Radiation Protection in the design of the Flamanville 3 EPR

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CHANGER L'ÉNERGIE ENSEMBLE

Contents

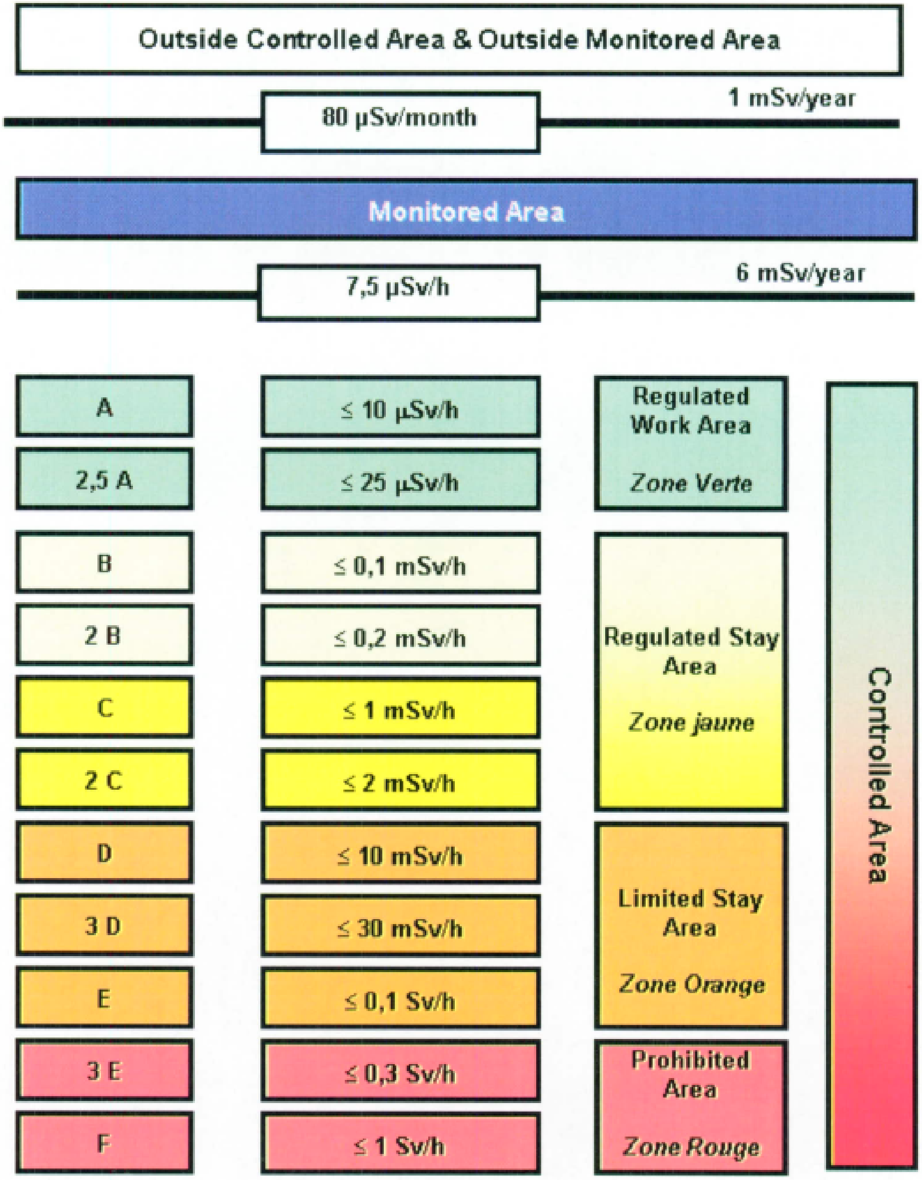
1. Introduction

The designers:

- **consider the radiation protection at the Safety level,**
- **place the EPR plant in a step of progress compared to the best French nuclear plants**
  - Layout and civil work requirements regarding Radiation Protection
  - Use of the good performances of existing plants and of operational feedback
  - Dose optimisation for the most exposed activities and workers
- **allow the operator to work in the Reactor Building during power operation**
  - In order to improve the plant availability while complying scrupulously with the radiation protection rules

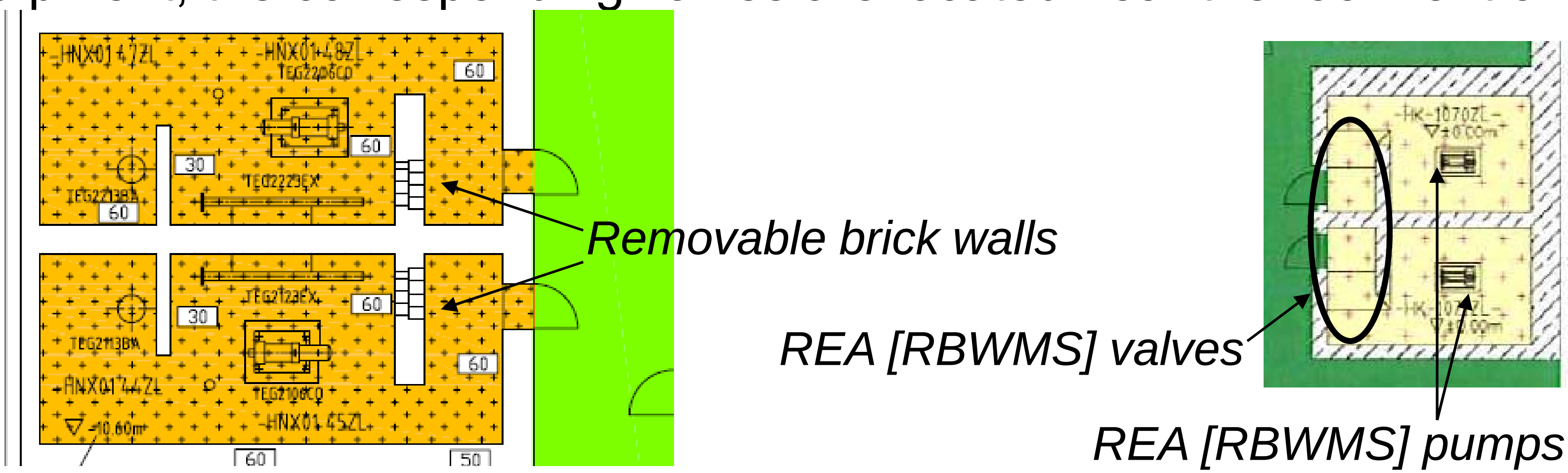
2. General layout requirements: zoning

- French Regulatory exposure limits:
  - 20 mSv over 12 consecutive months for A classified workers,
  - 6 mSv over 12 consecutive months for B classified workers
- French Regulatory radiation protection zoning



2. General layout requirements

- Encasement of active equipment,
- Good accessibility to equipment requiring regular maintenance,
- Shielding mazes or shielding doors shall be foreseen to access to active equipment, the corresponding valves are located near the room entrance



- Sufficient space is foreseen for:
  - A low dose area to prepare and monitor the activities,
  - Maintenance of the equipment in the buildings,

2. General layout requirements: dose limits

- Hot lab in Operation Building: 7.5 µSv/hr

- Sampling laboratories in Nuclear Auxiliary Building and frequent passageways (corridors, staircases): 10 µSv/hr

- 25 µSv/hr limit for:
  - Access to working areas, safety exits, control valves rooms
  - Edge of the spent fuel pit in the Fuel Building
  - Reactor building at shutdown: edge of the refuelling cavity

- Reactor building at power, accessible area
  - Neutron dose rate: 2.5 µSv/hr,
  - Effective dose rate: 25 µSv/hr

3. ALARA at the design stage (1/6): approach

Reference collective dose

↓

Design evolutions of the EPR concerning Radiation Protection

- Source Term
- Dose rates
- Exposed time

EPR Initial Dose Assessment

↓

Priority to activities with high dose level (contributing to more than 50 % of collective dose) :

- Thermal insulation
- Opening and closing reactor vessel
- Steam generator controls
- Logistics
- Primary Valves
- Spent fuel Evacuation
- Waste Conditioning

↓

EPR optimised collective dose

O P T I M I s A T I O N

3. ALARA at the design stage (2/6): approach

High-dose activities selection:

- Thermal insulation removal and reinstallation
- Site logistics
- RCP, RCV, RIS/RRA [RCS, CVCS, SIS/RHRS] valves

} **High exposed workers**

- Reactor pressure vessel opening/closing
- Fuel evacuation

} **High collective dosimetry**

- SG preparation and tests

} **High dose rate activity**

- Waste conditioning

} **Radiological cleanliness**

50 % of the collective dose

3. ALARA at the design stage (3/6): reference dose

- The reference dose is based on:
  - The operational feedback,
  - Dose statistics of the best French nuclear plants in operation

- Recent plants: P'4 (newest 1300 MWe) and N4 (1450 MWe)
  - 18-month cycle
  - Averaged over 10 years
  - Outages cycle:
    - 3 Normal Refuelling Outages (NRO)
    - 2 Refuelling Only Outages (ROO)
    - 1 10-year outage

➔ 0.44 Man.mSv/year/unit

3. ALARA at the design stage (4/6): initial dose

- Source term
  - Significant reduction of stellites™ amount in valves and RPV internals
  - Optimisation of the main primary chemistry

    ➔ global profit of 15% in the dose rate

- Dose rates reduction
  - Pressurizer spray lines separated from pressure relief valves by a concrete shielding
  - Reduction of «hot point traps»

- Exposed time limitation
  - Fast mounting thermal insulation
  - Optimisation of steam generator channel head
  - Use of valves with modular maintenance

➔ 0.36 Man.mSv/year/unit

3. ALARA at the design stage (5/6): optimised dose

- Thermal insulation removal and reinstallation
  - Thermal insulation and pipe identification
  - Operation with water in the pipes

- Site Logistics
  - Fast mounting/dismounting scaffolding
  - Fix platform around SG manhole, handhole and eyehole

- RCP, RCV, RIS/RRA Valves
  - Limitation of Stellite™ amount
  - Improvement of valves tightness: double leak tightness barrier

- Reactor pressure vessel opening/closing
  - Core internals handling under water
  - Dedicated zone for the vessel header storage

3. ALARA at the design stage (6/6): optimised dose

- SG preparation and tests
  - Fast mounting nozzle dams
  - Increase of the primary/secondary manholes diameters

- Waste conditioning
  - Waste selection near their production location
  - Possibility to check the waste conformity in the NAB

- Fuel evacuation
  - Help for the fuel trolley positioning

+ Access in the Reactor Building during power operation

OPTIMISATION

Reference collective dose — 0.44 Man.Sv/yr/unit

Design evolutions of the EPR concerning Radiation Protection
- Source Term
- Dose rates
- Exposed time

EPR Initial Dose Assessment — 0.36 Man.Sv/yr/unit

Priority to activities with high dose level (contributing to more than 50 % of collective dose) :

- Thermal insulation
- Opening and closing reactor vessel
- Steam generator controls
- Logistics
- Primary Valves
- Spent fuel Evacuation
- Waste Conditioning

EPR collective dose = 0.35 Man.Sv/yr/unit

4. Cleanliness/waste consideration

- Basis concept: controlled zone ≠ contaminated zone

- Goals
  - To get a radiological cleanliness at the best international operators level
  - To adapt the protection to the contamination risk identified where the action takes place and limit the contamination at its source
  - To facilitate the access and working conditions in the controlled zone
  - Be a mean of progress in the plant cleanliness: the zoning has to be maintained

- At the design stage,
  - It required a general contamination view:
    - Identification of the nuclear / conventional areas (N vs K) ➔ Regulatory
    - Evaluation of the contamination level in the nuclear areas (Np, N1, N2)

  } Cleanliness/waste zoning

  - It led to requirements regarding:
    - Ventilation routing
    - Contamination containment
    - Operators access

⚠ The Cleanliness/waste zoning is a tool for the plant design. The operator can apply it or not.

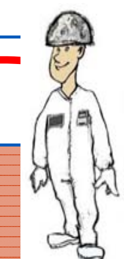
Methodology:

1. Classification of each room based on: the systems installed, the actions to be performed, the waste produced…

2. Evaluation of the overall building level to have a consistent zoning with the operation: routing from the less contaminated to the most

3. Implementation of contamination barriers

Zone	Conventional waste zone	Nuclear waste zone		
Waste zoning	Conventional: K	Nuclear: N		
Cleanliness zoning	K Conventional	Np Nuclear clean	N1 Nuclear slightly contaminated	N2 Nuclear contaminated
Room surface contamination (Bq/cm²)	< 0.4 No neutron flux	< 0.4	0.4 < conta.< 4	> 4
Cleaning and control	Cleaning program Cleanliness periodic tests program			No cleaning and test program

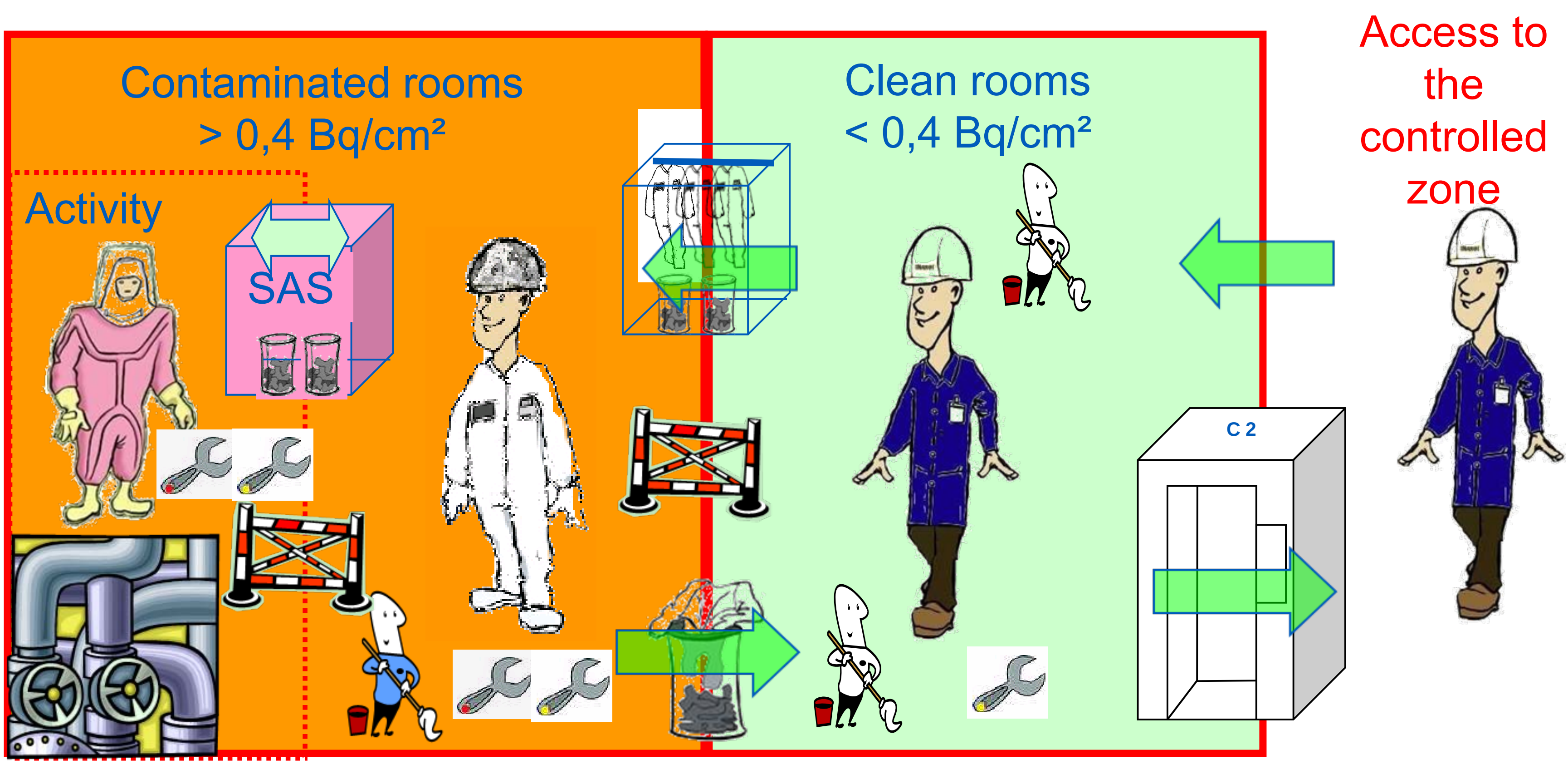


Clean

Contamination barrier

No-clean

4. Cleanliness/waste consideration



All the EPR rooms have a cleanliness/waste classification

4. Cleanliness/waste consideration

- Reactor in operation
  - « in blue » access to K and Np zones, including the RB accessible area
  - Over clothes put at the N1 and N2 contamination barriers
- Reactor at shutdown
  - The reactor building is N1 or N2
  - The over clothes for activities in the RB are taken in the Access tower and completed at the RB entrance
  - The over clothes are left at the RB exit
- The « in-blue » access is reversible:
  - « cold » changing rooms kept in the Operation Building
  - « hot » changing rooms operate (level -2)
  - all the devices and systems are foreseen, the ventilation is designed as for « in-white » access, decontamination showers are implemented

5. Conclusion

The Flamanville 3 EPR designers considered:

- the radiation protection Regulatory requirements
- specific radiation protection requirements
- the ALARA approach
- the contamination containment and limitation

to place the EPR into an evolutionary approach

FA3, general view

FA3: Reactor Building

FA3: pumping station

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Thanks for your attention