Source Term Challenges at LaSalle Station

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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. For example, adjustments in core flow due to failed fuel has contributed to the redistribution of source term to ex-core surfaces.

As a result of these integrated issues, aggressive and broad based actions to mitigate risk in the areas of radiological and nuclear safety are prudent. Provided in this presentation are the proposed actions, the basis and the expected results. In addition, we will cover the reasons the source term in Unit 2 is higher than Unit 1.

Overview

LaSalle has experienced challenging source term issues on Unit 2. Currently, Unit 2 is at the bottom of the 4th Quartile in CRE with a 2-year rolling average of 304.9 rem and “0” INPO points.

- With the current strategy and work scope Unit 2 will not achieve full points and 1st Quartile performance until after 2022.
- With the initiatives proposed we can achieve full points and 1st Quartile performance in 2019.

In the past year, the high source term inventory has compounded accumulated dose, resulting from:

- Equipment reliability, e.g., 2B33-F067A/67B (RR discharge valves) and U-2 Inboard MSIV repairs
- During the previous operating cycle on Unit 2, BRAC values have increased from an average of 217 mrem/hr to 244 mrem/hr. Increasing Co-60 inventory without a corresponding improved removal capacity has contributed to increased BRAC values and Unit 2 CRE.

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LaSalle CEI and Cobalt Information

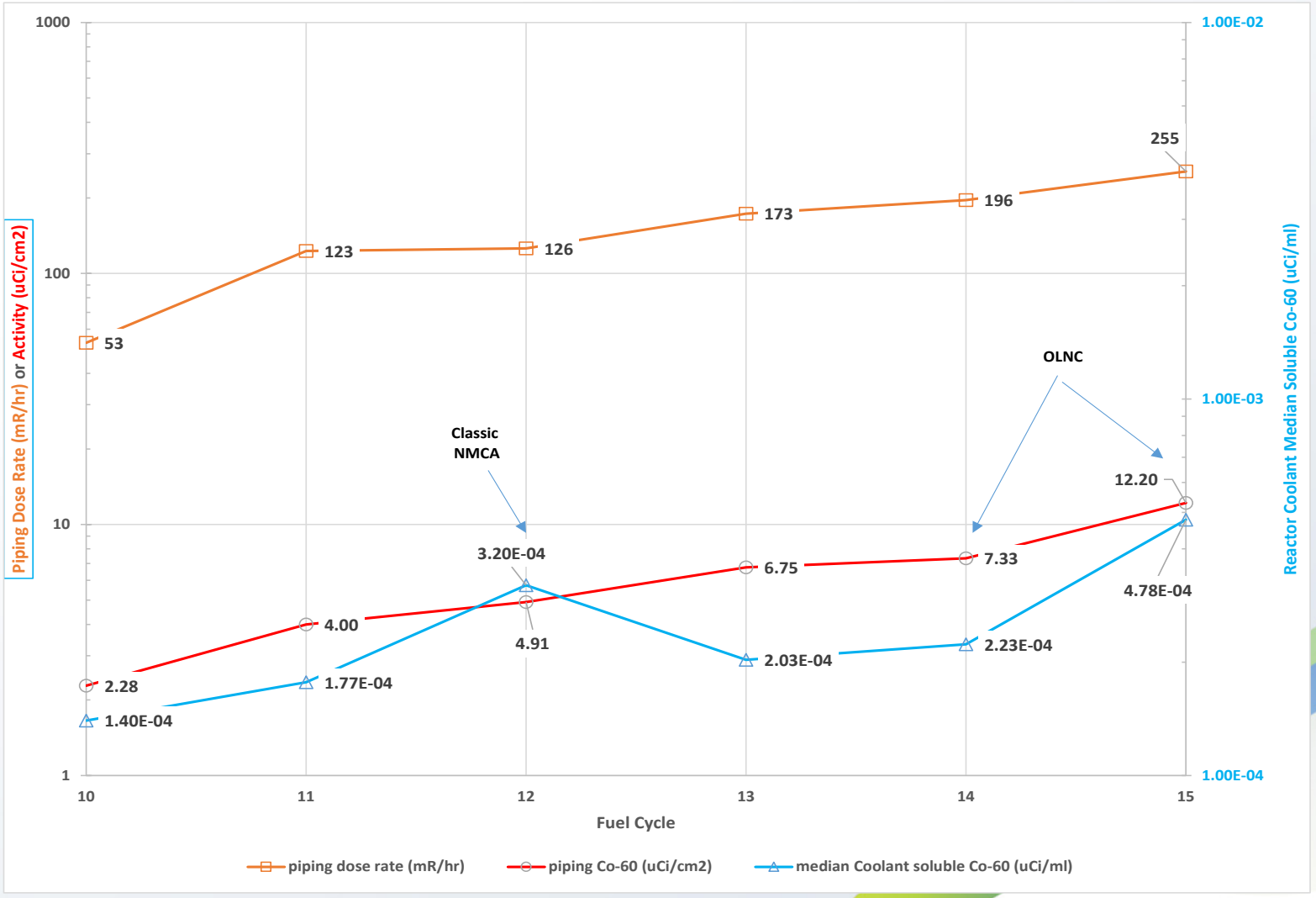
Cobalt Check-in Assessment Information:

Based on industry data for soluble Co-60 (BWR 5/6 design) Unit 1 is ranked 6th and Unit 2 is 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**

- LaSalle Unit 2 is bottom of the fourth quartile for soluble cobalt activity which is impacting Condition 5 of the CEI. Condition 5 monitors soluble cobalt activity along with zinc control.
- Soluble cobalt activity for Unit 1 & Unit 2 from cycles 9 -15 was reviewed; Unit 2 soluble cobalt activity is much higher at 9.00 E-4 uCi/g whereas Unit 1 is 1.80E-4 uCi/g.

Unit 2 BRAC/Cobalt Trends



Unit 2 Source Term Analysis

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

- Root cause report (RCR) to determine the cause for the increased cobalt activity in Unit 2. (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, Exelon Corporate RP/Chemistry personnel and LaSalle stake-holders
- EPRI/Finetech study (June 2015)
- ALARA BWROG Assessment (June 2015)

All studies conclude that the recommended on the following slides are prudent and warranted. Furthermore, actions should be performed simultaneously during a refueling outage to prevent system recontamination and migration of legacy source term/crud.

Unit 2 Cobalt Root Cause Analysis Summary

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- released elemental cobalt
- 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)

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.

Summary of Root Cause Analysis

- **Relative magnitude of legacy Co-60 sources** projected to the L2R16 refueling outage in February 2017:
  - **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%)

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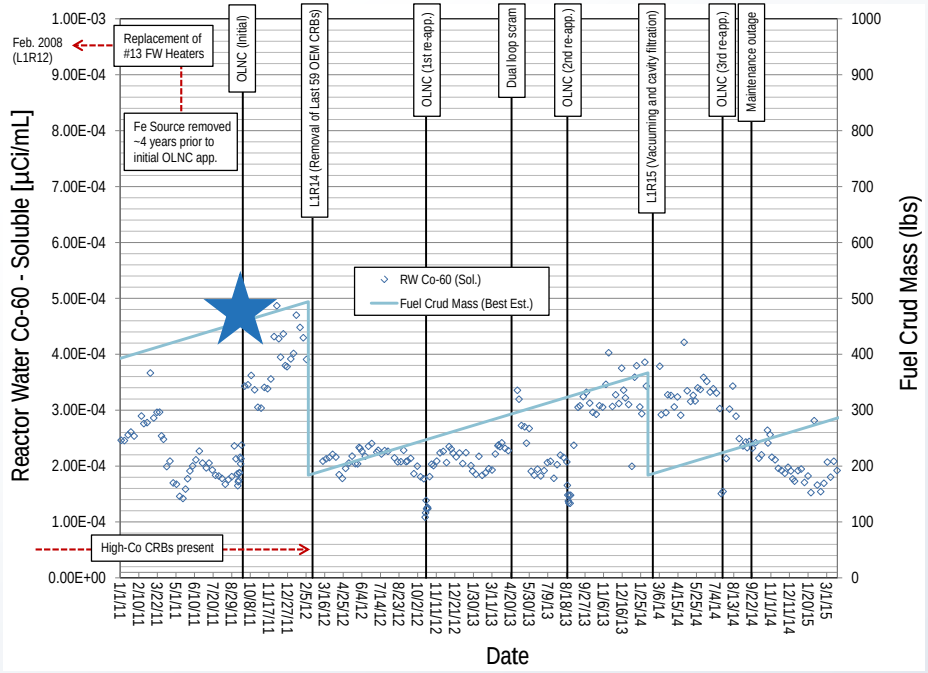
Co-60, Fuel Crud Mass and Event Timeline

FW Heater Repl.

~4 years earlier

1st OLNC

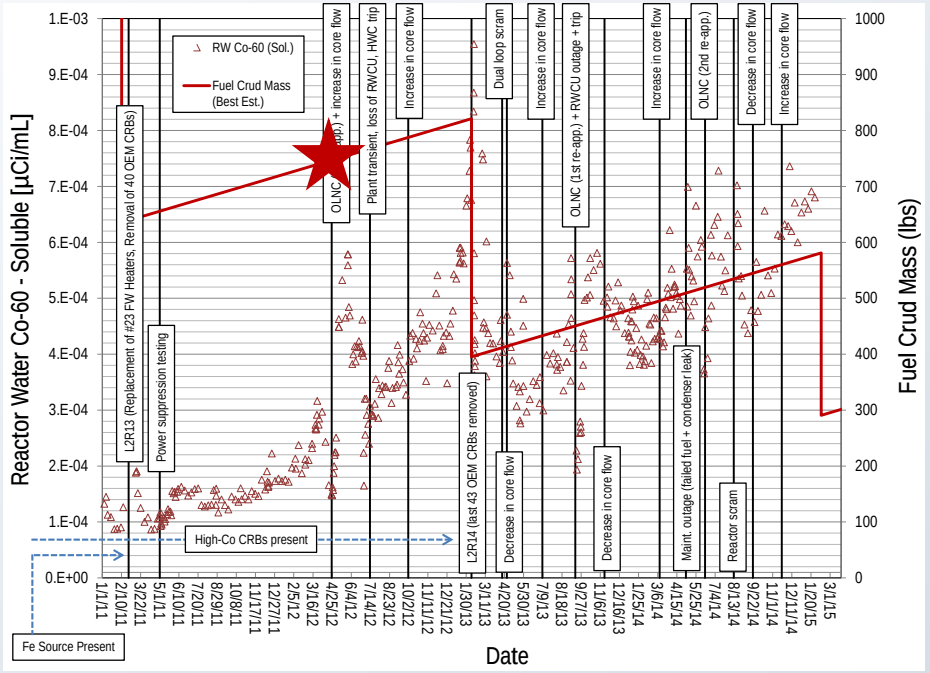


Unit 1

FW Heater Replacement

1st OLNC

Frequent occurrence of subsequent plant transients



Unit 2

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

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

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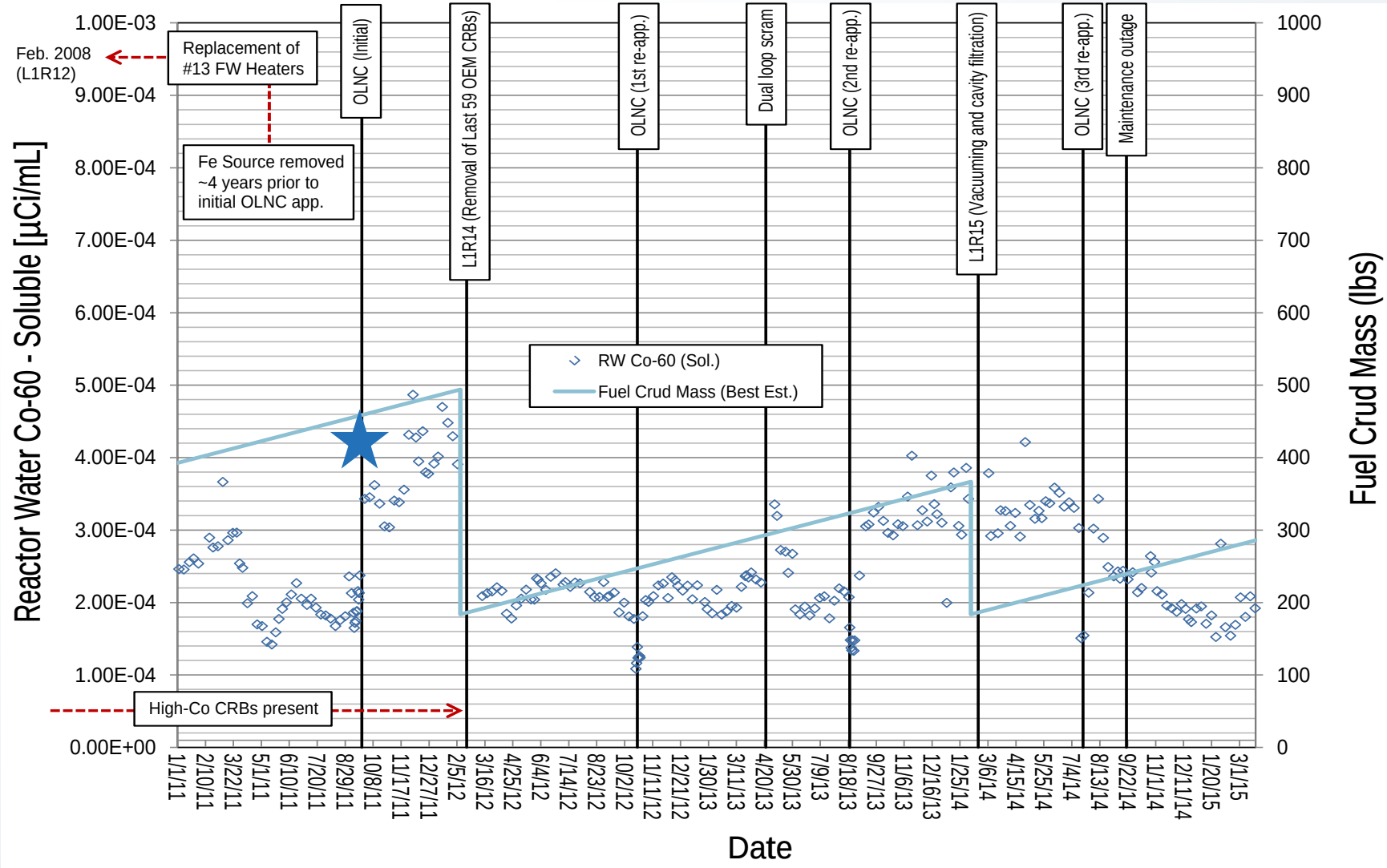
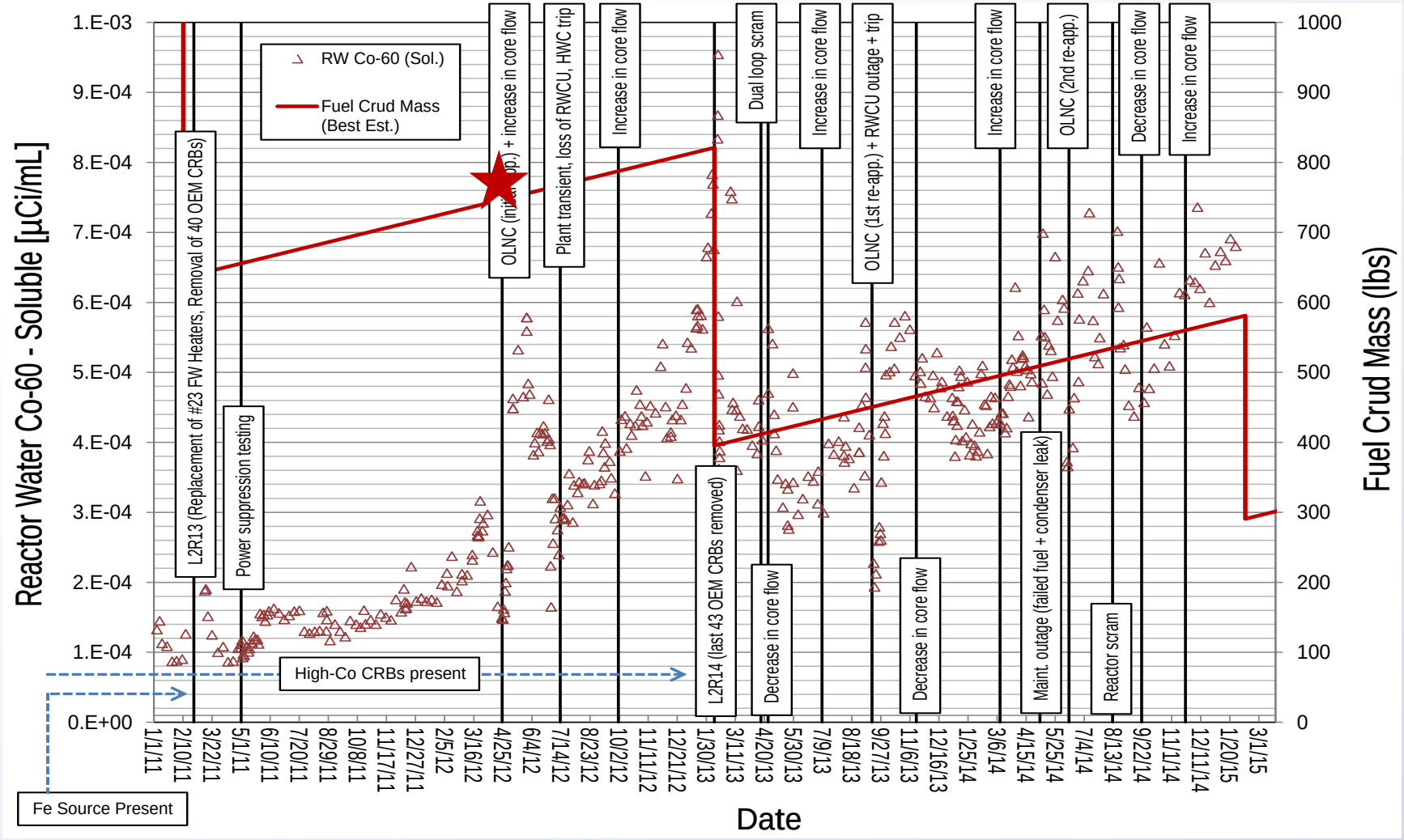
Unit 1 Timeline – Zoomed View



Unit 2 Timeline – Zoomed View



Recommended Actions

Below are the top L2R16 source term reduction actions recommended by the RCR, Blue Ribbon Panel, EPRI/Finetech source term assessment, and the BWROG:

- Fuel cleaning (2/3 of core)
- 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

Additional items:

- RWCU Bottom Head Drain Line Replacement- major drywell source of radiation
- 2B33-F067B valve (RR discharge) replacement- replace entire valve with a non-Stellite, electro-polished valve to eliminate source of foreign material and elemental cobalt

Fuel Cleaning

Summary

This is the most significant source term reduction action:

- Legacy Cobalt - Fuel crud is by far the largest source term removal mechanism of legacy Co present in BWRs (through refueling)
- Fuel is the largest surface area facilitating transport between the reactor water and ex-core surfaces.
- 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).

- **High Efficiency Ultrasonic Fuel Cleaning (HE-UFC) is the process recommended:**
  - > 90% of fuel crud removed during HEUFC (1st and 2nd burn)
    - OPEX indicates a 2x - 10x reduction in reactor water cobalt levels
    - Legacy Co-60 in the crud layer redistributes to new fuel (up to 40%) and plant components at the start of the cycle.
    - Reference EPRI Technical document, 3002005482, issued in June 2005 for further information

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Fuel Cleaning

Operating experience and analysis

2015 EPRI Technical Report “High Efficiency Ultrasonic Fuel Cleaning as a Source Term Reduction Tool in Boiling Water Reactors – Results of Scoping Benefits Study” (Document 3002005482)

- HE-UFC removes 100% of loose (brushed) crud layer and between 20 and 80% of the tenacious (scraped) crud layer
- LAS 2 is listed as 1 of 6 candidate plants (NM2 and PB 3 are also recommended) due to high source term
- Dose rate reduction and CRE savings could not be quantified for past BWR fuel cleanings at QC 2 pilot and BF1 restart
- The cleaning is efficiency is 3x higher than conventional UFC
- An all metal filter module (AMFM) will be used that is 100x more efficient than conventional filters. It is able to be back-washed. The AMFM design with its’ all metal construction allows it to be handled and stored long-term like fuel assemblies.

Expected Results

- Estimated time – Cleaning can be completed during fuel shuffling or during defuel window (if core is offloaded to the pool). Time to clean per bundle is 3 minutes.
- Projected to remove 234 lbs of crud and 35,400 Curies. In comparison, RWCU removes ~ 480 Ci per cycle.
- Estimated Dose Savings – ~ 74 rem (L2R16/L2R17 - online)
- Soluble cobalt 60 expect to go from 8.49E-4 to 9E-5 uCi/gm with all recommended actions completed.

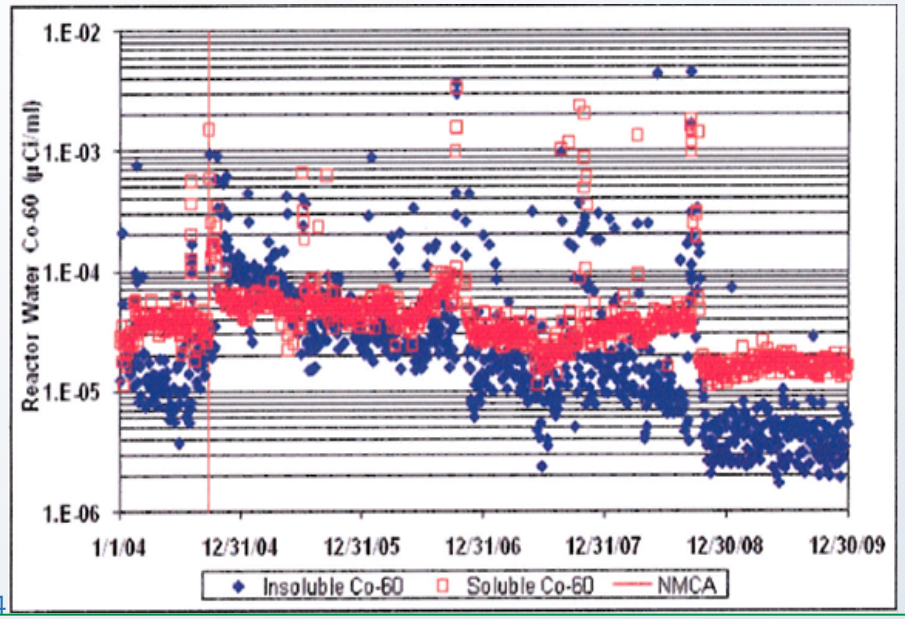
Reactor Vessel Vacuuming

Summary

The RPV vacuuming in L2R16 is a fully viable method to:

- Reduce foreign material in the vessel and the potential for fuel defects
- Remove legacy crud and improve CEI and CRE performance

Fitzpatrick Vessel Vacuuming OPEX



Co-60 concentrations at Fitzpatrick took a step change decrease following the fall 2008 refuel outage. According to the station, in the fall 2008 refueling outage, a significant effort was implemented to **vacuum** out portions of the RPV. The annulus between the core shroud and RPV shell was vacuumed, in addition to vacuuming of the guide tubes during CRB exchange (vacuum performed from the refuel floor).

Reactor Vessel Vacuuming

Expected Results

- Remove several hundred Curies
- Soluble cobalt 60 reduced to 9E-5 uCi/gm with all recommended actions completed
- Estimated Dose Savings – ~21 rem
- Contributes to fuel defect reduction

Guide Tube Vacuuming

Summary

The guide tube vacuuming in L2R16 will;

- Remove legacy crud
- The removal of crud from the guide tubes will improve CRD system performance which has been noted as problematic
- Prevent migration of crud during plant transients

Guide Tube Vacuuming

Operating experience and analysis

- Dresden (D3R21) vortex flushing
  - 40% reduction in dose rates at the CRD flange
  - 33 guide tubes

- L2R15 guide tube vacuuming
  - Approximately 150 Ci removed
  - 56 guide tubes
  - Reduced dose for drive exchange from 623 mr/drive during L2R14 to 320 mr/drive during L2R15

- L2R13 dose rate transient under vessel (RCR 01175716)
  - "The explanation for the dose rate decrease several days into the outage is that filling of the reactor vessel with the CRD cooling pumps flushed the crud in the flange area in the CRD mechanisms back up into the CRD housings and spud end. The CRD cooling pump flow was approximately 200 gallons per minute thru the CRD system. When a reactor scram occurs from full power as experienced in August 2009, two sources of water are used to scram the drives. Initially high pressure water (approximately 1100 psig) from the Hydraulic Control Unit (HCU) accumulator is provided to the CRD under piston area through the CRDM flange ball check valve. When reactor pressure exceeds HCU accumulator pressure, reactor water flowing through CRD guide tubes enters the under piston area through the flange ports. Based upon differential pressure established across the CRDM flange ball check valve, the HCU accumulator will be isolated from the CRDM and reactor water will complete the drive insertion for the scram. The reactor water flowing from the CRD guide tubes will transport some of the crud located in these guide tubes to the under piston area. Following the scram this crud will settle in under piston area as it is the low point of the process flow.

  - *The CRD system is used initially for flood-up. The CRD pumps provide water through the CRD charging header into the under piston area of the CRDM's. **This water flow provides a driving force to redistribute the crud that has settled in the under piston area following a scram.***

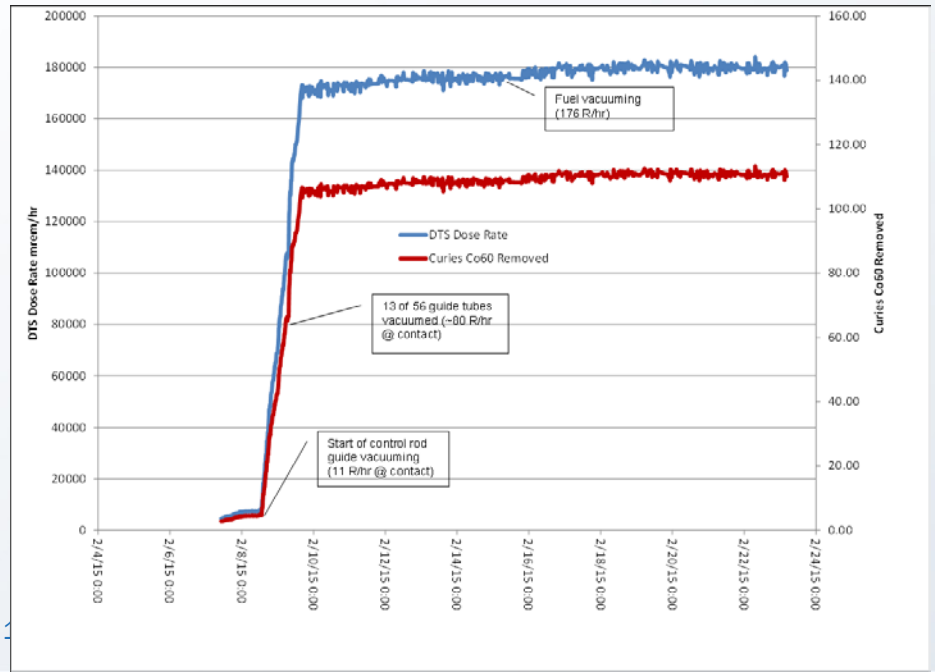
Guide Tube Vacuuming

Expected Results

- Remove approximately 400 Curies
- Estimated Dose Savings – ~21 rem
- Improve CRD system performance

L2R15 DTS Operating Experience

The Diversified Technology Systems ® (DTS) filtration system is a high flow (≥850gpm) system used for gross filtration of reactor cavity water to control ntrol dose by capturing fine particulate during the open vessel window. The DTS removed approximately 110 Curies of Co-60 activity during L2R15. The majority of the activity removed was from 56 control rod guide tubes. In L1R15 only four control rod guide tubes were vacuumed.



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CEI Projections

Chemistry Effectiveness Index (CEI) (24 months rolling Average)	2015	2016	2017	2018	2019	2020
Current Business Plan (BP) projection	11.61	10.74	10.5	10.45	10.45	9.75
Projection with Vacuuming (RPV/guide tubes) only (assuming 25% reduction in RCS Cobalt)	11.61	10.74	10.5**	10.0	9.5	9.0
Projection with fuel cleaning only (assuming 50% reduction in RCS Cobalt)	11.61	10.74	10.5**	9.5	9.0	4.0
Projection with both vacuuming and Fuel cleaning	11.61	10.74	10.5**	6.9*	1.8*	0.9*

* RCS Cobalt levels will be much lower after combined efforts of RPV Vacuuming/Fuel cleaning than vacuuming or fuel cleaning alone

** Due to 24-month rolling average impact

Assumptions:

- RPV Vacuum: 25% RCS cobalt reduction based on Curie removal RCR estimate and Fitzpatrick OPEX
- Fuel cleaning: 50% RCS cobalt reduction based on Curie removal estimates

Chemical Decontamination

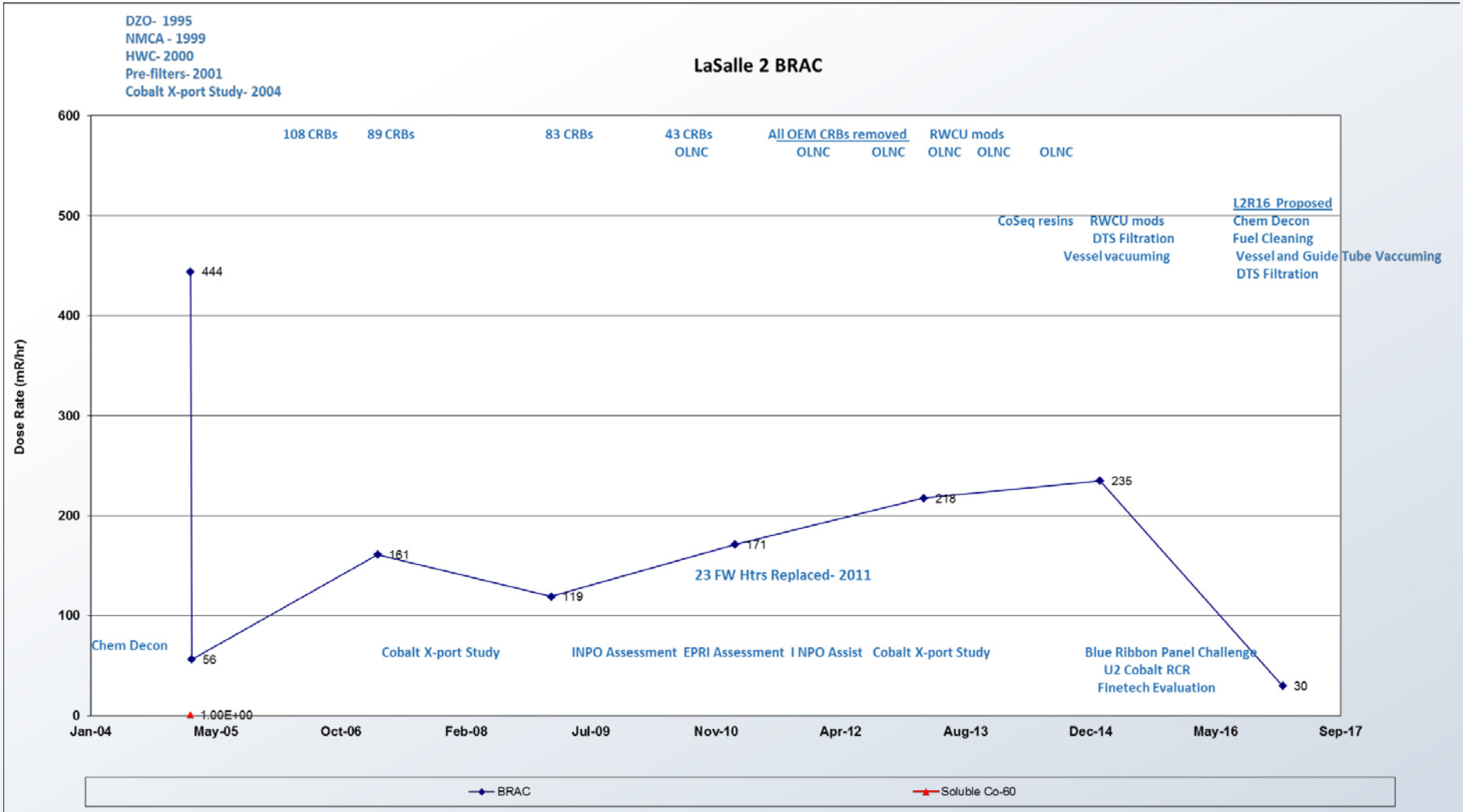
Summary

Perform chemical decontamination on Unit 2 RR and RWCU and RHR piping for:

- Removal of legacy source term
- Immediate CRE reduction L1R16; major projects benefitting will be the RR pump and motor replacement and RWCU piping replacement

Note: We do not anticipate rapid recontamination of piping due to vessel vacuuming and fuel cleaning, thus it provides a sustained impact.

Unit 2 BRAC Projection



Chemical Decontamination

Expected Results

- Estimated time for actual decon ~3 days
  - Project duration will be ~17 days
- Projected to remove 100 Curies
- Estimated Dose Savings – ~ 120.5 rem (L2R16/L2R17-online)
  - Positive impact on RR work activities: RR motors, seals and 2B33-F067B valve replacements
  - RWCU bottom–head drain replacement
  - Positive impact on all other activities requiring 740’ drywell access

Vacuum 100% of Suppression Pool

Summary

Vacuuming of 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 FME resulting in improved fuel reliability.
- Eliminates a source of crud for distribution within the plant during ECCS pump runs.

RWCU Bottom Head Drain Replacement

Summary

The RWCU piping is the primary source near the inboard MSIVs, CRD Track and "B" VP Chiller. The portions being replaced are carbon steel which is very porous. The piping already has four layers of permanent shielding, however the dose impact is still significant. General area dose rates are 600-1800 mr/hr. Hot spots up to 24,000 mR/hr are present.

- Replace carbon steel piping with electro-polished chrome-moly piping
- L2R16 is the best time to perform; the BHD line or portions thereof can be chemically deconned prior to cut-out. With full core off-load, the BHD orifice can be plugged.

Expected Results

- Dose to cut-out/replace (w/chemical decontamination): 12 rem
- Estimated Dose Savings – ~ 18 rem (L2R16/L2R17)

2B33-F067B Replacement

Summary

The Root Cause Report for the L2C15 fuel failures (1734116) 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 valve.

- Replacement of the 2B33-F067B valve will ensure that the valve will no longer wear and possibly result in debris capable of causing fuel failures being introduced into the vessel.
- Replacement during L2R16 will result in reduced CRE as a result of chemical decontamination.
- Material condition issues warrant the replacement of the 2B33-F067B valve. The replacement will improve equipment reliability and reduce elemental cobalt inputs to the reactor vessel.
- Contingency replacement of the valve is possible after a boroscope inspection of the valve is performed.

2B33-F067B Replacement

Expected Results

- Dose to cut-out/replace (with chem decon)- 10.5 rem
- Estimated Dose Savings – ~ 10 rem (L2R17)

2B33-F067B – Stellite Guide damage (L2R14)

Option 1

Not Recommended

Maintain the present course and continue with the current source term reduction and fuel reliability strategy:

- Fuel replacement
- OLNC
- Outage crud burst reduction actions
- Use of the DTS filtration system
- EPRI CoSeq resins
- RWCU improvements
- Outage flushes

Not recommended since CEI and CRE performance will take ~ 8 years to recover based on limited removal of source term. Expected full INPO points and Top Quartile performance in 2023. Does not mitigate future potential fuel reliability issues.

Option 2 – Fuel Cleaning only

Not Recommended

Perform fuel cleaning only (2/3 of core)

Not recommended because deferring the CRD Guide Tube and RPV vacuuming will result in legacy crud in the CRD guide tubes and RPV for distribution throughout various systems, resulting in hot spots and elevated dose rates on system components. It also fails to eliminate legacy FME as well as address the recirculation discharge valve as an FME generator. In addition, not performing a chemical decontamination will result in elevated dose rates on the RR and RT system piping, which will adversely affect L2R16 and future outage CRE performance.

Option 3 - Perform All Actions

Recommended

- Fuel cleaning (2/3 of core)
- 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
- Perform all other current actions noted in Recommendation 1

Additional items:

- RWCU Bottom Head Drain Line Replacement- major drywell source of radiation
- 2B33-F067B valve (RR discharge) replacement- replace entire valve with non-Stellite, electro-polished valve to eliminate source of foreign material and elemental cobalt

It is imperative that all of the recommended actions are implemented simultaneously during L2R16 to obtain the maximum benefit. Performing all recommended actions will result in sustained reduction of source term and CRE while also providing an environment free of foreign material which will improve fuel performance,

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Outage Impact

An outage duration of ~30 days will be required to accomplish the following:

- Full core offload
- Fuel cleaning
- Reactor vessel and guide tube vacuuming
- Chemical decontamination of both RR loops and RWCU
- 2B33-F067B replacement
- RWCU BHD replacement
- Suppression pool vacuuming

The fuel cleaning is planned to be off of critical path. The primary schedule impact is from the chemical decontamination, RR motor and 2B33-F067B replacement sequence due to restricted access in the work area.

Summary

The following L2R16 actions will reduce foreign material concerns, legacy cobalt and will allow us to achieve and maintain 1st Quartile CEI and CRE Performance:

- Fuel cleaning (2/3 of core)
- 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

Additional items:

- RWCU Bottom Head Drain Line Replacement- major drywell source of radiation
- 2B33-F067B valve (RR discharge) replacement- replace entire valve with non-Stellite, electro-polished valve to eliminate source of foreign material and elemental cobalt

Recommended Actions - Dose Impact and Savings

Recommended Actions - Dose Required versus Estimated Savings in rem								
	L2R16 - 2017		Cycle 17 - 2018		L2R17 - 2019		Cycle 18 - 2020	
Outage /Cycle	Dose Recv'd	Est. Savings	Dose Recv'd	Est. Savings	Dose Recv'd	Est. Savings	Dose Recv'd	Est. Savings
Action								
Fuel Cleaning	1.500	27.000	0.000	7.200	0.000	31.000	0.000	8.800
RPV / Guide Tube Vac	3.000	9.000	0.000	1.000	1.000	10.000	0.000	1.000
RR/RT/RHR Chem Decon	28.000	65.000	0.000	2.000	0.000	52.000	0.000	1.500
RWCU BHD line replacement	12.000	9.000	0.000	0.000	0.000	9.000	0.000	0.000
2B33-F067B replacement	10.500	0.000	0.000	0.000	0.000	10.000	0.000	0.000

* Estimated savings are based upon quantifiable dose rates.

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