MANAGEMENT OF ALPHA EMITTERS AT EDF/DPN AND COMPARISON WITH INTERNATIONAL UTILITY APPROACHES

PRESENTATION OF THE DATA COLLECTED FROM AN ISOE QUESTIONNAIRE

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INTRODUCTION

- **Alpha risk**
  - Low Annual Limit Intake values for alpha emitters
  - Alpha contamination remains in the primary circuit even when the defects occurred much earlier in the plant's history (particulate form, long lived nuclides)

- EDF/DPN implemented a graded approach to manage the alpha risk and wanted to compare its practices to that of other utilities → CEPN

- **Questionnaire sent to the ISOE network**
  - 9 utilities*

15 NPP

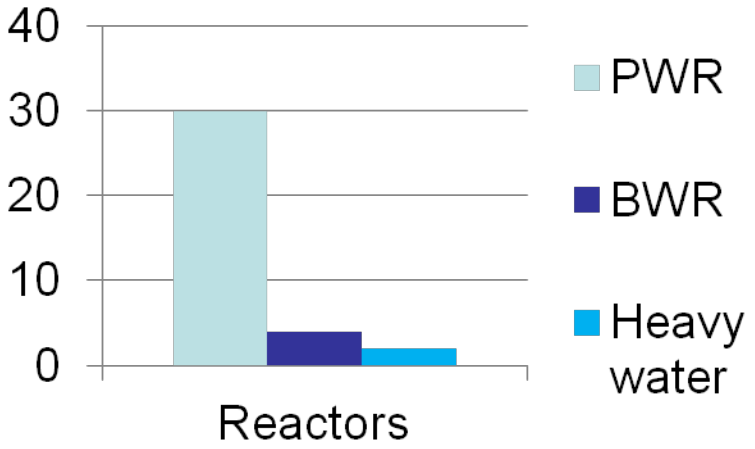
36 units

  - + EDF fleet (UO2 + MOX fuel)

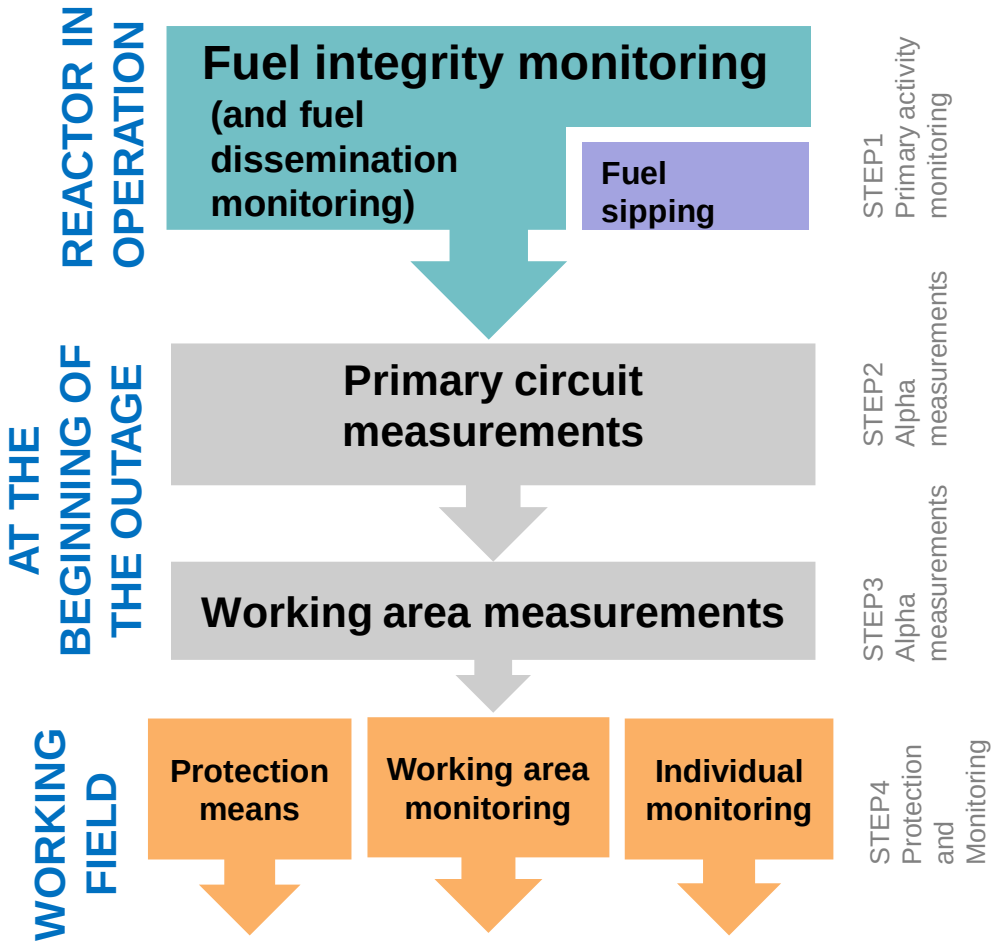
***: Engie Electrabel, Dominion, Loviisa NPP, CEZ, Cernavoda NPP, Sizewell B NPP, Forsmark NPP, Leibstadt NPP, CGN**

The data presented here are not comprehensive

Fuel : UO2 (no MOX)



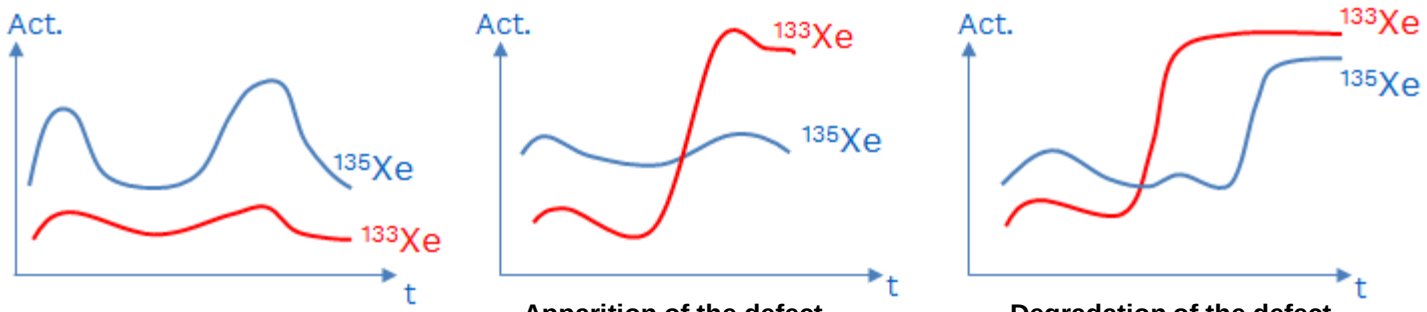
OVERALL APPROACH OF THE ALPHA RISK MANAGEMENT



Intake from alpha emitting nuclides management, waste management,…

1. PRIMARY ACTIVITY MONITORING (1/3)

- Indicators to **detect and monitor** a fuel cladding defect or fuel degradation (reactor in operation):
  - Iodine: Dose equivalent in ^{131}I (Engie Electrabel, CEZ, Sizewell B), $^{131}I/^{133}I$, ^{131}I (Forsmark, for maximum allowed fuel defects), iodine isotopes
  - Xe 133: Dose equivalent in ^{133}Xe, $^{133}Xe/^{135}Xe$ (Loviisa NPP), $^{85}Kr/^{133}Xe$
  - Other nuclides: ^{87}Br, ^{88}Kr, ^{92}Sr (Forsmark, for maximum allowed fuel defects and tramp uranium), ^{239}Np (Sizewell B, indicator of significant fuel failure), ^{134}Cs, ^{137}Cs
  - WANO Fuel Reliability Indicator (FRI) (Loviisa NPP, CEZ, Sizewell B NPP)
  - **At EDF**: fuel failure → $^{133}Xe/^{135}Xe$ ratio (indicator defined in the Radiochemical Specifications)



Apparition of the defect **Degradation of the defect**

1. PRIMARY ACTIVITY MONITORING (2/3)

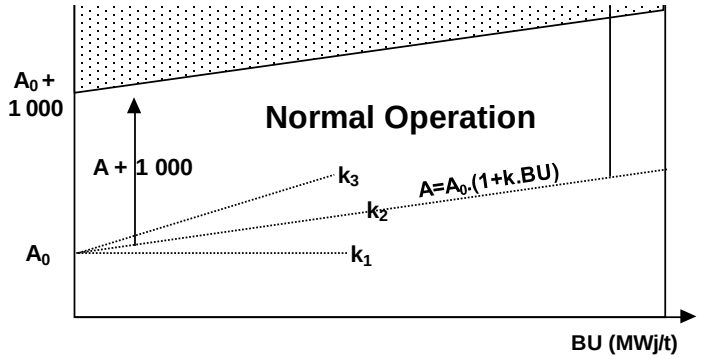
- At EDF/DPN, the **1st step of the alpha risk management**, from a radiation protection point of view, is the following:

ALPHA POTENTIAL RISK if :

- Act (^{134}I) > A+1000 MBq/t (1300 MWe series), A+2000 MBq/t (N4 and 900 MWe series) (= fissile material dissemination risk), **or**
- α.G > 1 Bq/l, or
- The previous outage was at alpha risk

A = A0 + k.BU

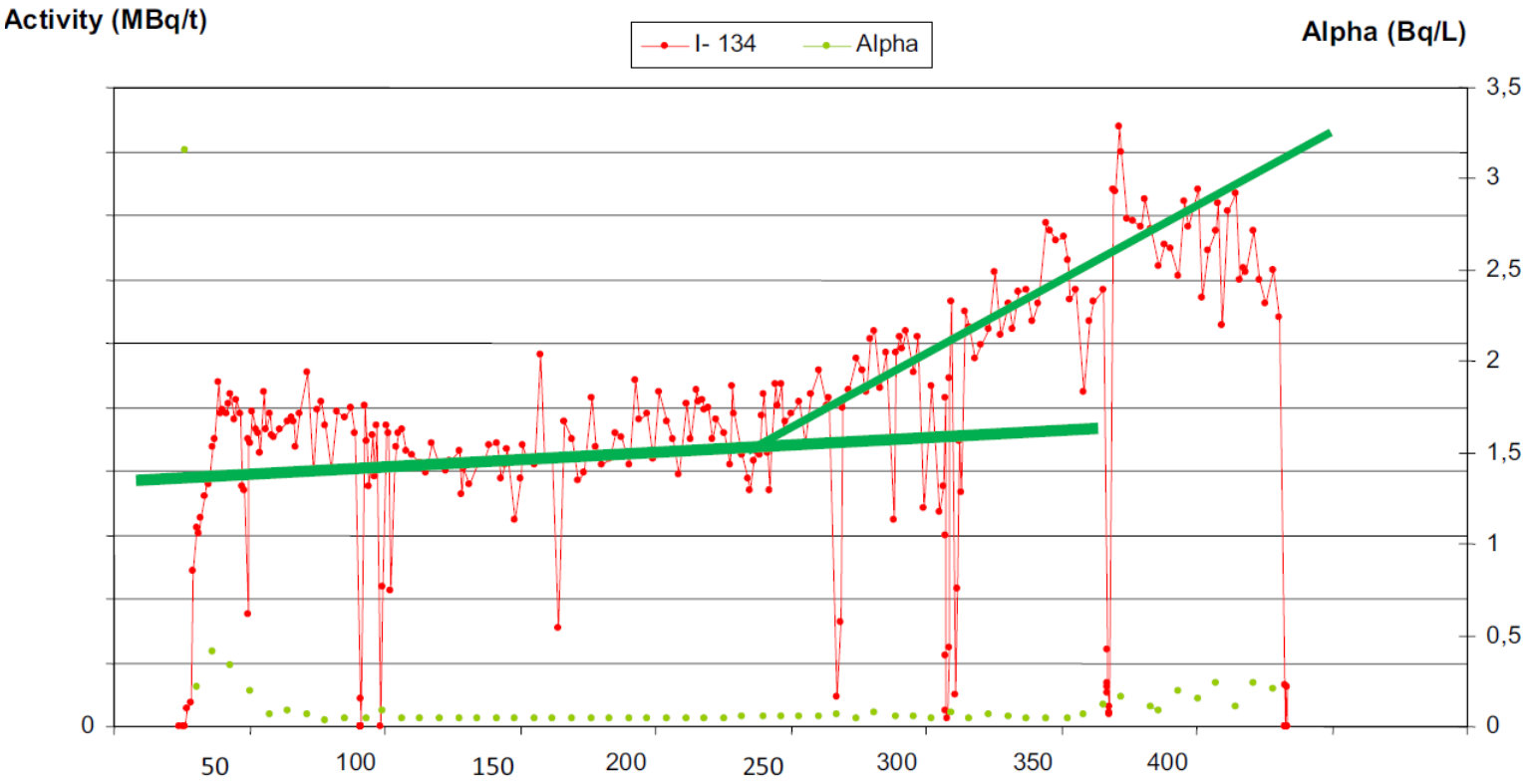
Remaining alpha activity



1. PRIMARY ACTIVITY MONITORING (3/3)

- ^{134}I specific activity: a better indicator than gross alpha activity
  - Significant shift of the slope of ^{134}I activity in comparison with the linear evolution expected

  → Representative of a fuel dissemination



2. RCS MEASUREMENTS AT THE BEGINNING OF THE OUTAGE TO ASSESS THE ALPHA RISK (1/2)

- In which situation ?
  - EDF/DPN: unit at alpha potential risk
  - Engie, CGN: confirmation of fuel rod failure
  - Dominion, CEZ, Forsmark and Leibstadt NPPs: systematically

- What kind of measurements ?
  - **Swipes (most of the cases): from 10 to 100 cm²** (EDF/DPN: 100 cm²)
    - Counting (Engie, Forsmark, Cernavoda)
    - Gamma and/or alpha spectrometry (Dominion, Cernavoda)
  - **Oxyde grinding** (Leibstadt NPP) for gamma and alpha spectrometry
  - **Primary coolant sampling** (CEZ): alpha spectrometry

- Where ?
  - Under the vessel head (Engie, EDF)
  - Manhole of the pressurizer (EDF)
  - On the vessel or RCS
  - Areas which are going to be visited
  - Systems (with primary water) to be opened

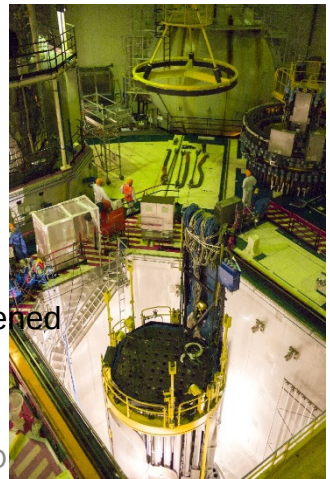


Photo © Christel SASSO

- Which criteria to report the outage at Alpha risk ?
  - Alpha surface contamination above :
    - **8 Bq/cm²: CGN, EDF**
    - **20 Bq/cm²: Engie Electrabel**
  - Contamination above a specific threshold for each alpha emitter : Leibstadt NPP

Radionuclide	Surface act. (Bq/cm²)
^{242}Cm	100
^{241}Am	3

- Comparison of the βγ/α ratio to a threshold value (as recommanded by the EPRI Guidelines): Dominion — βγ/α
- Comparison of the β/α ratio to a threshold value : Cernavoda NPP — β/α
- Comparison of the βγ and the α values to thresholds: Forsmark NPP — βγ and α

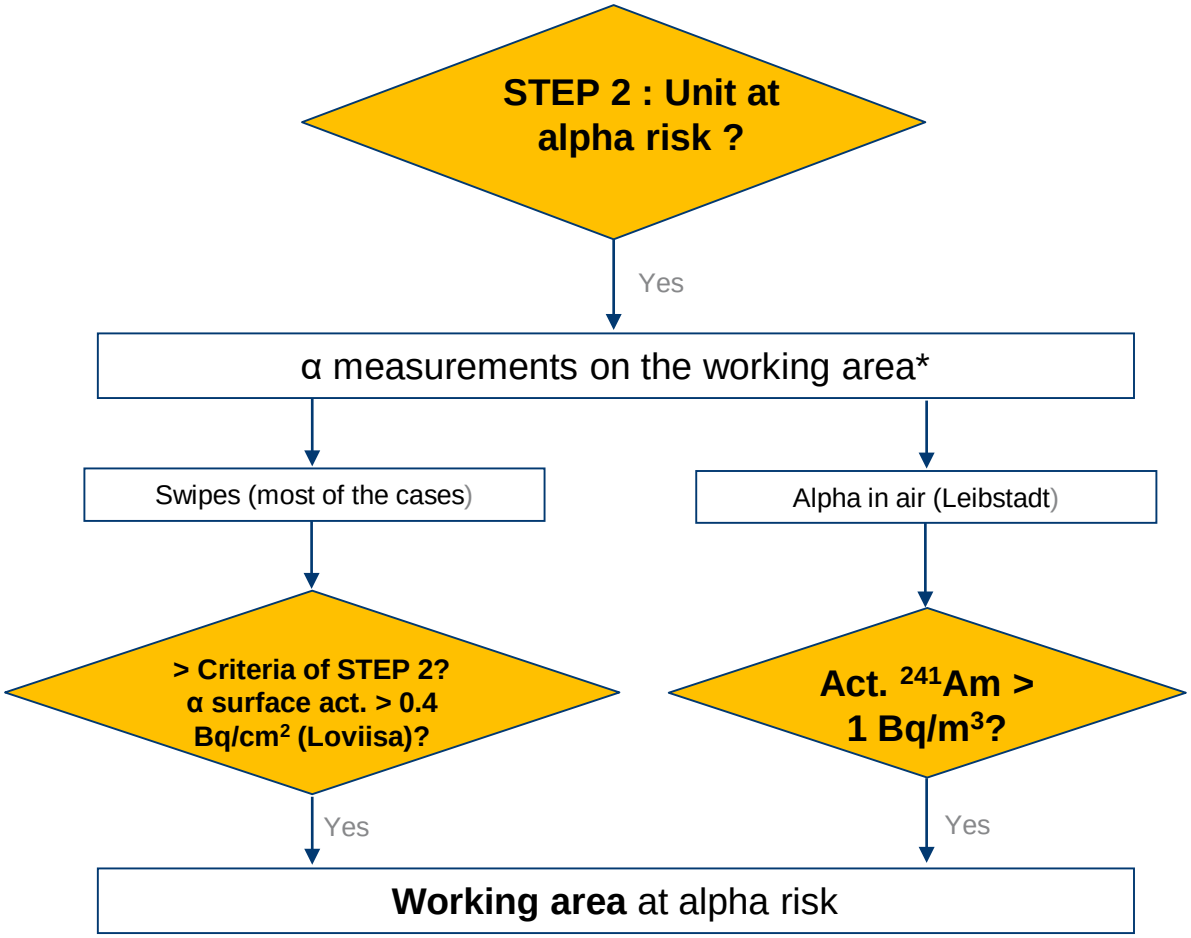
2. RCS MEASUREMENTS AT THE BEGINNING OF THE OUTAGE TO ASSESS THE ALPHA RISK (2/2)

- At EDF/DPN, if the unit is at « alpha risk », working area at « alpha presence » are identified.

→ 4 types:

- **A type** : elevated risk of dispersion of alpha contamination (inside contaminated capacities, diam. > 400 mm, abrasive works)
  - Works into the channel heads of the SG, inspection of the control rod mechanisms, jobs on the vessel mating surface, valve maintenance, RHRS heat exchanger water box inspection, opening/closing of the PZR, material decontamination, jobs in the pool bottom (empty pool), jobs on the ventilation systems,…
- **B type** : medium risk of dispersion (diameter < 400 mm)
  - Valve maintenance with 25 < diameter < 400 mm, inspection of the RCP seals
- **C type** : low risk of dispersion
  - Valve maintenance with diameter < 25 mm
- **D type** : no risk of dispersion.

3. ALPHA MEASUREMENTS AT THE WORKING AREA AT THE BEGINNING OF THE OUTAGE

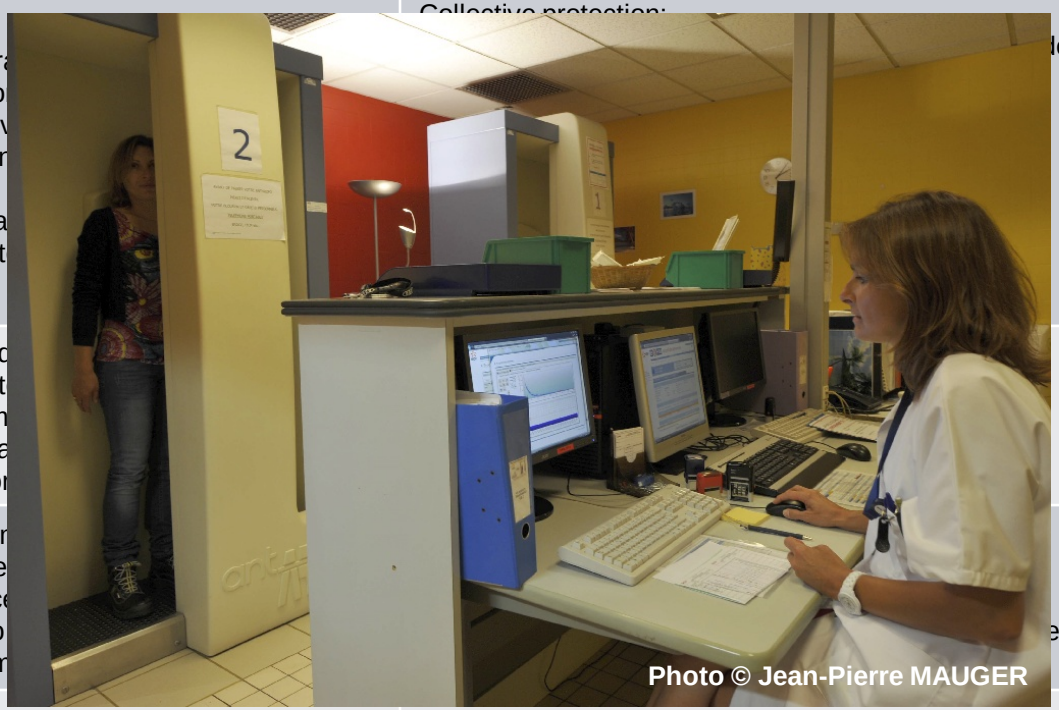


*Leibstadt: … except if we can be sure, thanks to the gamma measurement (^{60}Co), that the alpha limit won't be reached

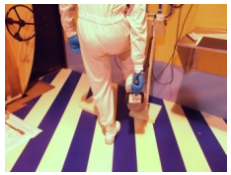
- At EDF/DPN, the working area is said to be at "alpha presence"

4. PROTECTION MEANS AND INDIVIDUAL MONITORING: EDF APPROACH

Type of activity	Criteria	Prevention and protection means	Medical monitoring
A : high risk of alpha contamination dispersion	Penetra compo Abrasiv elemer …) Interna diamet	Collective protection: …device	- Nasal smears (nose blow) of the workers at the end of the day *If positive results:* - Anthropogammametry - Complementary radiotoxicological exams (under medical advice)
B : medium risk of alpha contamination dispersion	Limitec diamet Dynam evacua the wo		
C : low risk of alpha contamination dispersion	Very lir (diame Surfac lead to contam	…eded	
D : no risk of alpha contamination dispersion	Work in wet environment or in wtaer Loose alpha surface contamination < 8 Bq/cm^2	Personal protection: - Basic clothing - Disposable clothing to prevent from water	None



4. INDIVIDUAL MONITORING



- Detection of an alpha intake

	α surface contamination	βγ surface contamination	Anthropogam-mametry	Excreta
Engie Electrabel		> 1 Bq/cm²		X
Dominion	If βγ/α < 50		X*	If α dose > 1 mSv
Loviisa	> 0.2 Bq/cm² (skin) > 0.4 Bq/cm² (clothes)			
CEZ		> 0.3 Bq/cm²	X	
Cernavoda			> 50-80 Bq (^{60}Co)	
Sizewell B	ND			
Forsmark		> 3.5 Bq/cm²	> 2000 Bq (^{60}Co) > 0,25 mSv **	
Leibstadt		X	kind of…	
CGN	> 0.2 Bq/cm² (skin) > 0.4 Bq/cm² (clothes)		> 200 Bq (^{60}Co)	

To confirm an alpha contamination suspicion

* if air sampling results show a suspected intake of α+β+γ emitting radioactivity equal or greater than 4 DAC-hours or 0.2% ALI within a 7 consecutive days

** first value: committed dose calculated ; second value: alpha dose recorded

- Job scaling factor (anthropogammametry) : Dominion, Cernavoda, Forsmark

CONCLUSION

- **This inquiry shows a quite similar approach among the respondents to manage the alpha risk, from a fuel defect/dissemination to the individual monitoring.**

- **The inquiry shows also at each step of the approach a wide variety of indicators and criteria:**
  - Radioisotopes in the primary coolant to detect a fuel defect/dissemination,
  - Criteria to identify the outage or the working area at alpha risk: gross alpha with various thresholds, alpha spectrometry with threshold for each radionuclide, βγ/α ratio, β/α ratio, …
  - Criteria related to the individual monitoring, …

α risk management: a common global strategy but different ways to implement it

Would be useful to benchmark in depth the practices to identify the best ones

Thank you

APPENDIX 1

- **Step 1 (Primary activity monitoring) : WANO Fuel Reliability Indicator**

$$FRI = \left[(A_{131)})_N - k(A_{134})_N \right] \left[\left(\frac{L_N}{LHGR} \right) \left(\frac{100}{P_0} \right) \right]^{1.5}$$

where:

FRI	=	Average steady-state primary coolant I-131 activity, µCi/g, corrected for tramp uranium, and normalized to a common purification rate and LGHR.
$(A_{131})_N$	=	Average primary coolant steady-state I-131 concentration normalized to a purification constant of 2E-5 s^{-1}, µCi/g
$(A_{134})_N$	=	Average primary coolant steady-state I-134 concentration normalized to a purification constant of 2E-5 s^{-1}, µCi/g
k	=	Tramp correction coefficient. (A constant of 0.0318. This coefficient essentially is the recoil ratio of I-131 to I-134 assuming a 30% U-235 and 70% Pu-239 fission source.)
L_N	=	Linear heat generation rate used for normalization, 5.5 kW/ft
LHGR	=	Actual average linear heat generation rate at 100% power, kW/ft
P_o	=	Average reactor power in percent at time activities were measured

APPENDIX 2

- **Steps 2 and 3 (alpha measurements) : comparison of the criteria**

  - **Dominion : use of the EPRI guidelines* values**

The guidelines recommend that plant areas and systems be classified according to the abundance of loose alpha contamination relative to the presence of loose beta-gamma contamination

Table A-1
Area Action Level Matrix

	Level I Areas (Minimal)	Level II Areas (Significant)	Level III Areas (Elevated)
Activity Ratio[1,2] (βγ/α)	>30,000	30,000 – 300	<300

**EPRI Alpha Monitoring and Control Guidelines for Operating Nuclear Power Stations, Revision 2.* EPRI, Palo Alto, CA: 2013. 3002000409.

  - **Cernavoda NPP**

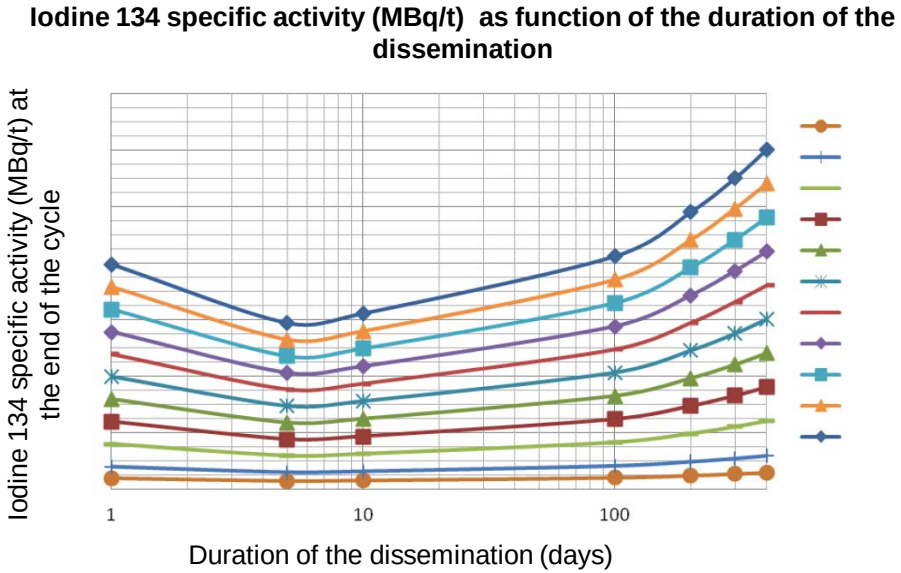
β/α ratio	Minimum risk	Medium risk	Elevated risk
	> 15 000	15 000 > … > 150	< 150

  - **Forsmark NPP**

β-γ activity And α activity	Minimum risk	Medium risk	Elevated risk
	βγ < 4 Bq/cm^2 and α < 0.4 Bq/cm^2	4 < βγ < 100 Bq/cm^2 and 0.4 < α < 10 Bq/cm^2	βγ > 100 Bq/cm^2 and α > 10 Bq/cm^2

APPENDIX 3

- Example of abacus elaborated with the OSCAR code to assess the amount of fissile material disseminated from the iodine 134 specific activity measurement

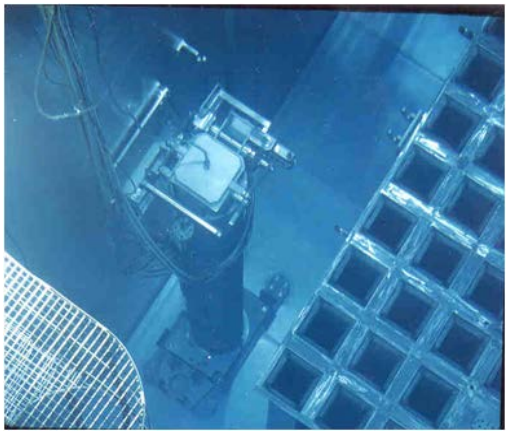


Continuous dissemination from a 2nd cycle fuel assembly

APPENDIX 4: FUEL SIPPING

- Complementarily to the primary coolant monitoring, fuel assembly inspections during the outage are performed to assess the fuel tighness …
  - In case of (suspicion of) cladding failure, 6 out of 9 utilities/NPPs (Engie Electrabel, CEZ, Sizewell B, Forsmark, Leibstadt, CGN) use the “fuel sipping” technic.
  - Dominion and Loviisa mention also a fuel scanning/inspection in case of fuel defect.

- At EDF, the fuel sipping is aimed at monitoring the 1st barrier integrity but is not *stricto sensu* part of the 3 monitoring levels of the alpha risk…



4.1 PREVENTION & PROTECTION MEANS

- **Zoning and signaling:**
  - Barriers, « rubber areas » (rubber-soled shoes), signaling (e.g.: In the EPRI guidelines, systematic signaling for high alpha risk area (β/α<300))
- **Information and training**
- **Collective protection means:**
  - Lockairs with vacuum generating device and HEPA filter
  - Gamma and bêta air radiation monitor
  - Control of worker devices at the exit of the working area
  - Adhesive surfaces, water spray, …
  - Down draft step off pads
  - Fixation of contamination on protective equipment (lacquer)
- **Examples of personal protection means:**
  - Overboots, vinyl gloves, protective clothing,…
  - Disposable clothing
  - Respiratory protection
- **Examples of personal protection means:**
  - Assistance with removal of protective clothing

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4.2 FIELD MONITORING

- **Means quoted by the respondents:**
  - **Air radiation monitoring** (not specific to the alpha risk): Engie Electrabel, Cernavoda
  - **Swipes**: Engie, Dominion, Leibstadt NPP, Forsmark, Sizewell B
  - **Air sampling**: Leibstadt NPP, Dominion, Sizewell B
  - **Lapel Personnal air sampling**: Dominion (level III or high alpha risk)
  - **Nasal smears (nose blow)**: Engie Electrabel
  - **Alpha material contamination control**: Dominion (if βγ/α ratio < 50)

STEP 4 (PREVENTION AND PROTECTION MEANS, FIELD AND INDIVIDUAL MONITORING): EDF/DPN APPROACH

- **Information:** The unit informs the workers (including external service providers') regarding the state of the unit, the risks on the working area, the prevention and protection means, the organization to be implemented

- **Training**: The workers are trained to the job

- **Signaling**: The working area at "alpha presence" are indicated

- **Monitoring of the working area**: β/α ratio, monitoring of the transit lanes (Contamination has to be < 4 Bq/cm^2 in β and < 0.4 Bq/cm^2 in α ; size of the swipes: 300 cm^2), alpha beta airborne activity monitor on the working area (evacuation if α > 0.25 Bq/m^3) and at the exit of the working place, alpha surface contamination monitor (threshold : 0.4 Bq/cm^2)…

- **Organization**: The list of the workers is updated every day
- **At the end of the job**: tools used on working area at "alpha presence" have to be decontaminated (limit = 0.4 Bq/cm^2)

- **Anthropogammametry**: at the end of the job and if an alpha contamination is suspected