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Recycling facility Periodic Safety Review

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Engineering & Projects Organization

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1. Periodic Safety Review

- A **legal requirement**

  "The licensee of a nuclear installation carries out a safety reassessment of its facility periodically, [...]. The periodic safety review should occur every ten years."

  French Environmental Code

- **A two-step process**
  1. **A review of the facility's conformity with its reference safety frame**
  2. **A safety reassessment for each risk taking into account the state of the art**

» **Which methodology do we have to choose to achieve the criticality part of a PSR ?**

» **Methodology designed for UP3-A Periodic Safety Review**

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2. UP3-A, a recycling facility

Some of the process steps	Fissile materials	Pieces of equipment
Receiving, unloading and storage used fuels	$(U+Pu)O_2$ in used fuels	Fuel assemblies baskets
Dissolution	$(U+Pu)O_2$ in nitric solution	Dissolvers
Clarification	Undissolved $(U+Pu)O_2$	Centrifugal Clarifier
PF, Pu and U separation	(U+Pu) in nitric solution	Pulsed columns, mixer-settlers, annular vessels…
Pu purification	Pu nitrate	Pulsed columns, mixer-settlers, annular vessels…
Oxide conversion	PuO_2F_2, PuO_2	Precipitators, filter, calciner…
Hulls and end-pieces compacting and storage	$(U+Pu)O_2$ in hulls	Hulls containers in storage

- **UP3-A is characterized by a large variety of process and pieces of equipment (geometrically safe or favorable)**
- **A full-scale approach of the UP3-A criticality safety reassessment is it the best methodology for such a facility ?**

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3. PSR methodology

- **Purpose of the proposed PSR methodology**
  - To have an overall view of the safety frame, especially of the criticality calculation notes
  - To focus the resources on the Nuclear Criticality Safety issues

- **A three-step methodology**
  1. Evaluation of impacts, on nuclear criticality-safety studies, of conformity review, aging effects, and state of the art of criticality calculations
  2. Identification of sensitive systems from the above evaluated impacts and safety margins
  3. Additional studies for sensitive systems

Methodology designed for geometrically safe or favorable pieces of equipment optionally combined with a neutron absorber

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4. Step 1: Impacts evaluation on the safety frame
4.1. Conformity review

- **Purpose of a conformity review**

  To verify that the actual pieces of equipment are consistent with the design safety requirements of the reference safety frame

- **NCSDT : a key document for the conformity review**
  - **Released for each equipment before commissioning**
  - **Ensures that the criticality modelling bounds reality**

- **Process of a conformity review**
  1. **Comparison of "as built" dimensions and corrosion allowances to NCSDT information**
  2. **If discrepancies are highlighted, NCSDT are updated and possible non-compliances to criticality-safety requirements are highlighted**
  3. **To be solved, the highlighted non-compliances are inputs for the step 2 of the PSR Methodology**

4. Step 1: Impacts evaluation on the safety frame
4.2. Aging effects analysis

- **Purpose of aging analysis effects**

  To study how aging mechanisms involved can affect the safety functions of an equipment during an average operation period at least consistent with the plant's future operations

- **Aging effects analysis : a sharp analysis**
  - **Performing an inventory of the design features, the operating conditions and their historical changes for each equipment**
  - **Identification of aging effect involved**
  - **Rating of aging effect mechanism knowledge**
- **Action plans can be define to support aging effects analysis and prevent future non-compliances**
- **Possible future non-compliances are inputs for the step 2 of the PSR Methodology**

4. Step 1: Impacts evaluation on the safety frame
4.3. Criticality calculations' state of the art

- **Definition of criticality calculations' state of the art**
  - The latest best technical practices
  - The latest criticality codes or packages including V&V reports
- **Discrepancies between UP3-A criticality calculations notes and the current state of the art**
  - Pu isotopic composition
  - Density laws of actinide nitrates
  - Water content in concrete
  - The CRISTAL package

4. Step 1: Impacts evaluation on the safety frame
4.3.a. Pu isotopic composition

- Recycling Pu isotopic mass composition historically used for UP3-A design

83 % Pu^{239} / 17 % Pu^{240}
with {Hansen & Roach} or {JEF1/CEA86 + APOLLO1} χ-sections

- Recycling Pu isotopic mass composition currently used

71 % Pu^{239} / 17 % Pu^{240} / 11 % Pu^{241} / 1 % Pu^{242}
with {JEF 2.2/CEA93/V6 + APOLLO2} χ-sections

» For all UP3-A criticality calculations notes, a generic bias, $\Delta k_{eff}(Pu)$, bounding impacts on k_{eff} due to evolutions from historical to current Pu isotopic mass composition is evaluated

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4. Step 1: Impacts evaluation on the safety frame
4.3.b. Density law of actinide nitrates

- **Density laws of actinide nitrates have been evolving since the design stage of UP3-A**

- **The density law of actinide nitrates considered in CRISTAL V1.2 package is the one known as isopiestic law**

» **For all UP3-A criticality calculations notes, a generic bias, Δk_{eff}(nitrates), bounding impacts on k_{eff} due to evolutions from old actinide nitrates density laws to the isopiestic one is evaluated**

4. Step 1: Impacts evaluation on the safety frame
4.3.c. Water content in concrete

- **For the UP3-A design stage, the concrete was modeled by a Portland concrete with a 8,93 wt. % of water**

- **The water content value in concrete leading to a maximum k_{eff} value depends on**
  - **the kind of configuration studied**
  - **the concrete composition modeling**

» **The current best practice to model the water content in concrete is to determine for each configuration the optimum water content value**

» **For all UP3-A criticality calculations notes, a generic bias, Δk_{eff}(concrete), bounding impacts on k_{eff} due to evolutions from old water content in concrete hypotheses to the current best practice is evaluated**

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4. Step 1: Impacts evaluation on the safety frame
4.3.d. CRISTAL Package

- **Some of the criticality codes / packages used during the UP3-A design stage**

- **CRISTAL V1.2, the current state of the art of CRISTAL Package**

X-sections library for fissile media	X-sections library for non fissile media	k_{eff} calculation code
APOLLO2 V2.5.5 / CEA93.V6	APOLLO2 V2.5.5 / CEA93.V6	APOLLO2 (Sn-keff)
		APOLLO2 (Sn-Normes)
		MORET 4 V4.B.4
JEF 2.2	JEF 2.2	TRIPOLI-4.4

» **For all UP3-A criticality calculations performed with old codes / packages, a generic bias, Δk_{eff}(code), bounding impacts on k_{eff} due to evolutions from old codes / packages to the current state of the art is evaluated**

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5. Step 2: Identification of sensitive systems
5.1. Margins of safety

- **The modeling margins: qualitative margins related to differences between**
  - **The fissile media characteristics**
  - **The geometry modeling**

  and
  - **The reality**

- **The calculation margins: quantitative margins related to differences between**
  - **the maximal reactivity of the conservative configuration ($(k_{eff} + 3\sigma)_{max}$ or k_{eff})**

  and
  - **the Nuclear Criticality Safety Acceptance Criterion (NCSAC)**

$\Delta k_{eff}(\text{margin}) = \text{NCSAC} - (k_{eff} + 3\sigma)_{max}$, for a Monte Carlo calculation

or $\Delta k_{eff}(\text{margin}) = \text{NCSAC} - k_{eff}$, for a deterministic calculation

5. Step 2: Identification of sensitive systems
5.2. Identification methodology

1. **Determination of the calculation hypotheses of the conservative configurations**

2. **Evaluation, for each conservative configurations, of a state of the art bias, Δ_{SOTA}**

$$\Delta_{SOTA} = NCSAC - [(k_{eff} + 3\sigma)max + \Delta k_{eff}(concrete) + \Delta k_{eff}(Pu) + \Delta k_{eff}(nitrates) + \Delta k_{eff}(code) + \Delta k_{eff}(margin)]$$

3. **Identification of sensitive systems**

If

- $\Delta_{SOTA} \geq K$
- **Geometrical hypotheses of calculation note bound conformity and ageing studies conclusions**

» **The studied system is not a sensitive system**

» **For all other cases, a further analysis is conducted, taking into account qualitative margins. Following this analysis, the safety engineer decides if the system is to be considered as a sensitive one**

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6. Step 3: Complementary studies for sensitive systems

- **For sensitive systems, calculation notes are updated taking into account**
  - **the state of the art of criticality calculations**
  - **the geometrical hypotheses by taking the conclusions of conformity and ageing studies**
- **If the NCSAC is still not respected, new hypotheses such as process or geometrical hypotheses could have to be considered**

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- **The proposed PSR methodology allows at the same time**
  1. **To have an overall view of the safety frame, especially criticality calculation notes**
  2. **To focus the resources on the Nuclear Criticality Safety issues**

- **Key points to achieve successfully the criticality part of a PSR**
  - **A deep knowledge about the facility by the criticality safety engineers**
  - **A close collaboration with the operator**

- **The current application of this methodology on the UP3 safety frame shows that there's no major impact of conformity, aging studies and state of the art on UP3 criticality calculation notes conclusions**

» **Anticipation of future evolutions by engineering teams during the UP3 design stages**

Some of the criticality codes / packages used during the UP3-A design stage

Package	X-sections library for fissile media	X-sections library for non fissile media	k_{eff} calculation code
-	HANSEN & ROACH	HANSEN & ROACH	DTF IV
-	HANSEN & ROACH	HANSEN & ROACH	MORET I / II
-	APOLLO1 / CEA86	HANSEN & ROACH	MORET I / II / III
SCALE 4	ENDF-BIV	ENDF-BIV	KENO Va
CRISTAL V1.2	APOLLO2 V2.4.3 / CEA93.V4	APOLLO2 V2.4.3 / CEA93.V4	APOLLO2 (Sn-k_{eff})
	APOLLO2 V2.4.3 / CEA93.V4	APOLLO2 V2.4.3 / CEA93.V4	APOLLO2 (Sn-Normes)
CRISTAL V0.2	APOLLO2 V2.4.3 / CEA93.V4	APOLLO2 V2.4.3 / CEA93.V4	MORET 4 V4.A.6
CRISTAL V1.0	APOLLO2 V2.5.4 / CEA93.V6	APOLLO2 V2.5.4 / CEA93.V6	MORET 4 V4.B.2