Ringhals - Operational Experience on Silver and Antimony related to doses

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Ringhals NPP site overview

Unit 3 (1981)
PWR Westinghouse 3 loop
2nd generation
(609+609 MWe)

Unit 1 (1976)
BWR - ABB1
(460+460 MWe)

- All units running 12 months cycle
- No zinc injection
- All PWRs have performed SGR
- Elevated pH/Li program (7,4)

Unit 4 (1983)
PWR Westinghouse 3 loop
2nd generation
(609+609 MWe)

Unit 2 (1975)
PWR Westinghouse 3 loop
1st generation
(455+455 MWe)

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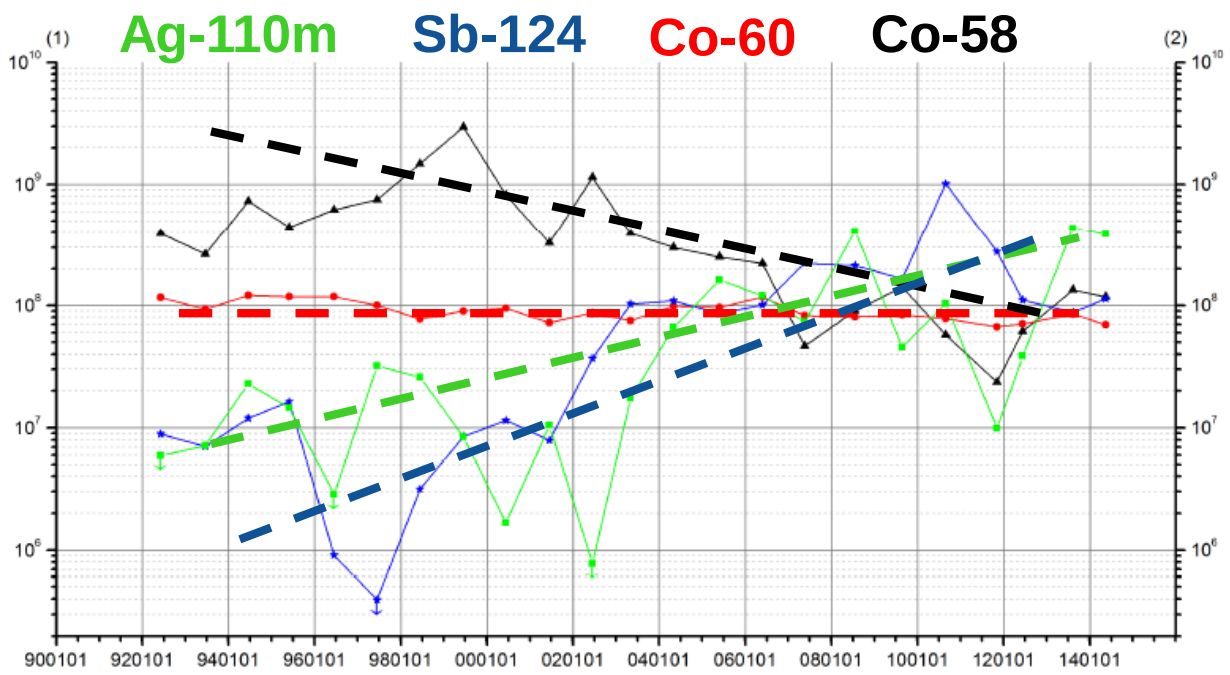
Problem statement



Gamma spec trend from SRMP point CVCS let down (Unit 3)

Co-60 is **NOT** the only concern…

How well do we know the sources and behaviour of other species and the impact on generating radiation fields?

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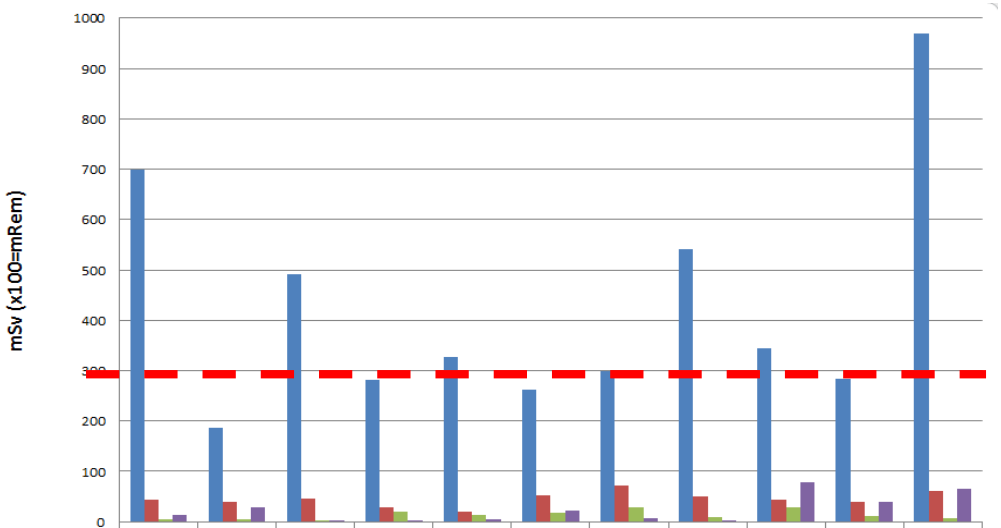
Collective Radiation Exposures – Ringhals Unit 3

From CRE best quartile to worst quartile….



	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
R3:Tot.Annual	698	186	492	283	328	262	300	542	344	283	970
RCS	43,4	40,1	45,8	29,1	20	53	71	51	43	39	62
CVCS	4,88	4,1	0,3	20,3	12,5	17	29	10	28	11	6
RHR	12,77	27,8	0,6	3,1	5,5	22	8	3	79	39	66

2013
ICES Report 310988, Increased Dose Rates due to High Amounts of Silver (Ag-110), Sept. 25

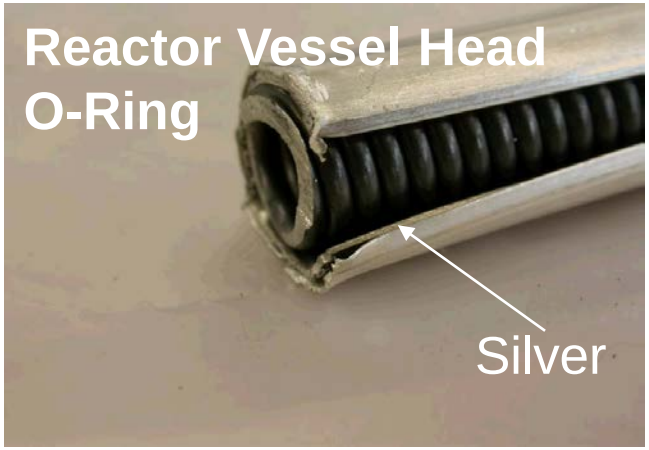
2014
Unit 2 experienced Sb-124 transport and deposit on the RHR system. 60% Sb-124 contribution to dosrates. Radiation fields increased by a factor 2-3. Estimated additional outage dose 250 mmanSv.

How do we get from reactive to proactive?

- Should CRE be the only indicator for ALARA perfomance?
- Industry Source Term Reduction Indicator/Index?

Silver Sources

Estimation that 2 grams of silver had been activated in Ringhals 3 in 2013



<u>Refuel Outage Unit 3 in 2010</u>
A piece from the O-ring was found with the weight of 0,15 gram. It could not alone had caused the elevated levels of silver in the coolant.

<u>Refuel Outage Unit 3 in 2013</u>
7 of 48 inspectied control rods showed axial cracks on one or more fingers.

More likely the source

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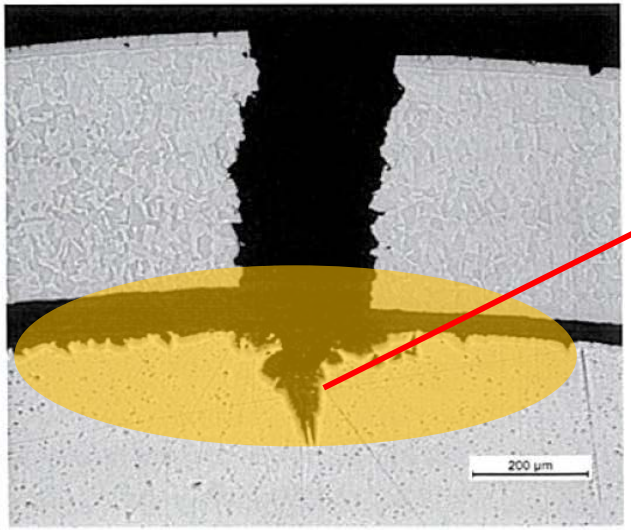
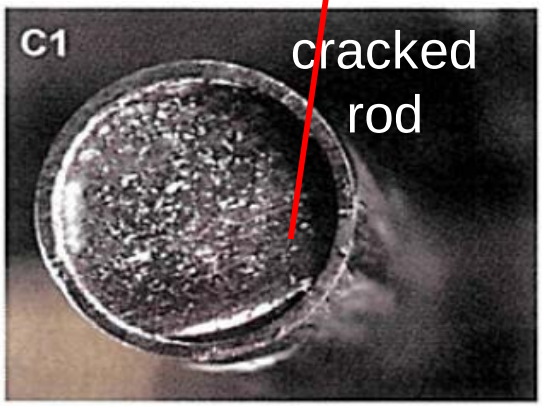
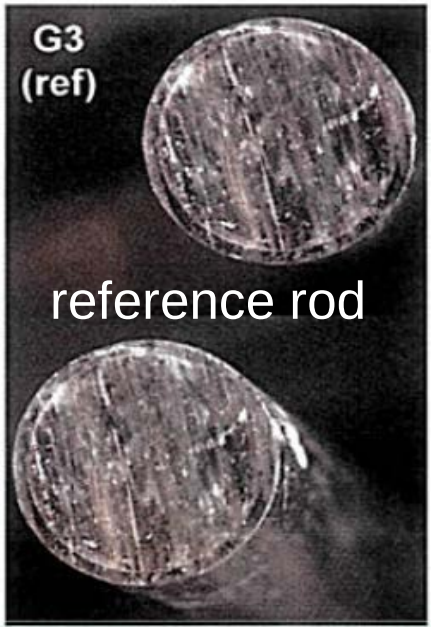
Inspection of control rod finger from Ringhals 3 (Studsvik)



loss of absorber





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Experience from control rod inspections

Ringhals 2

Styrstav	Antal cykler i härd	Antal cykler i CBD-poition
R008	15	1
R029	15	3

Ringhals 3 (2013)

Styrstav	Antal cykler i härd	Antal cykler i CBD-poition
R113	17	3
R117	16	4
R118	16	5
R119	16	3
R120	16	4
R122	16	1
R123	15	4

Ringhals 4 (2014)

Styrstav	Antal cykler i härd	Antal cykler i CBD-poition
R138	19	1

All control rods inspected with cracks are supplied by the same vendor and all from the same generation, -93. Several other control rods have been running under similar conditions but it is only the control rods from this generation inspected with cracks.

The cause is undetermined, but it can not be ruled out manufacturing tolerances or other manufacturing defects.

Reactor safety was not affected by the problem occurred R3. Inspections of the rods in recent years have not shown any reportable swelling that would prevent the control rods falling in the expected manner.

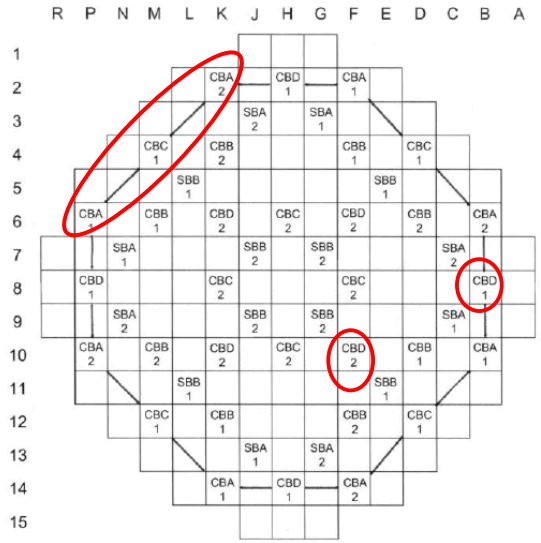
The problem at R4 was that we were running with control rods from the same delivery as the cracked rods from R3.

Experience from inspections of R34 is that cracks are detected before control rod fingers swell.

Revised Control Rod (replacement) Management

Even rods with tiny cracks (hairline crack) can cause leakage of the absorber materials into the reactor water. These cracks occurs by radiation-induced stress corrosion cracking (IASCC). This type the damage does not affect the control rod function but must be replaced due to ALARA and radiation safety concerns.

Experience from inspected control rods with cracks indicates that number of cycles in the core should be reduced (17 for R3 and R4, 15 for R2) and that the following limits on the permitted neutron fluence shall apply: $42 \leq Ø \leq 54$



Optimized positioning for control rod time in the core:

- 2 to 3 cycles in CBD-position
- 8 to 9 cycles in inner core region
- 3 to 4 cycles in outer region non CBD pos.

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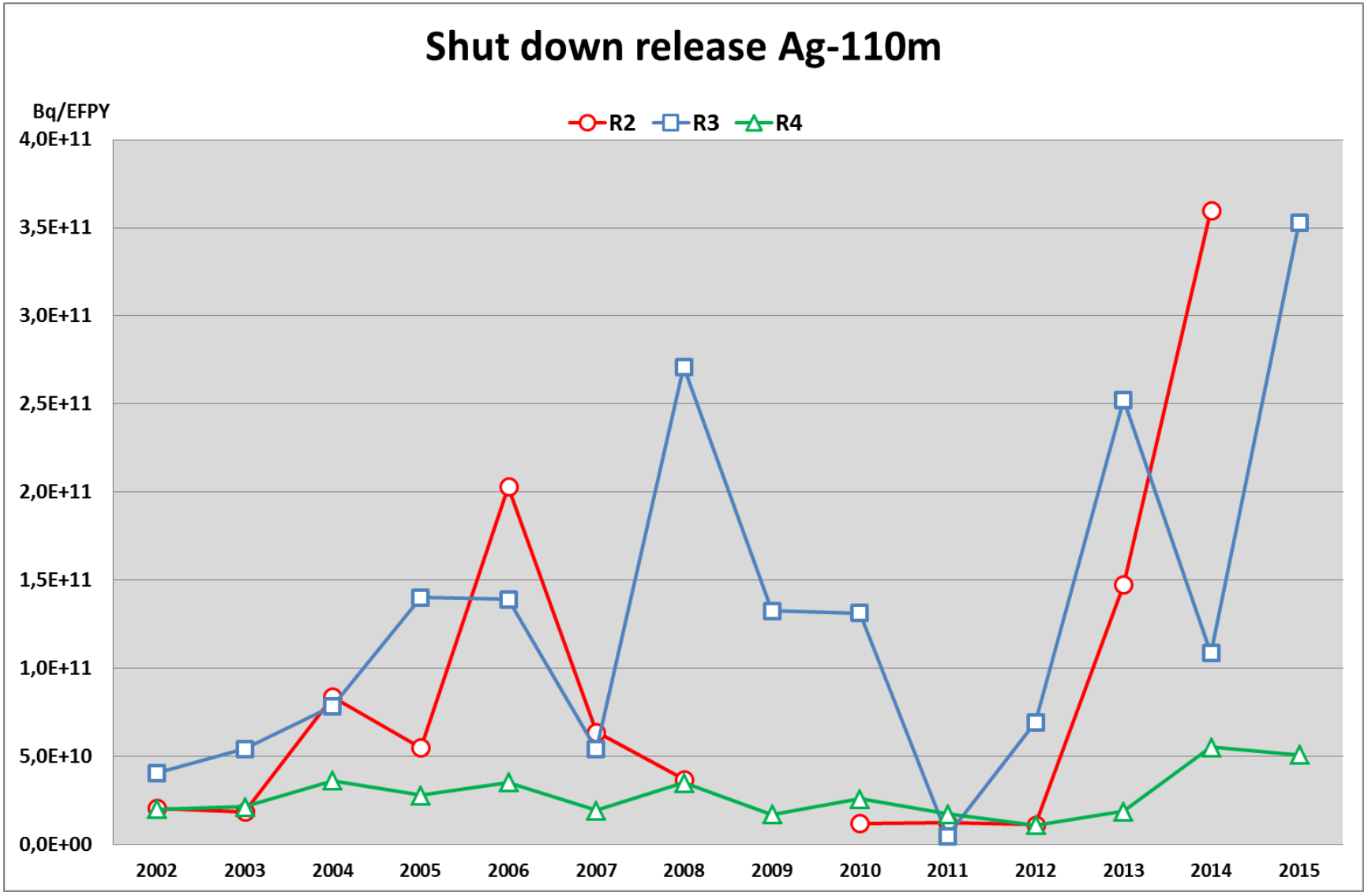
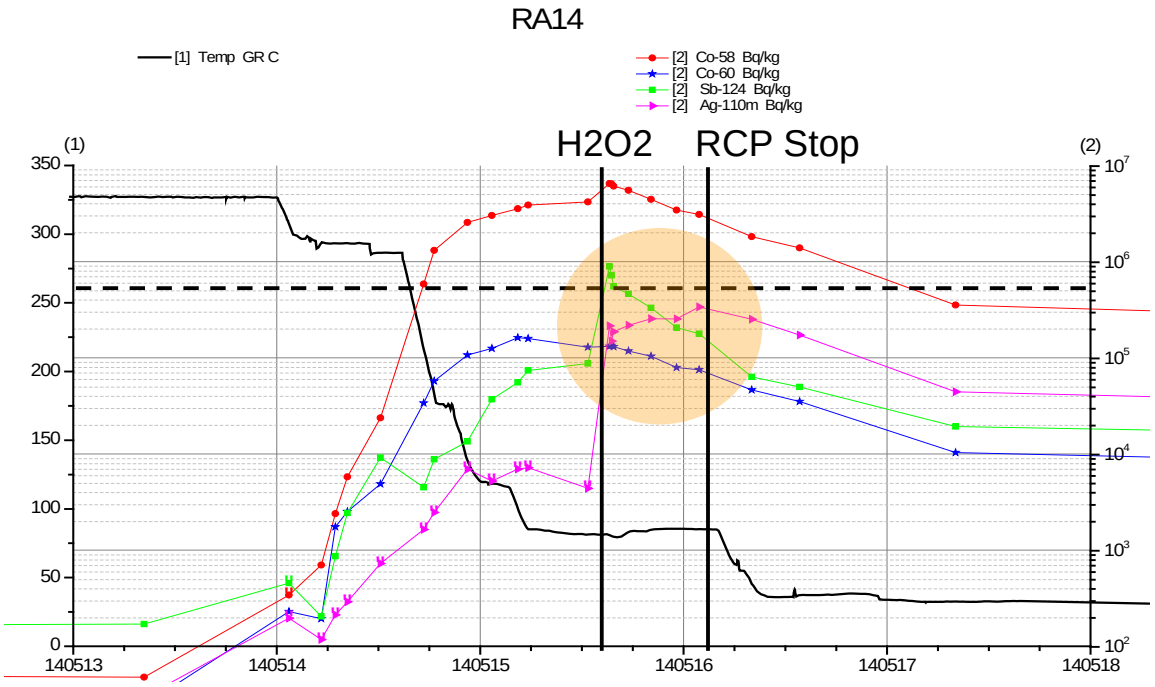
Accumulated release of Ag-110m during shut down



Shut Down Release Unit 3



Different behaviour for Ag-110m observed

Only one criteria for shut down release clean up:

- lifting reactor vessel head 5E5Bq/kg (Co-58)
- No criteria for Ag
- No criteria for Sb

Extended RCP run time from 12 hours to 18 hours

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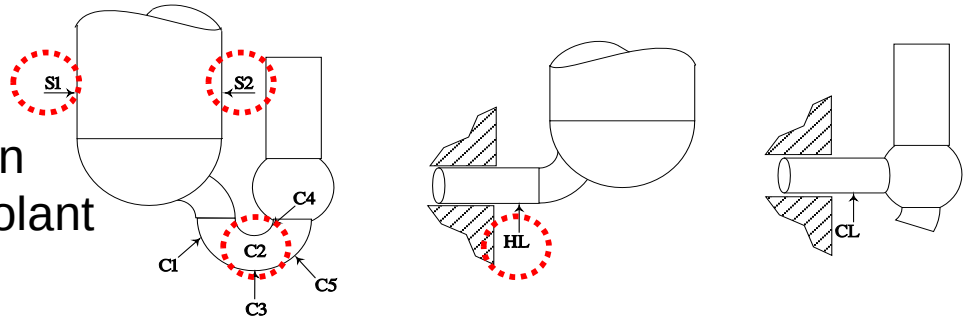
Monitoring program - Survey locations for GSA and doserates

RCS

- EPRI SRMP (Standard Radiation Monitor Program) – **R**eactor **C**oolant **L**oop **P**iping

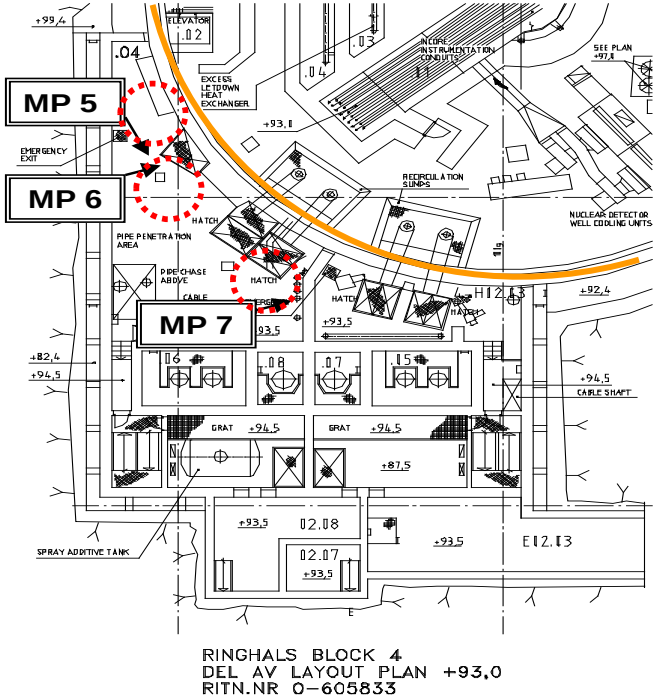


CVCS

- 9 survey points:
  - Let down piping
  - Heat exchangers

RHR

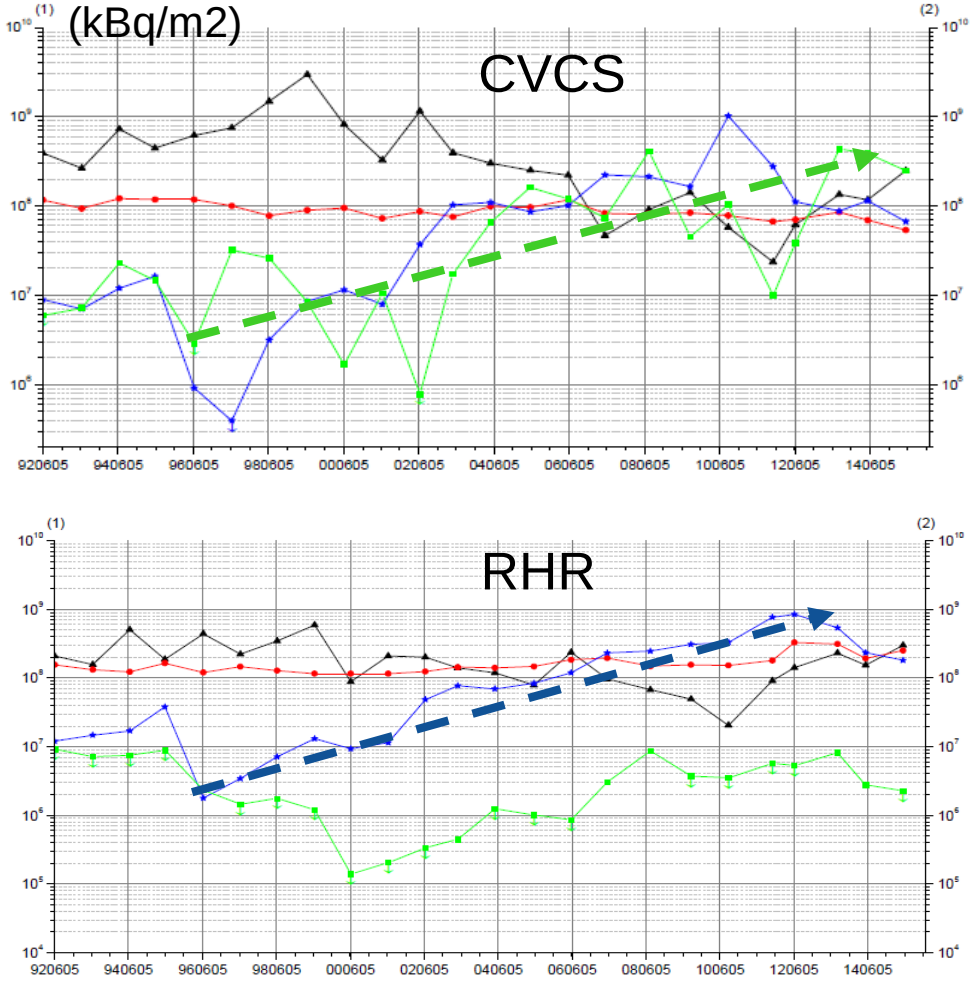
- 6 survey points:
  - RHR piping (4)
  - Heat exchangers (2)



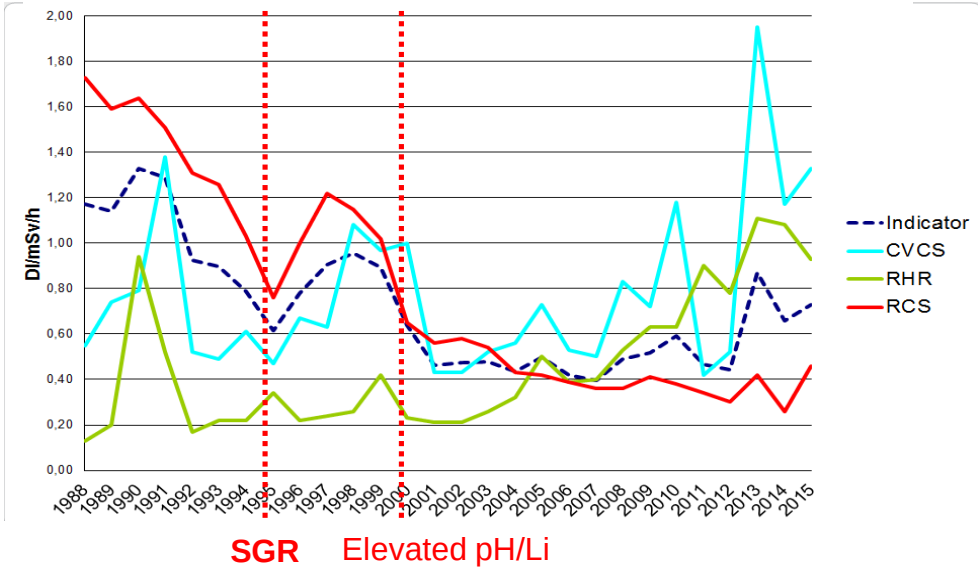
○ = GSA survey point

Trending data Ringhals 3

Co-60 **Sb-124** **Co-58** **Ag-110m**



Doserate Indicator (DI) / system - Ringhals 3



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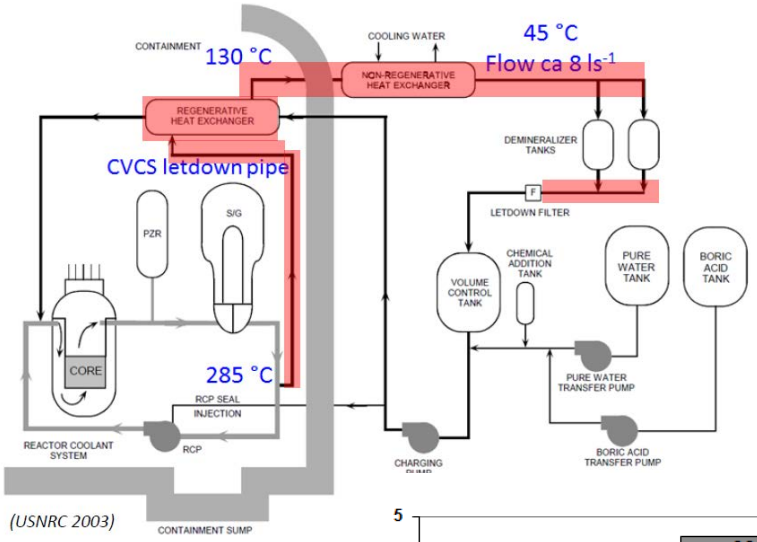
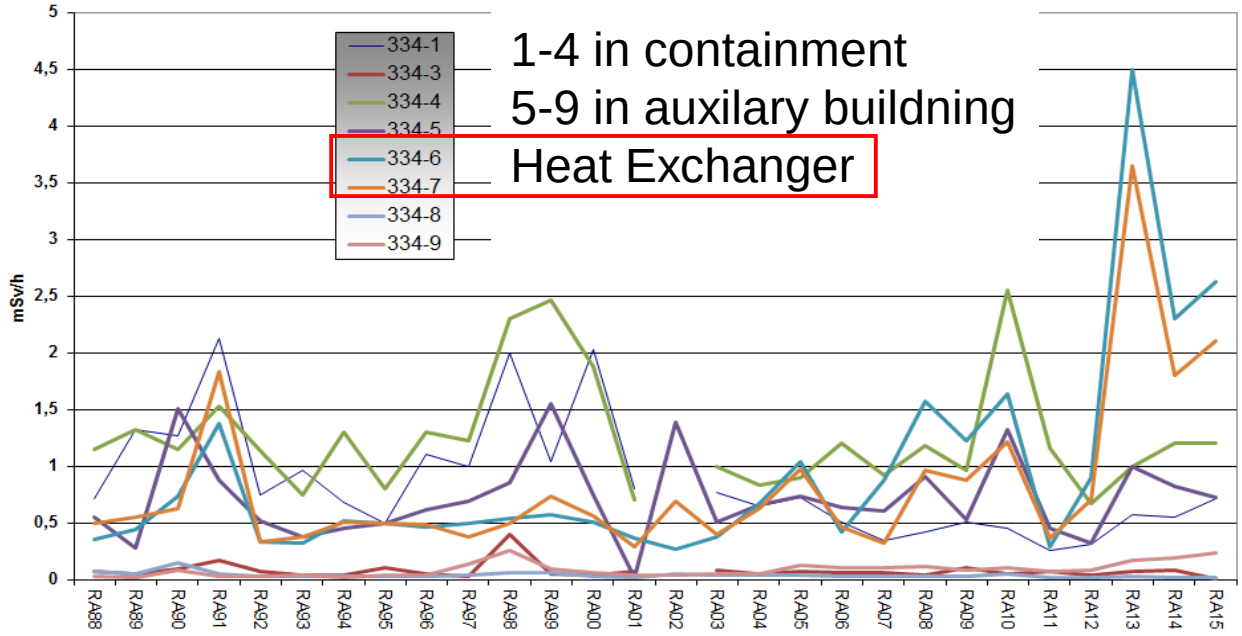
Silver and Antimony deposition Impact on radiation fields



(USNRC 2003)

Deposition of Ag-110m ocurrs mainly in CVCS where it locally can cause very high radiation fields.

Deposition of Sb-124 occurs mainly in RHR and CVCS



1-4 in containment
5-9 in auxilary buildning
Heat Exchanger

Summary of measures and R&D work

- Literature study *(completed)*

- Expanded radiation field monitoring
  - Installation of permanent installed GSA equipment *(TBD)*

- An overlay macroporouse resin has been put on ion exchanger in Ringhals 3 after 2015 refuel outage.

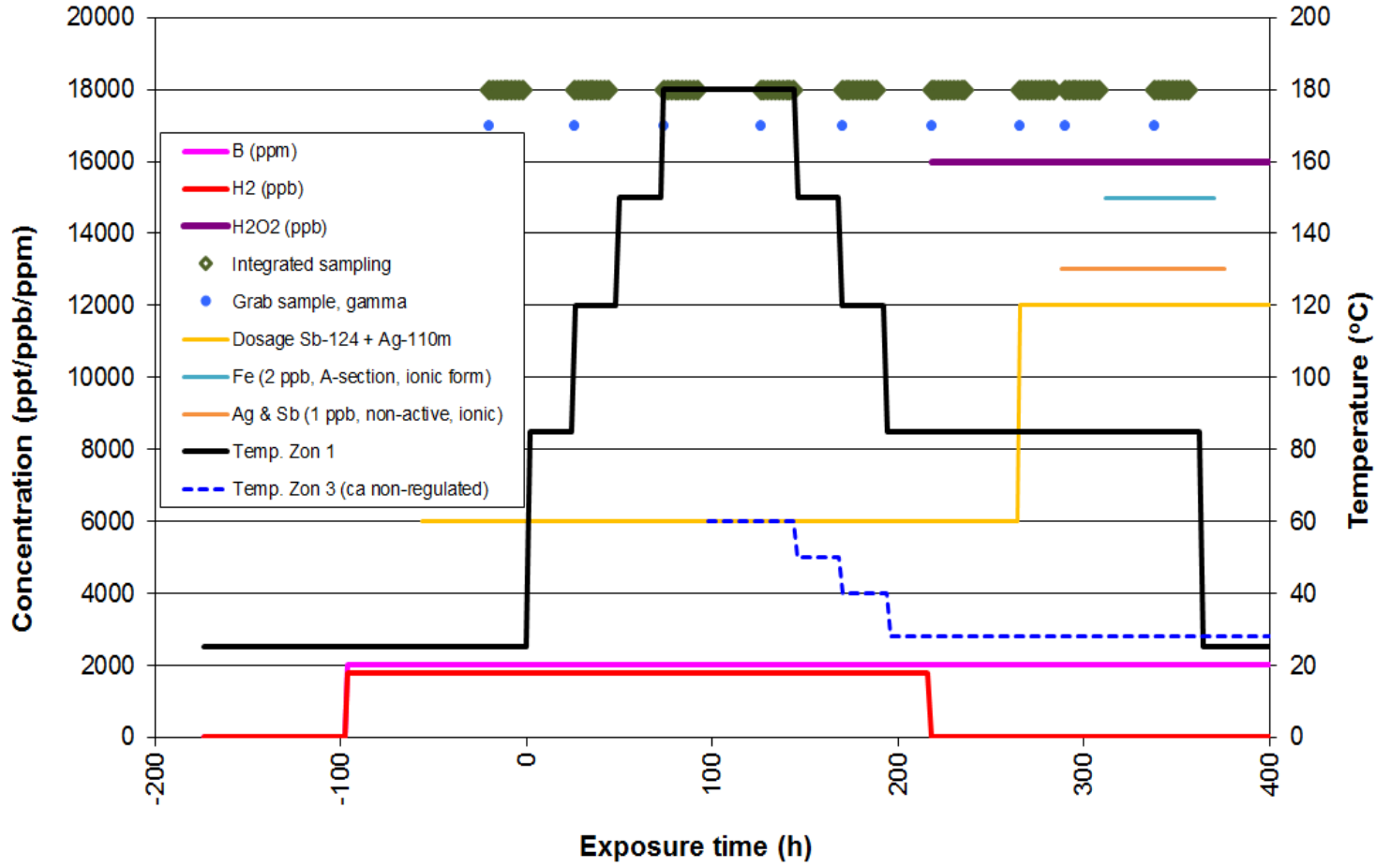
- Extended RCP run time during shut down release. Implementation of stopping criteria *(TBD)*

- Document - Technical Basis for Materials (TBM) has been updated with limitations regarding Ag and Sb.

- Ultra Sonic Fuel cleaning implemented at all Ringhals PWR units. Implementation of alternative shut down operations. *(TBD)*

- Loop testing to identify Sb behaviour under various coolant chemistry conditions (Initiated project in collaboration with Studsvik)

Schematic illustration of the loop test exposure scheme



To be continued…

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Thank you!