Impacts of Ag-110*m* on Radiation Field Generation: Review of an innovative experiment

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SUMMARY

1. AG-110M: EDF OPERATING EXPERIENCE
2. REAL TIME MONITORING OF SILVER CONTAMINATION: THE CIVAUX EXPERIMENT
3. CONCLUSION

Ag-110m: EDF operating experience

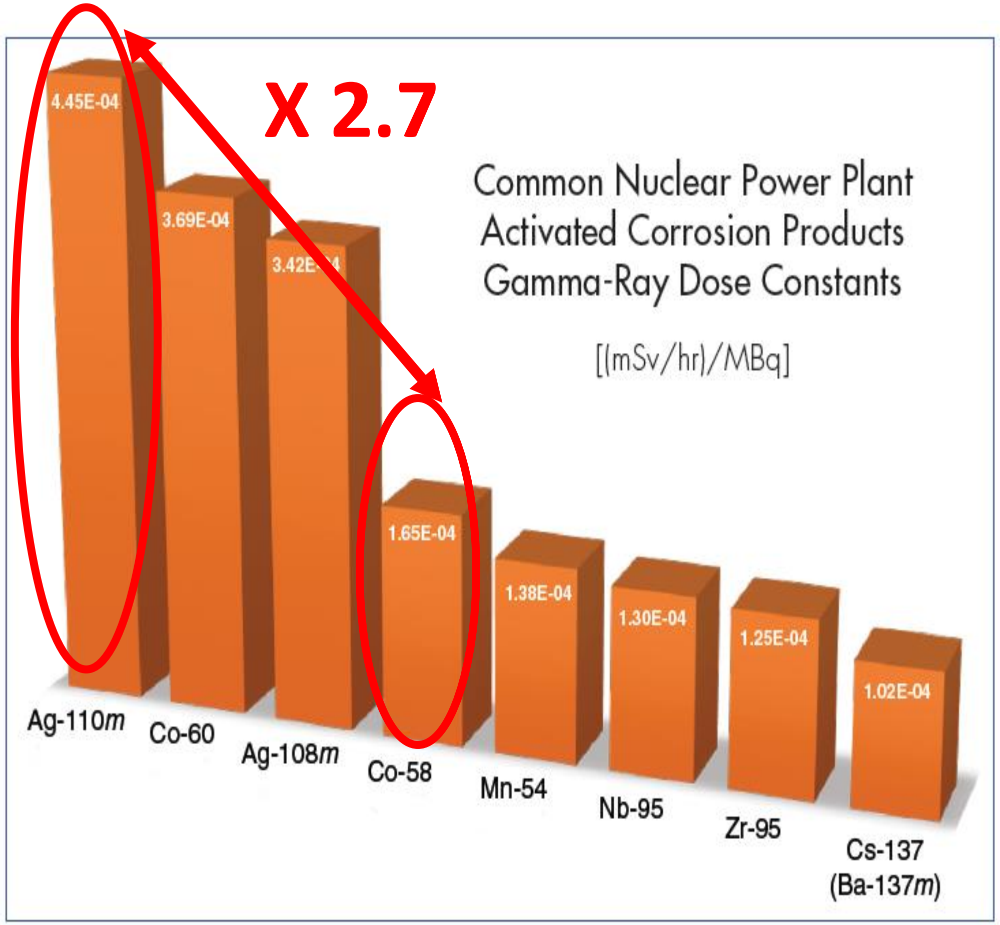
Primary coolant Ag-110m issue:

- Ag-109 (48.2 atom%) from elemental silver can be activated in Ag-110m. Some calculations have shown that less than 100 g of silver are enough to generate significant impacts.
- At EdF, Ag-110m has been observed since the start-up of the plants and is still an issue for a part of the actual fleet.

- **It impacts the plants at different levels :**
  - **Radiation protection:** **5 to 15% of some plants total outage exposure.**
  - **Plant availability:** **A specific radiochemical behavior that can disrupt the shutdown schedule.**
  - **Environment:** **For certain plants, it also impacts liquid discharges activity as Ag-110*m* is difficult to retrieve from liquid discharges.**

A MAJOR IMPACT ON RADIATION FIELD GENERATION (I)

Very specific radiological characteristics



Radionuclide	Period	Specific activity in reactor after one year
Ag-110m	250 days	$5.31.10^{11}$ Bq/g
Co-58	71 days	$4.8.10^{10}$ Bq/g
Co-60	5.27 years	$3.1.10^{12}$ Bq/g

An impact on dose rate that is roughly three times higher than Co-58.
It has a relatively long period and so it could be a long term concern for radiation field generation

A MAJOR IMPACT ON RADIATION FIELD GENERATION (II)

A radionuclide that tends to deposit in specific areas

Deposited activity (GBq/m²)		RCS	CVCS	RHR
900 MWe	Before O_2	0.06	0.16	0.06
	After O_2	0.07	**0.44**	0.02
1300 MWe	Before O_2	0.03	0.06	0.02
	After O_2	0.02	**0.17**	0.05
1450 MWe	Before O_2	0.04	0.21	0.06
	After O_2	0.04	**1.23**	0.18

A radionuclide that tends to deposit during forced oxygenation and mostly in the « cold parts » of the reactor. Dose rates can be increased by several decades.

A DIFFICULT RISK ASSESSMENT

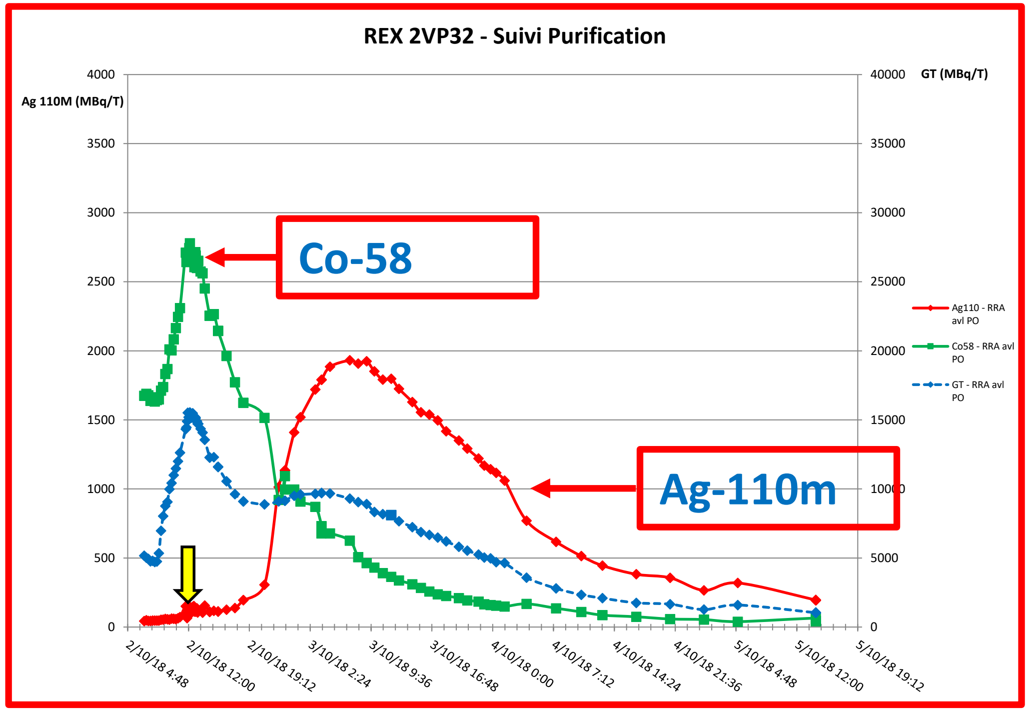
At full power

An activity that is not very noticeabe at full power and that is not linked with the risk of contamination

During shutdown

- A low increase to reach a maximum value after 10h to 15h.
- The maximum value stays in a plateau for several hours.
- The value decreases slowly and takes 15 to 30 hours to reach values considered as acceptable (1 GBq/t).

	Average Activity in RCS (MBq/t)		
	Full Power	Power Transients	Forced oxygenation
900 MWe (1988-2018)	3.19	6.56	483
1300 MWe (1990-2016)	2.52	3.76	11.9
1450 MWe (2003-2012)	1.97	3.40	71



Real time monitoring of silver contamination: The Civaux Experiment.

THE NEED FOR IMPROVEMENT

As previously seen:

- Ag-110*m* can be an issue for the contamination of the "cold" portions of the plants and more specifically for the CVCS system.
- Actual practices are not always efficient to prevent contamination in certain parts of RHRS and CVCS circuits.
- Radiochemical measurements of Ag-110m, more precisely the sampling by NSS system, doesn't give a very precise assessment of the radionuclide's impact on radioprotection.
- On addition to radiochemical survey monitoring silver deposition after forced oxygenation is done by some plants with the real-time monitoring of dose rates on some key components.
- Therefore, there is room for improvement…

The Civaux experiment:

- The experiment carried out in CIVAUX nuclear power plant in 2019 was more ambitious by the number of sensors installed and the methodology used to analyze the results.
- The goal was to calculate the factor of recontamination for each radionuclides in strategic points of RHRS and CVCS circuit surfaces during shutdown.

EXPERIMENTAL DISPOSAL: SENSORS LOCALISATION

RHRS Zone

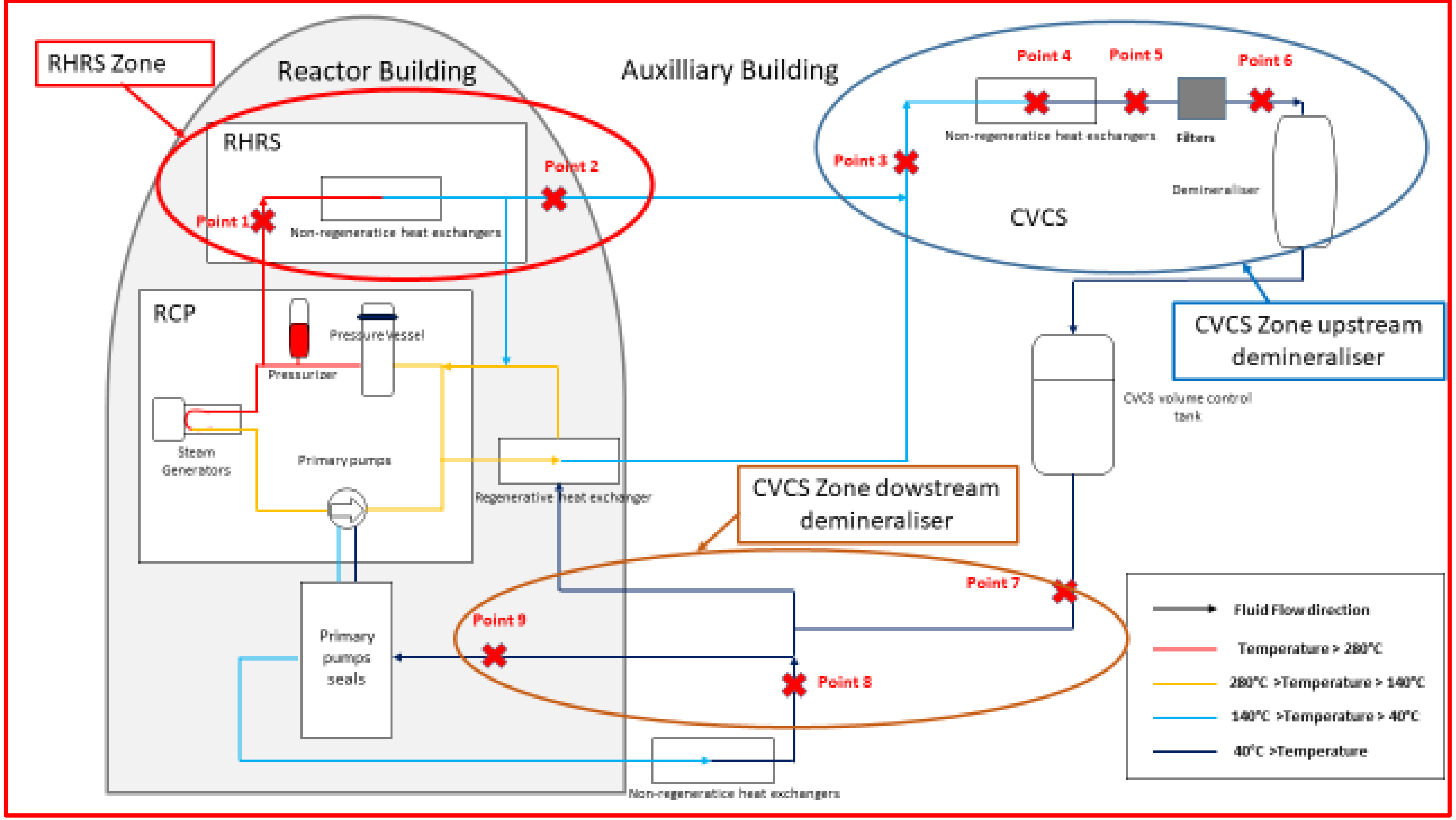
- **Point 1:** Representative of RCS coolant before entering RHRS.
- **Point 2:** Representative of RHRS coolant after cooling.

CVCS upstream zone

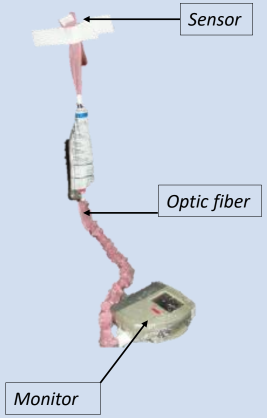
- **Point 4:** CVCS non-regenerative heat-exchanger main point to survey globally silver contamination on CVCS circuit.
- **Points 3 and 5:** Points upstream and downstream heat exchanger.
- **Point 6:** Point downstream filter and upstream demineralizer.

CVCS downstream zone

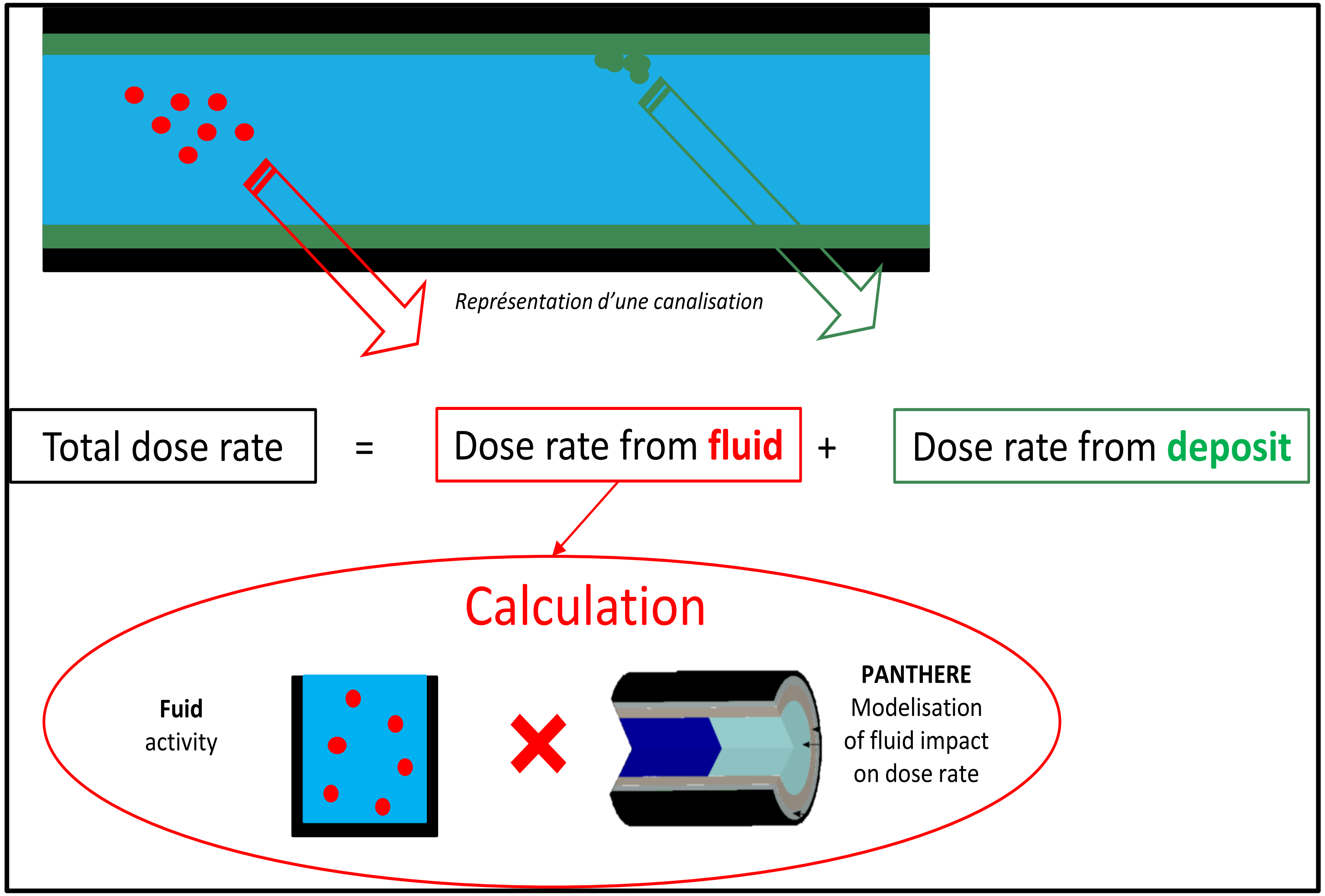
- **Points 7, 8 and 9:** Points downstream the demineralizer to survey contamination on the primary coolant pumps seals injection line.



EXPERIMENTAL DISPOSAL: DEVICES USED FOR THE EXPERIMENT

Reactor Area		Dosimeter		Spectrometer
		Stand alone dosimeter	Radiameter	CZT
RHRS Zone	Point 1	X		X
	Point 2	X		X
CVCS upstream zone	Point 3	X		
	Point 4	X	X	X
	Point 5	X		X
	Point 6	X		
CVCS downstream zone	Point 7	X		X
	Point 8	X		X
	Point 9	X		X
Devices Characteristics		 Record dose rates every hour. Data treatment is made after the experiment	 Allows to report data in a control room for real-time survey	 Detect radionuclides

DATA TREATMENT



DEPOSITION FACTOR

DF is simply the dose rate issued from deposit before and after forced oxygenation factor.

$$DF = \frac{Dose\ rate\ after\ oxygenation}{Dose\ rate\ before\ oxygenation}$$

NOTABLE RESULTS: DEPOSITION FACTOR ON CVCS AND RHR

RHRS Zone

- **Point 1:** The global deposition factor is moderate **(1,8)**. Deposition begins slowly before forced oxygenation, it reaches a maximum value just after hydrogen peroxide injection and decreases rapidly. The deposited radionuclides are **Ag-110*m*, Sb-124 and Co-58**.
- **Point 2:** The global deposition factor is moderate **(1,9)**. The deposition only begins after forced oxygenation and stops several hours after hydrogen peroxide injection. The deposited radionuclides are **Ag-110*m*** and **Co-58**.

CVCS upstream zone

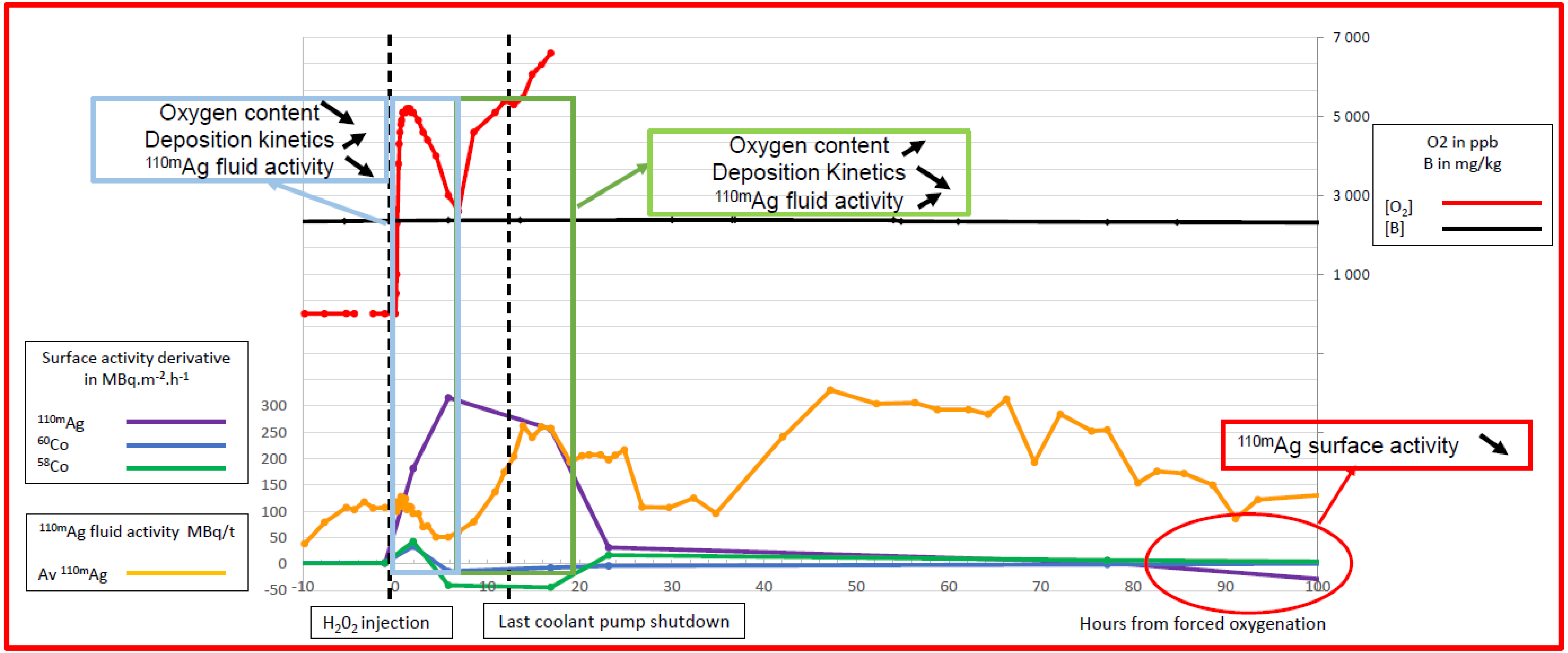
- **Points 3 and 6:** An important deposition factor is observed (**8 for point 3 and 8,2 for point 6**). At least on point 3 **Ag-110*m*** is responsible for more than 90% of the dose rate and is the main radionuclide responsible for this recontamination.
- **Point 5:** A very important factor is observed **(12).** The deposition begins since forced oxygenation and occurs for 25 hours. The CZT measurements showed that **Ag-110*m*** was the main contributor with a deposition factor for this radionuclides going up **30**.

CVCS downstream zone

- **Points 7, 8 and 9:** A very moderate deposition factor **(1,1)** is observed for all the points. CZT measurements show that that this very light contaminations is mostly due to **Ag-110*m*.**

NOTABLE RESULTS: CVCS NON REGENERATIVE HEAT-EXCHANGER (POINT 4)

Surface activity of Ag-110*m* increases by a factor of 15.
Deposition occurs just after oxygenation and goes on during 30 hours.
It's not related with Ag-110m activity and can only be related with the oxygen content.
After 80 hours, one can observe a decrease in Ag-110*m* surface activity.



Conclusion

LESSONS LEARNED

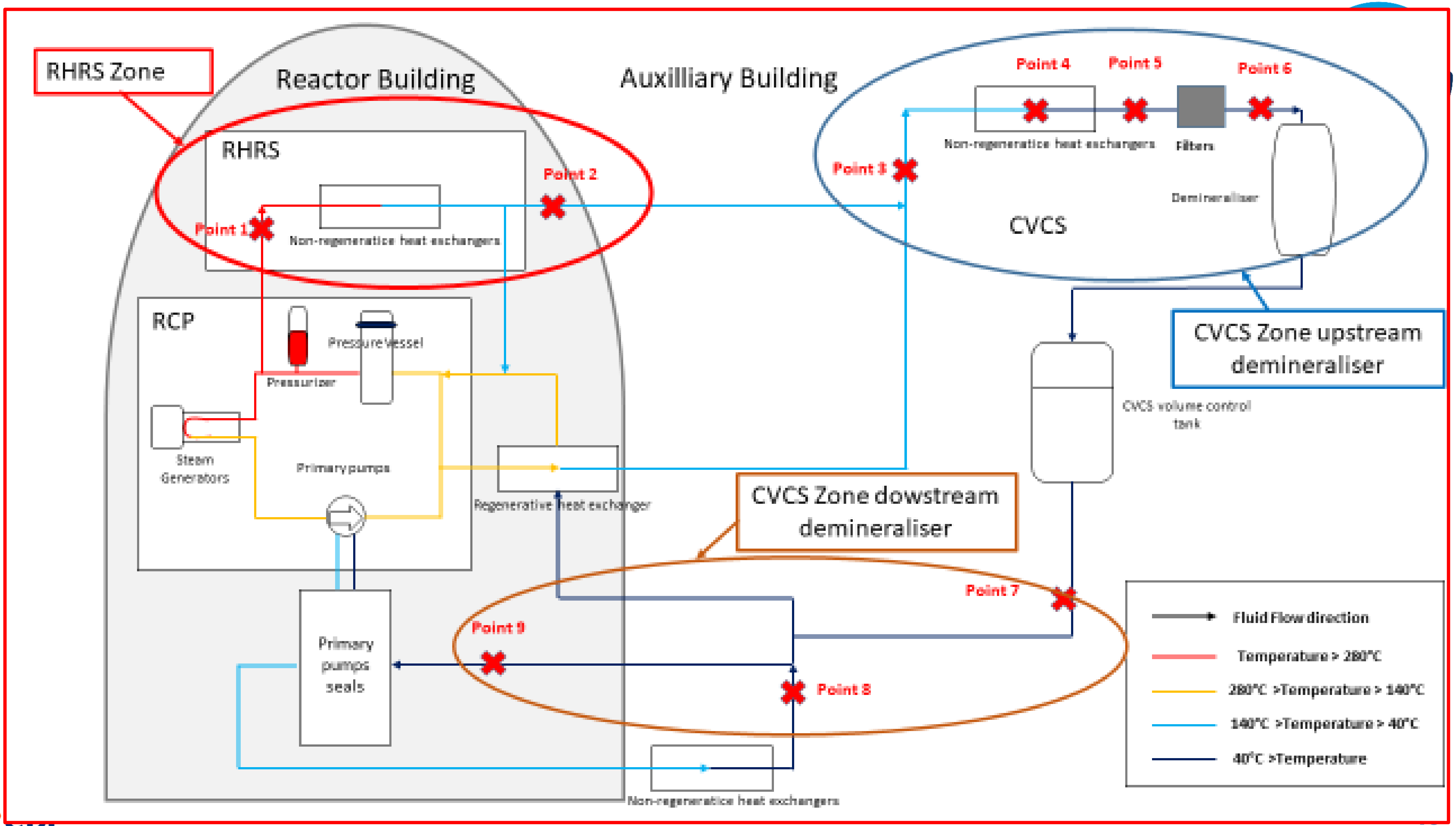
❑ At plant level:

- Demonstrate the value of such a disposal to insure real-time survey of surfaces contamination.
- Identify for the plant the portions of the circuits that are most sensitive to silver contamination.
- Verify the relevance of the shutdown strategy that was implemented for this outage:
  - ✓ No contamination on the CVCS downstream the demineralizer.
  - ✓ A dosimetry 20% lower than the projected one.

❑ At corporate level:

- Identify an approach that can be duplicated on other plants at least those with an Ag-110*m* issue.
- Collect relevant data on the behavior of silver on the nuclear power plants circuits and more precisely the CVCS.
- Questions our strategy on silver treatment during shutdown and start-up.
  - ✓ Look for ways to maintain for each plant a high level of oxygen immediately after forced oxygenation.
  - ✓ Maintain as long as possible an efficient circulation on CVCS circuit as solubilization of silver and thus dose rate decrease can occur several days after forced oxygenation.
  - ✓ Optimize maintenance activities on CVCS circuit to integrate this specific behavior.
  - ✓ Work on an optimized start-up procedure to remove and retain on filters and resins a part of silver deposited on CVCS surfaces.

ANNEX


RHRS Zone
Reactor Building
Auxilliary Building
RHRS
Point 1
Point 2
Non-regeneratice heat exchangers
Point 3
Point 4
Point 5
Point 6
Filters
Demineraliser
CVCS
RCP
Pressure vessel
Pressurizer
Steam Generators
Primary pumps
Regenerative heat exchanger
CVCS Zone upstream demineraliser
CVCS volume control tank
CVCS Zone dowstream demineraliser
Primary pumps seals
Point 7
Point 8
Point 9
Non-regeneratice heat exchangers
Fluid Flow direction
Temperature > 280°C
280°C >Temperature > 140°C
140°C >Temperature > 40°C
40°C >Temperature

Thank you