
- HE-UFC
- Vacuum reactor vessel to include bottom head region
- Vacuum guide tubes
- Chemical decontamination of both RR loops, RWCU and RHR
- Vacuum 100% of suppression pool
- 2B33-F067B valve (RR discharge) repair/replacement

The fuel cleaning not on critical path. The primary schedule impact is from the chemical decontamination, RR motors and 2B33-F067B replacement sequence due to restricted access in the work area.

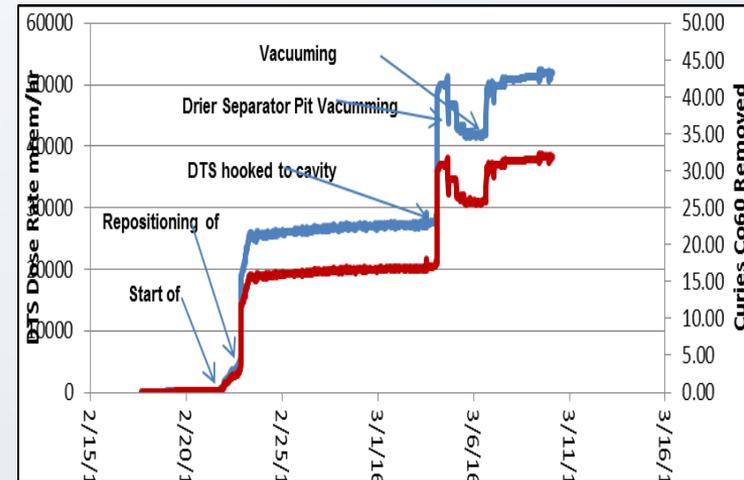
Additional Dose Reduction Actions

Polaris H3D ® Gamma-Ray Imaging camera :

This device provides a precision overlay of gamma-ray and optical images. The reactor cavity with the drywell head installed is shown to the right:



Diversified Technology Systems Filter (DTS) ® is used to filter reactor cavity water, vacuum the reactor cavity and guide tubes. Use of the DTS eliminated the need to handle hundreds of TriNuke filters in favor of one easy to transport canister. The DTS removed 30 curies of Cobalt-60 in L1R16 and was used to vacuum 59 guide tubes; related graph is shown to the right:



360 Fly Virtual Reality camera ® is used to record select portions of the plant to use for pre-job briefings, minimize high rad entries and for worker orientation.

Additional Dose Reduction Actions

CoSeq Resin ® was developed jointly by EPRI and Exelon for the reactor water cleanup system and fuel pool cooling system to improve cobalt removal.

Reactor Water Clean-up (RWCU) System Modifications/improvements:

- **New Internal Flow Distributors:** This modification changes the flow path of water in the filter demineralizers such that a much more even velocity profile is obtained.
- **New Precoat Metering skid:** The precoat metering skid allows for a precise concentration of resin to be applied to the filters at a constant rate, which is essential to creating a uniform resin later. These skids allow operators to dump in all of the resin into the new slurry prep tank then walk away to a low dose area.
- **Replaced all of the RWCU filter septas**
- **Increase RWCU system Flow**