EDF feedback on the impact of the last RCP shutdown on primary circuit contamination

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CHANGER L'ÉNERGIE ENSEMBLE

1. Introduction
2. International practices
3. Impact on the coolant flow rates
4. Impact on the purification of the primary coolant
5. Impact on the deposited activity and activity concentration
6. Impact on the dose and radiation level

Introduction (1/1)

- At EDF, **the criteria to shutdown the last reactor coolant pump** are based on ^{58}Co and total gamma primary coolant activities. The last RCP must be secured only after reaching the radiochemical limits :

^{58}Co < 50 GBq/t & Total Gamma < 100 GBq/t

- The purification continues with CVCS pump until :

^{58}Co < 2 GBq/t & Total Gamma < 4 GBq/t => Criteria to fill the cavity in

- What is the goal of the criteria :
  - Reduce the impact of the activity concentration due to oxygenation
  - Dose rate near the Reactor Bulding cavity less than 50 µSv/h

=> Compromise between radioprotection aspects and planning

Introduction (2/2)

- **FAQ by NPP RP teams :**

  “feeling” : the longer RCPs are in operation after oxygenation, the lower the dose rates are. **Is it interesting to purify with RCP in operation during a longer period ?**

- Edf engineering study based on theoretical calculations and measurement campaigns.

  What is the impact of RCPs stopping

  - On the coolant flow rates ?
  - On the purification of the primary coolant ?
  - On the deposited activities and radiation level ?
  - On the activity concentration and dose rates

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International practices

- The parameters considered to define the criteria to stop the last RCP are :
  - Outage planning,
  - RCS temperature,
  - ^{58}Co oxygenation peak and/or is decrease,
  - The % of solubilised ^{58}Co (based on measurements of solubilised and particles of ^{58}Co),
  - Activity concentration of the different radionucleides in the RCS.

- Most of the time: the timing and the planning of the outage are the most important criteria

- For american NPP operators:
  - Very different practices between the different units:
    - Before or after oxygenation,
    - Depending or not on the RCS temperature,
    - Most of the time : based on the purification of the RCS, either x hours after injection of H_2O_2 or after oxygenation peak, or a % of ^{58}Co activity concentration reduction
  - When based on ^{58}Co activity concentration: from 1,85 to 185 GBq/t

- An EPRI study is ongoing on this subject

No direct link between the criteria to shutdown the last RCP and the doses rates around RCS pipes

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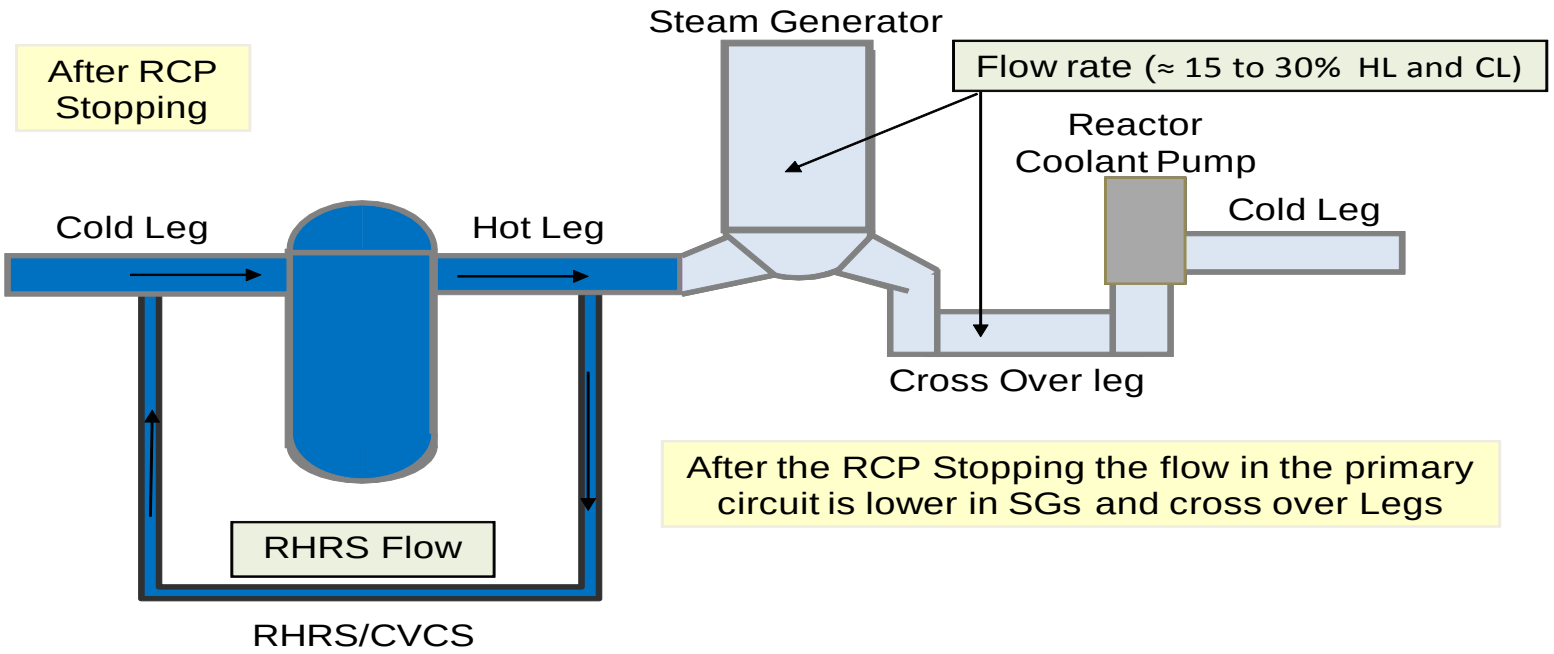
Impact of RCP stopping on coolant flow rates



- Simulation of coolant flow during reactor shutdown by SIPA Code (post-Accident Simulator)

- **Decrease** of 15% (900 MWe) to 30% (1300 MWe) **of the flow rate** in zones of SG tubes, SG channel heads an cross-over legs for a few hours

  - ⇒ Is the primary coolant purified uniformly throughout the circuit ?
  - ⇒ Does the deposition occur preferentially in the reduced flow areas (Cross over legs and SGs) ?

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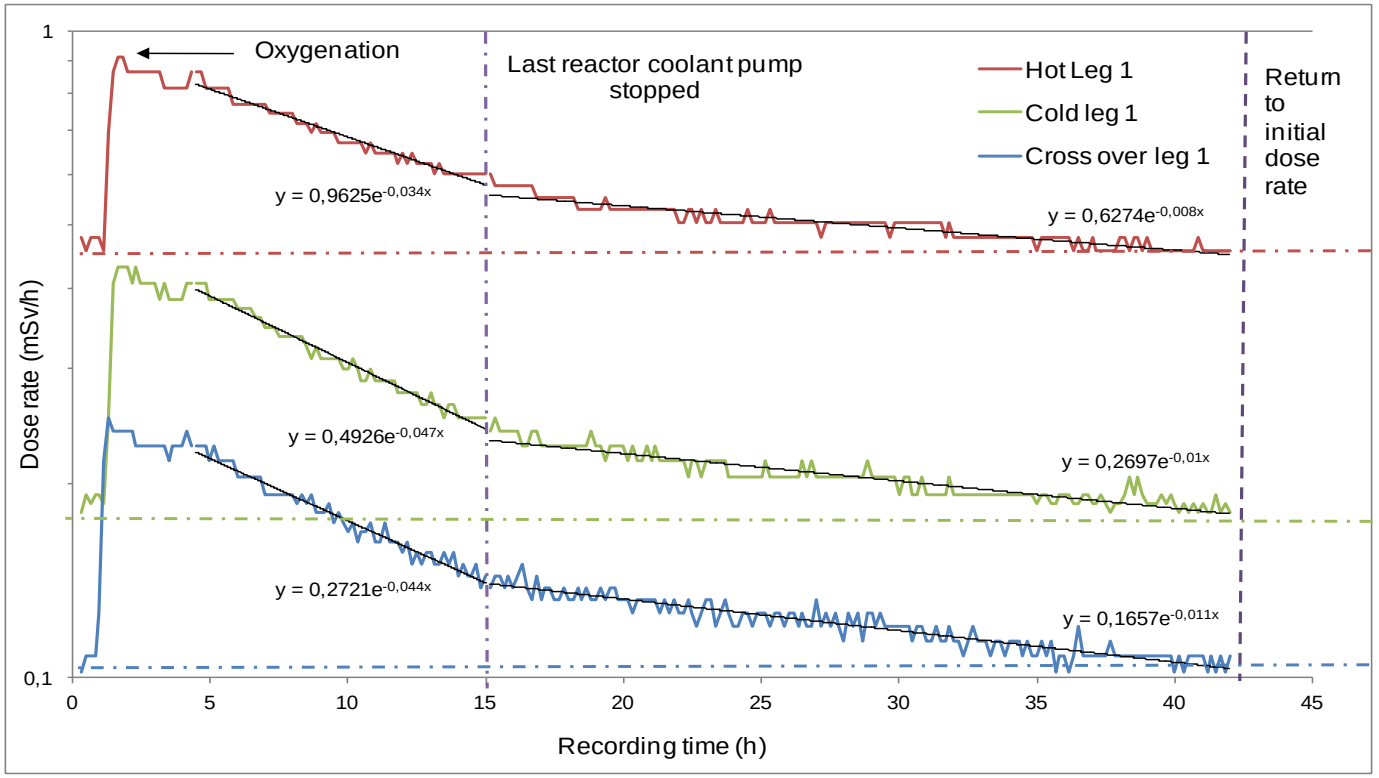
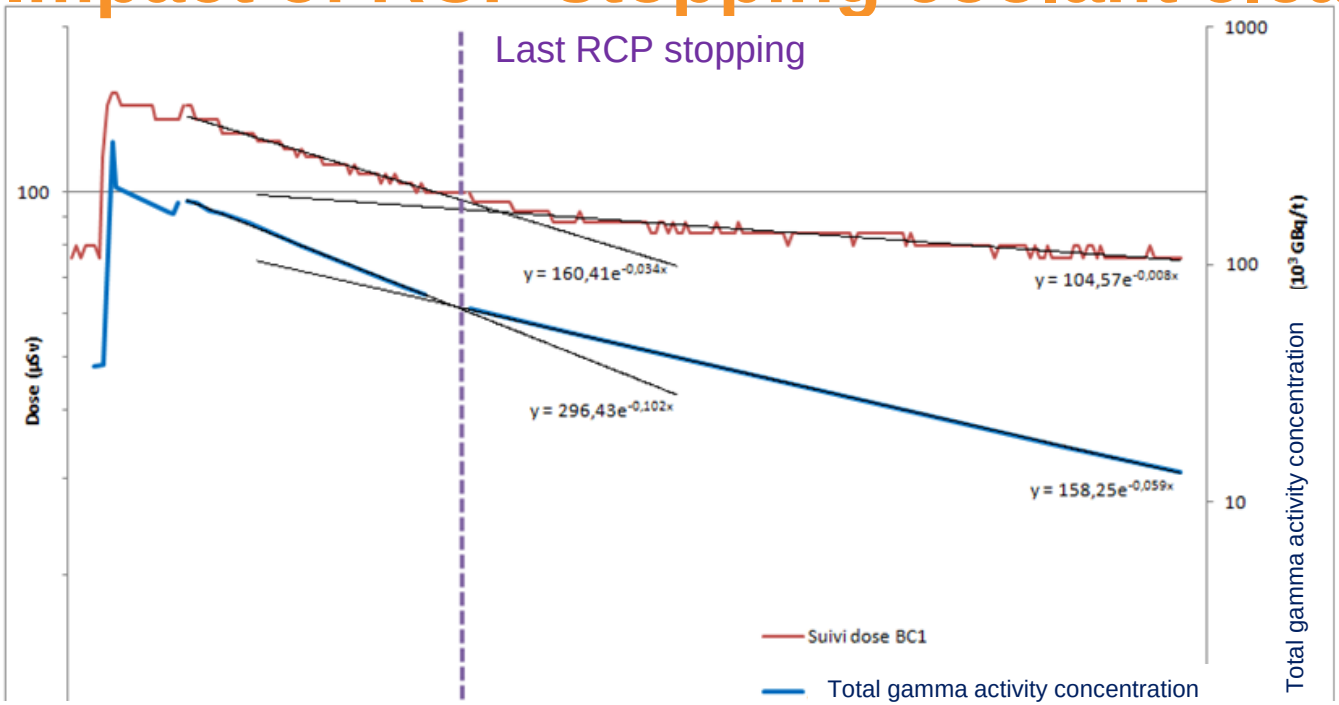
Impact of RCP stopping on the purification of the primary coolant (1/2)



- HL, CL and cross over leg dose rates follow the same evolution
- HL, CL and cross over leg dose rates reach the initial values (values before oxygenation) at the same time.

→ **The lower flow rate caused by the RCP stopping has no impact on dose rate evolution**

Impact of RCP stopping coolant cleanup (2/2)



- clean up

$$\ln\left(\frac{A(t)}{A_0}\right) = -\frac{Q_{CVCS}}{M_{RC}} \times t \times \left(1 - \frac{1}{F_d}\right)$$

- Before RCP stopping : measured CVCS flow 46,3 t/h

$y = 296{,}43.e^{-0{,}102\,x}$ Q_{CVCS} / M_{RC} = -0,102 for M_{RC} = **453 tones**

- After RCP stopping : measured CVCS flow 26,3 t/h

$y = 158{,}25.e^{-0{,}059\,x}$ Q_{CVCS} / M_{RC} = -0,059 for M_{RC} = **454 tones**

→ **The slope variation is not due to the RCP stopping. It is due to the CVCS flow variation**
Important to have a high and constant CVCS flow rate

→ **The RCP stopping after the oxygenation have no impact on the coolant purification**

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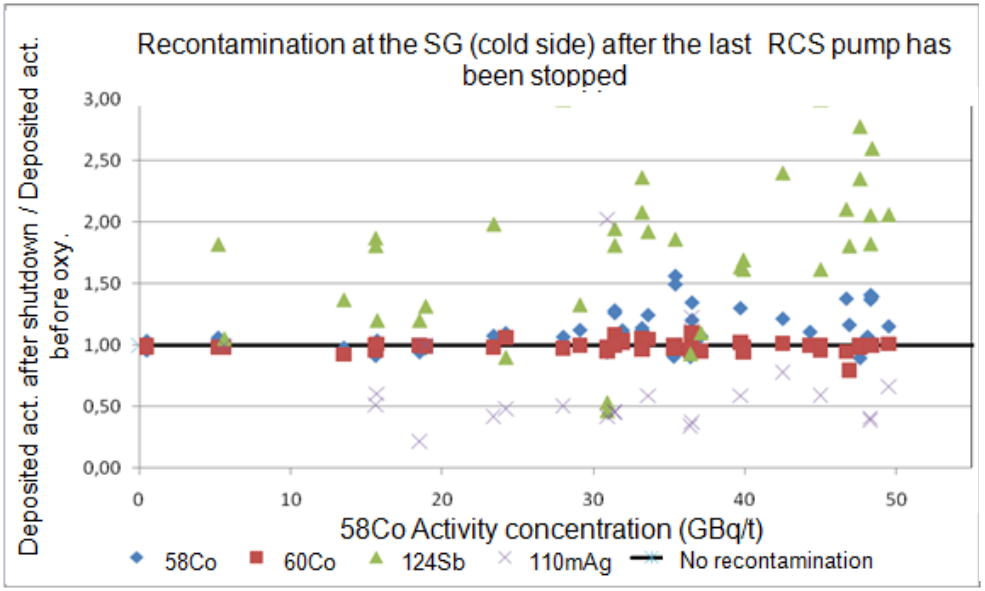
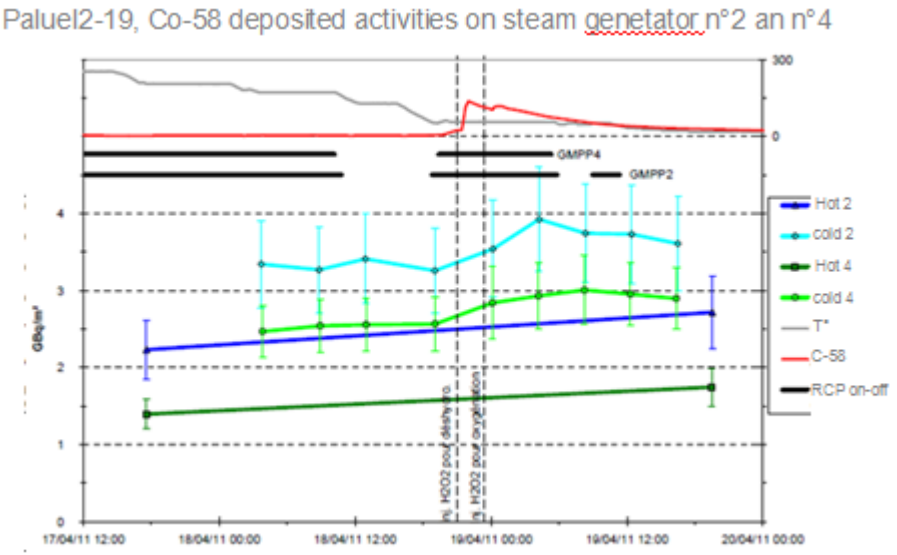
Impact of RCP stopping on the deposited activity





- No obvious difference of recontamination for $30 < {}^{58}Co < 50$ GBq/t
- Are the cases of contamination by Co-58 and Sb-124 at the end of reactor shutdown due to the RCP stopping ?

- Analysis of Paluel 2-19 measurement campaign :
  - Co-58 and Sb-124 SG contamination occurs after the coolant oxygenation and before the stop of the last RCP

    The contamination is not due to the last RCP stopping
- No difference between the 4 loops (loop 4: stop of the RCP at 77 GBq/t in ^{58}Co – loop 2: stop of the RCP at 42 GBq/t in ^{58}Co)

Impact of RCP stopping on the activity concentration

	Cross Over Legs			Steam Generator		
Deposited activity contamination	Low	Medium	High	Low	Medium	High
Activity concentration (^{58}Co) (GBq/t)	Dose rate (Activity concentration) / Total Dose rate			Dose rate (Activity concentration) / Total Dose rate		
500	92%	81%	68%	89%	49%	31%
100	69%	46%	30%	61%	16%	8%
50	53%	30%	17%	44%	9%	4%
30	40%	20%	11%	32%	5%	3%
10	18%	8%	4%	14%	2%	1%

- PANTHERE calculations
- Impact of the ^{58}Co activity concentration particularly for the cross over legs
- Difference of contribution to the dose rate of the activity concentration (between 50 and 30 GBq/t) :
  - 6 to13% for cross over leg
  - 1 to 12% for steam generator
- At the end of purification (^{58}Co=2 GBq/t) :

  Deposited activity >> Activity concentration

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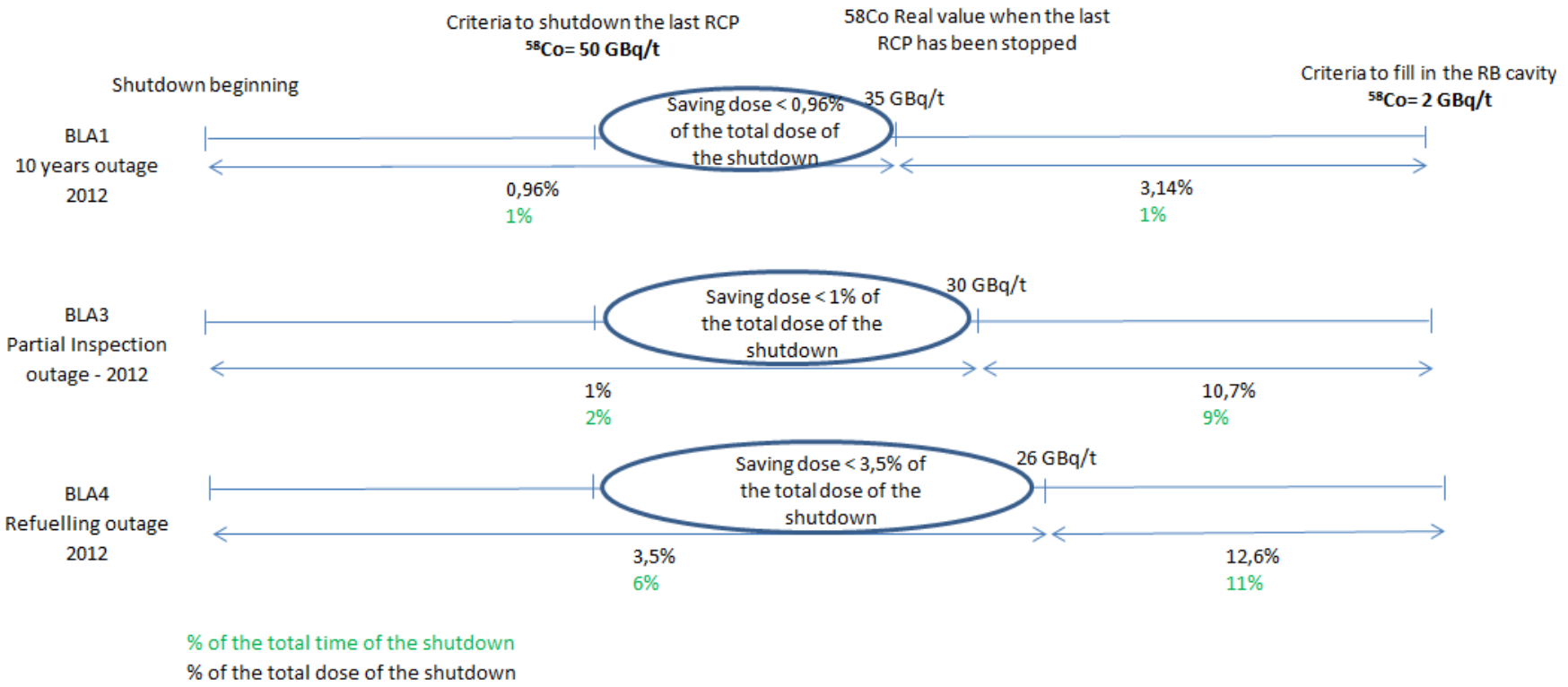
Impact of RCP stopping on the dose and radiation level (1/2)

- Hypothesis: dose taken between 50 GBq/t and the stop of the last RCP due to the activity concentration only



- A limited saving dose to obtain for a stop of the last RCP at 30 GBq/t

Impact of RCP stopping on the dose and radiation level (2/2)

Purification time

Purification time : $$t = -\frac{\ln\left(\frac{A(t)}{A_0}\right)}{\left(\frac{Q_{RCV}}{M_{CP}} \times \left(1 - \frac{1}{F_d}\right)\right)}$$

M RCS (M_{CP}) - 900 Mwe	300	tonnes	Criteria to stop the last RCP	50 GBq/t ^{58}Co
Purification factor (F_d)	100			30 GBq/t ^{58}Co
CVCS Flow rate (Q_{RCV}) - 900 Mwe	27	t/h		
Criteria to fill the RB cavity in	2	GBq/t en 58Co		

		Time to reach 50 GBq/t (h)	Time to reach 30 GBq/t (h)	Delta Purification time between 50 et 30 GBq/t (h)
Average oxygenation peak for ^{58}Co (=A_0)	200	15,6	21,3	6
	150	12,3	18,1	6
	100	7,8	13,5	6

		Time to reach the criteria to fill the RB cavity in (h)
Average oxygenation peak for ^{58}Co (=A_0)	200	51,7
	150	48,5
	100	43,9

Independant of the criteria to stop the last RCP

- Since there is no impact of the criteria to stop the last RCP on the deposited activity, **hope for dose gain is limited to the activities realized during a time slot of 6 hours**

Paluel 2	10-yearly outage *2005*	P.I *2006*	R.S *2008*	P.I *2009*	R.S *2011*	P.I *2012*
^{58}Co activity when last RCP stopped (GBq/t)	24	29	**25**	25	**42**	28
Total γ activity when last RCP stopped (GBq/t)	38	49	56	40	65	31
RCS Index (Bef. O2) (mSv/h)	0,29	0,23	0,28	0,28	0,23	0,29
RCS Index (Aft. O2 - ^{58}Co=50 GBq/t) (mSv/h)	-	0,40	0,44	0,34	0,30	0,40
RCS Index (Aft. O2 - End purif.) (mSv/h)	-	-	0,20	0,20	0,22	0,26
Hourly dose during shutdown (H. µSv/h)	13,60	11,10	10,80	10,60	9,20	9,90

P.I: Partial Inspection - R.S: Refuelling shutdown

- No obvious relation between the criteria for stopping the last RCP and radiation level indexes

Conclusion

- At EDF, the criteria to shutdown the last reactor coolant pump are

  ^{58}Co < 50 GBq/t & Total Gamma < 100 GBq/t

- RCP stopping causes a low flow rate in cross over legs and steam generators
  - but it has no impact on dose rate evolution and the deposited activity
  - a temporarily impact on activity concentration
  - **But it is important to keep the CVCS flow rate as high as possible**

- No obvious benefit on radiation level between 50 and 30 GBq/t

Thank you