THE EPR RADIATION PROTECTION STAKES

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Abstract

As part of the **EPR (European Pressurized Reactor) project** being deployed at Flamanville, EDF has proactively made the decision to focus on Radiation Protection (RP) aspects right from the start of the design phase, as it has done with nuclear safety. The RP target set by EDF for this new reactor is to engage in an effort of continuous improvement and optimisation, through benchmarking with the best French and German practices and the best performing plants of the French fleet. The approach adopted for managing RP-significant activities has been to include all involved stakeholders – designers, licensee and contractor companies – in the three successive phases, starting with a survey among workers and designers, followed by a proposal review, and finally ending with the decision-making phase entrusted to an ALARA committee. Efforts have focused on two parameters factored into dose calculation : dose rate and work volume exposed to radiation. The main RP design upgrades are improvements upon the most recent N4 plant series. This optimisation has resulted in a saving of 21 % when comparing the reference dose with the optimised EPR dose. The collective dose target is currently set at 0.35 man.Sv / year per unit, as an average over ten years for a 18-months equilibrium fuel cycle and including two Refuelling Only Outages (ROO), three NRO (Normal Refuelling Outage) and one ten-year refuelling outage (which is mainly used by EDF for implementing material modifications on its NPPs). To improve the plant availability, a new challenge has been set for work performed in the reactor building during normal reactor operation. Logistical arrangements for forthcoming jobs will be performed 7 days prior to shutting down the reactor and 3 days afterwards. For this purpose, two areas have been set up in the EPR's reactor building: one no-go area containing the primary circuit equipments, and one accessible area for normal operations, separated from the no-go area by purpose-built ventilation equipment and facilities. To offer protection against radioactive flux (neutrons and high energy rays), the first RP studies have identified the need of installing nuclear shielding at the outlets of primary circuit pipes. Steam generator bunkers and pumps also need specific reinforcement. All these measures will ensure that the accessible area can be posted as a green area (dose rate < 25 µSv/h), with a neutron dose rate of less than 2.5 µSv/h. In order to ensure radiological cleanliness, contamination must be contained as close to the source as possible on working units. A specific zoning is defined which enables the generation of conventional waste from radiologically controlled area and therefore the reduction of the quantity of nuclear waste produced during plant operation but also while dismantling. Moreover, as contamination controls will be performed at the exit of each potentially contaminated area (contamination barriers), the risk of contamination spread will be reduced.
As a strategic priority for the EDF Group, Radiation Protection is gradually becoming less and less confined to the happy few, and is becoming a cross-functional area where multi-disciplinary team work is of paramount importance from the very start of the design phase.

Key words : EPR, radiation protection, optimisation, zoning

1 - INTRODUCTION

EDF has decided to take Radiation Protection into account in the design phase of the Flamanville EPR project, as it is done with Safety. To meet this objective, the different aspects of Radiation Protection (RP) have been considered, from individual and collective dose uptake to radiological cleanliness for all the cycle life of the reactor (during operation, outage and for deconstruction).
Therefore, the EPR project takes into account the experience feedback of the French nuclear fleet in operation (figure 1).
The approach adopted to deal with activities with high Radiation Protection stakes has integrated all the concerned trades : designers, operators, workers. The first step was a technical investigation with designers and operators about possible improving solutions, which consisted in interrogating the concerned worker groups about their jobs, their experience feedback and the possible profits on their activities. The second step implicated the designers who analysed the results of the first step in order to define the requirements to apply and to evaluate the possibility of their integration (cost / benefit evaluation). At least, the third step consisted in creating an ALARA committee, composed of officials for design and operation, in order to validate the proposed solutions and to evaluate the optimised provisional dose of the EPR. This paper presents the EPR assets regarding this approach and the main options retained for the detailed design phase.

2 – THE MAIN RADIATION PROTECTION STAKES OF THE EPR

The Radiation Protection objectives that EDF adopted for this new reactor are :

- to bring a demonstration of the EPR Radiation Protection optimisation,
- to place the EPR in a step of progress compared to the best French nuclear plants
- to fix the dose objectives taking into account the good performances of the existing French plants :
    - collective dose objective set to 0,35 man.Sv / y per unit
    - dose uptake optimisation for the most exposed groups of workers (Figure 2)
- to perform work in the reactor building (RB) during power operation to improve the plant availability whiling scrupulously with Radiation Protection rules
- to obtain a level of radiological cleanliness similar to the best international nuclear operators. For that :
    - taking into account the cleanliness / waste zoning in the design phase,
    - minimization of the nuclear waste volume by orienting more waste into the conventional waste treatment,
    - making easier the access into the controlled area by adapting the protective clothes to the contamination of the rooms,
- to make easier the deconstruction operations.

3 – THE EPR OPTIMISATION APPROACH

Beyond an ambitious dose objective, the EPR optimisation approach (Figure 3) must also as a priority benefit to the most exposed worker groups (for example : thermal insulation, welders). The other activities with a high Radiation Protection stake are the activities performed during outage (opening / closing reactor vessel, Steam Generators controls, primary valve maintenance) and some additional specific activities as the spent fuel evacuation and the waste conditioning. As the final dose uptake is the result of the multiplication of the dose rate by the exposed time, three improvement axis have been defined :

- reducing the primary source term which has an influence on the overall dosimetry,
- reducing the local source terms which are more related to some specific equipments (“hot points”) and
- reducing the amount of the exposed time under ionising radiation.

The applied method complies with the ALARA principles and relies on the available Radiation Protection data and on the experience feedback (data and good practices) of the French fleet in operation. This approach allows to set a collective dose reference value to 0,44 man.Sv / y per unit, taking into account the best French fleet results. Starting from this value, the value of 0,37 man.Sv / y per unit is obtained through the source term optimisation and 0,35 man.Sv / y per unit is the dose objective after optimisation of the activities with high level regarding Radiation Protection and representing around 50 % of the collective dose (figure 3).

Note : the dose mentioned here are dose calculations performed for normalized 18-month fuel cycles, averaged over 10 years and taking into account 3 Normal Refuelling Outage (NRO), 2 Refuelling Only

Outages (ROO) and 1 ten-year outage (which are mainly used by EDF for implementing material modifications on its NPPs).

4 – MAIN DEPARTURES FROM N4 NUCLEAR POWER PLANTS

To improve the dose uptake, the two parameters constituting the dose calculation are concerned : the dose rate levels and the exposed time.
For the EPR, the main design evolutions from the newest existing French nuclear plants (N4) and concerning the Radiation Protection are :

- for the dose rates optimisation :
  - significant reduction of the use of the Stellites^{TM} (main Co60 source term) especially in primary valves and in reactor internal structures,
  - optimisation of the main primary circuit chemistry (with purification optimisation and high flowrate purification during shutdown),
  - reduction of the hot point traps in design,
  - optimisation of the layout (equipment separation according to their estimated dose rate level) : as example on the pressurizer, separation of the spray lines from the pressure relief valves by a concrete floor, which allows dosimetric gain during pressure relief valves maintenance,
  - adaptation of the civil works and ventilation systems for performing activities in the reactor building during reactor power operation.
- For the exposed time :
  - Equipment optimisation allowing to reduce the exposed time : improvement of the steam generator channel head shape and increase of its manhole diameter, Control Rod Drive Mechanism and pressurizer heaters with bolted connections (instead of welded), modular maintenance valves….
  - Rupture break preclusion on the primary branches which allows to reduce the amount of anti-whipping equipments to control,
  - Improvement of the working environment conditions (lighting, fast mounting / dismantling thermal insulation – Figure 5, adapted handling means…).

5 - REACTOR BUILDING ACCESSIBILITY DURING POWER OPERATION

The possibility to enter the Reactor Building (RB) during the reactor power operation is an important stake for the plant availability. On EPR, it is envisaged to access the reactor building 7 days before the outage and 3 days after for anticipating some outage activities and preparing the logistics of the maintenance operations.

During power operation, the main radioactive sources are Nitrogen-16 (gamma rays emitter) and Nitrogen-17 (neutrons emitter) and the core (neutrons and gamma rays emitter).

The overall design arrangement makes the RB accessibility easier by limiting the rays and neutrons leaks from the primary circuit area to the others parts of the building. Some openings are still necessary in the internal walls to allow the RB ventilation and also for safety reasons, which induces the need of specific biological protections.

5.1 – Risk of internal exposure – two rooms concept

During power operation, radioactive particles are in suspension in the RB atmosphere : their quantity is linked to the non collected primary leaks. This conduced to the creation of two zones in the RB of the EPR : one no-go area containing the main primary circuit equipments and an accessible area, which is separated from the other area by specific ventilation means (figure 6).

5.2 – Risk of external exposure – biological protections

During power operation, the neutrons and the high energy rays are emitted by the reactor vessel and the primary circuit : part of them flee through the steam generators and primary pumps bunkers. Without any specific arrangement (as it is on existing French NPPs), the dose rates at the RB pool level and in the annular space would be to high to allow any human activities during the reactor operation.
The Radiation Protection studies have led to the followings :

- 1,20 m concrete floor above the RB pool,
- additional gamma and neutron shielding equipments,
- reinforcement of SG and primary pumps bunkers.

These arrangement shall induce a green area classification of the accessible area (total dose rate level lower than 25 µSv / h) with a neutron dose rate lower than 2,5 µSv / h.

6 – THE RADIOLOGICAL CLEANLINESS FOR FLAMANVILLE 3

The cleanliness quest consists in confining contamination as close to the source as possible. Flamanville 3 EPR will be submitted to these requirements upon receipt of the nuclear fuel on site.

6.1 – CLEANLINESS / WASTE ZONING

The objectives of the cleanliness zoning are essentially :

- to allow production of conventional waste from controlled area and therefore minimise the quantity of nuclear waste,
- to reduce the quantity of nuclear waste during dismantling operations,
- to reduce the number of areas with contamination risks and therefore to avoid any contamination transfer outside the buildings.

The room classification is defined as follow (see also figure 8) :

- **K** applies to an area where the produced waste are conventional. No contamination.
- **NP** applies to an area with the same level of radiological cleanliness than the K area (no contamination) but the produced waste must be considered as nuclear.
- **N1** applies to an area where surface contamination is likely to occur,
- **N2** applies to an area where contamination is likely to occur and where cleaning programs can not be rigorously applied.

To reduce the contamination transfer risks, a particular attention is paid to the air transfers and to the frontiers between clean and unclean areas :

- the air transfer must come from the clean areas to the unclean areas,
- the frontiers between [K or NP] areas and [N1 or N2] areas must be equipped with contamination barriers.

6.2 – ENTRANCE TO CONTROLLED AREA IN “BLUE CLOTHING”

One particularity of the EPR will be to allow entrance to controlled area in blue clothing (as opposed to the white clothing usually used in the controlled area). The objective is to facilitate the access to the controlled area and to reduce the time waste in the changing rooms.

This approach is very linked to the cleanliness zoning as the access “in blue” is allowed in all the K and NP areas.

The access to a N1 or N2 area is possible after adding specific over-clothes which are adapted to the contamination of the area : the over-clothes are available near the contamination barrier, at the entrance of the area. On exit, they must be taken off at the contamination barrier where radiological controls are performed.

7 – SOURCE TERM REDUCTION

An optimisation of the source term reduction was required. The result of this optimisation lead to a reduction of stellites in valves, and in RPV internals, using Konvoi experience. The activity reduction will be of about 30 %, leading to a dose reduction of about 15 %

8 – CONCLUSION

As a strategic priority for the EDF Group, Radiation Protection is gradually becoming less and less confined to the happy few, and is becoming a cross-functional area where multi-disciplinary team work is of paramount importance from the very start of the design phase.

The EPR radiation protection approach

- is similar to the method used in safety, with objectives to fulfil and associated demonstrations
- is focused on the most exposed workers as the thermal insulation workers or the people in charge of steam generator or valve maintenance
- Takes part in the improvement of the plant availability
- Implies a large involvement of many trades specialists to succeed,

and therefore constitutes an important stake of the EPR Project.

Figure 1 : Performance of French nuclear plants – Evolution of collective dose per reactor (Men.Sv per year) for 15 years.
Note : for 18-months fuel cycles.

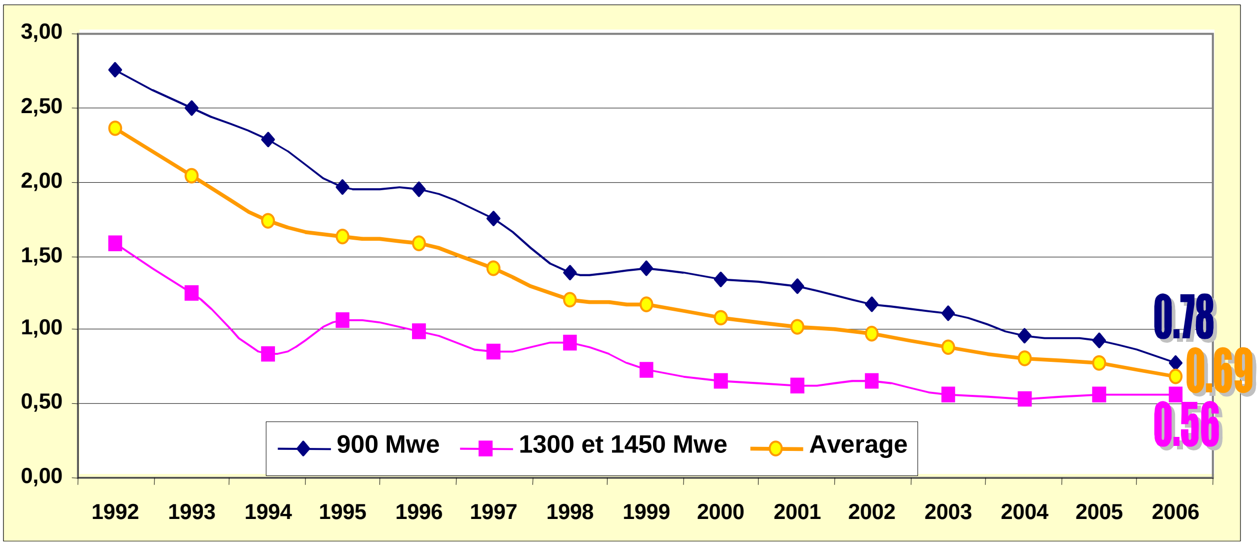


Figure 2 : Optimisation and Evolution of average individual doses per speciality (Thermal Insulation, Checkers, Welders, Mechanics, Logistics…)

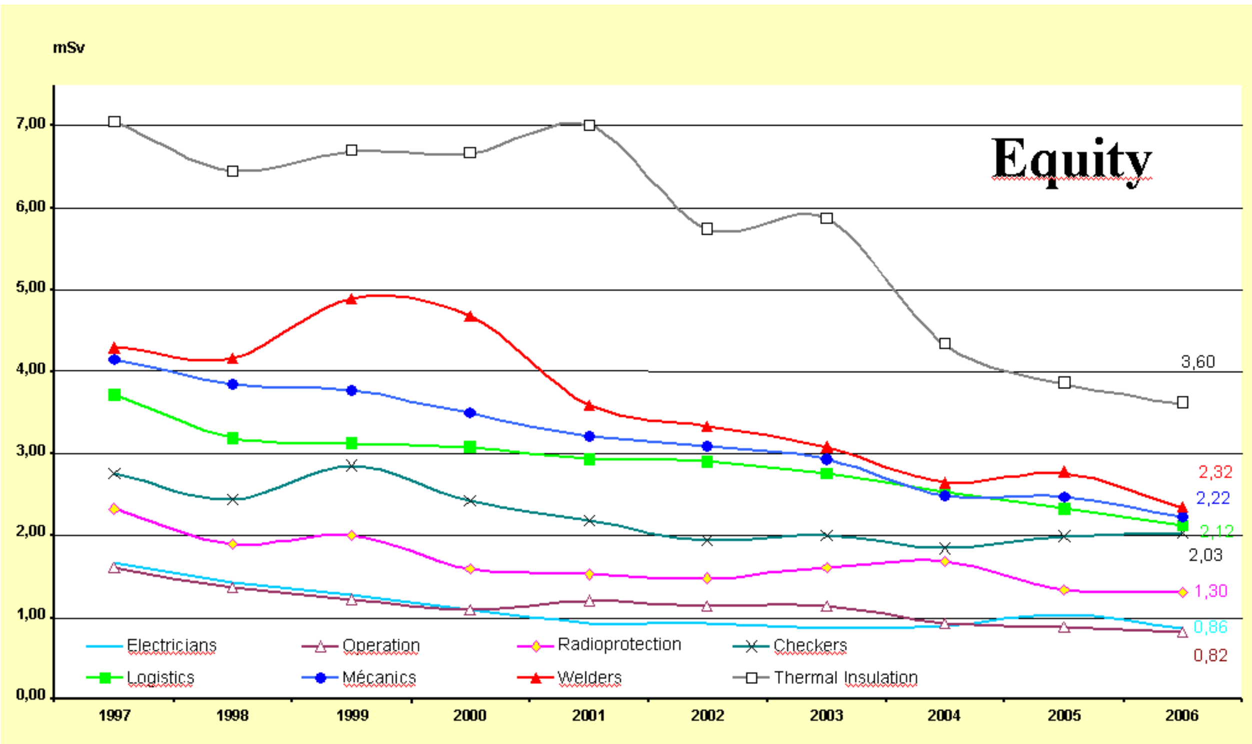


Figure 3 : the step of optimisation

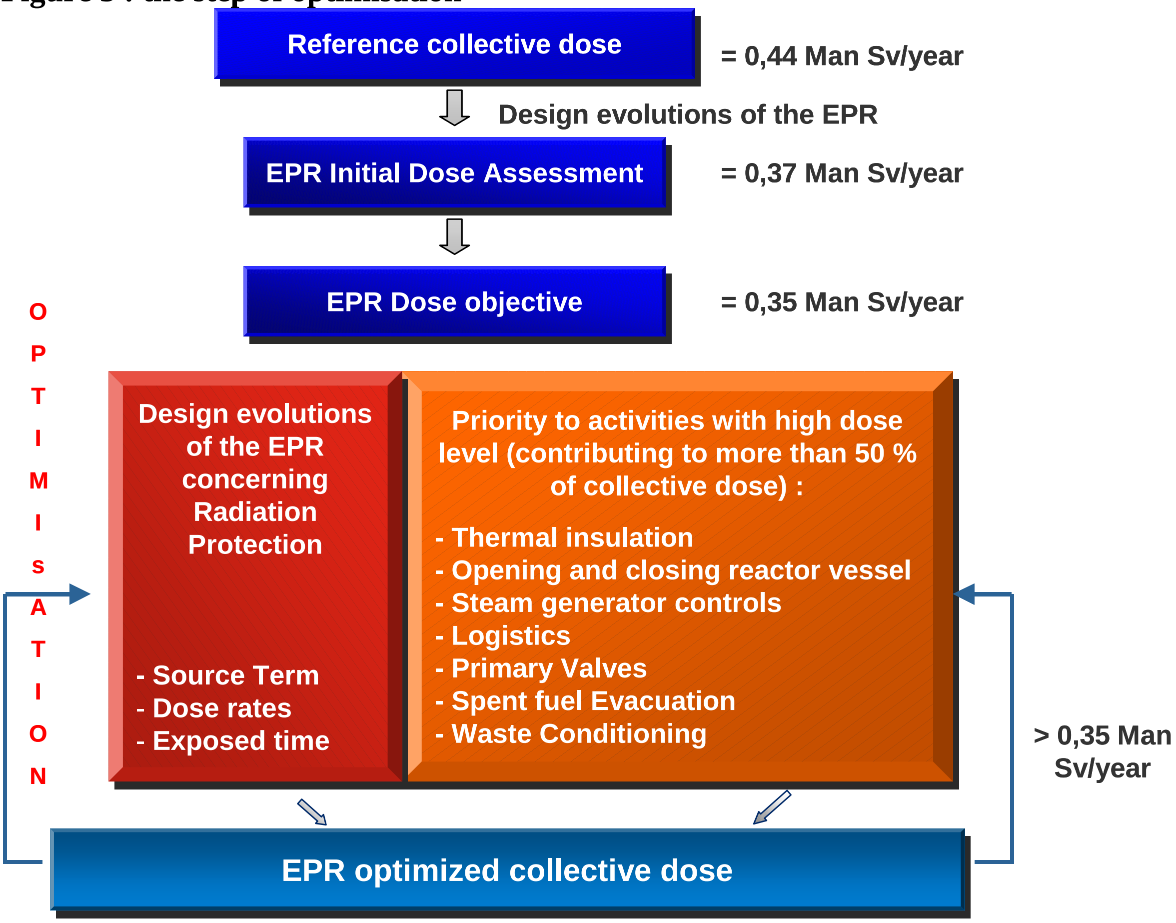


Figure 4 : modular maintenance valve → gain of 30 % on the valve maintenance dose

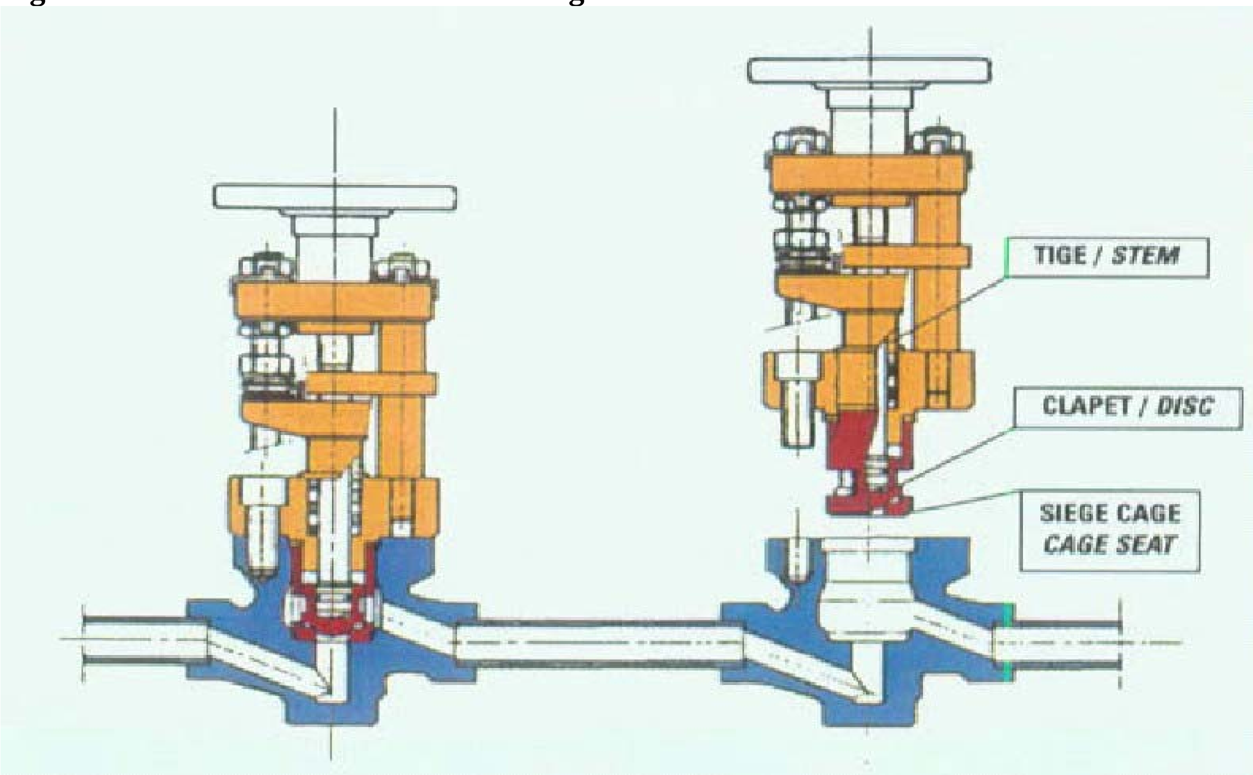
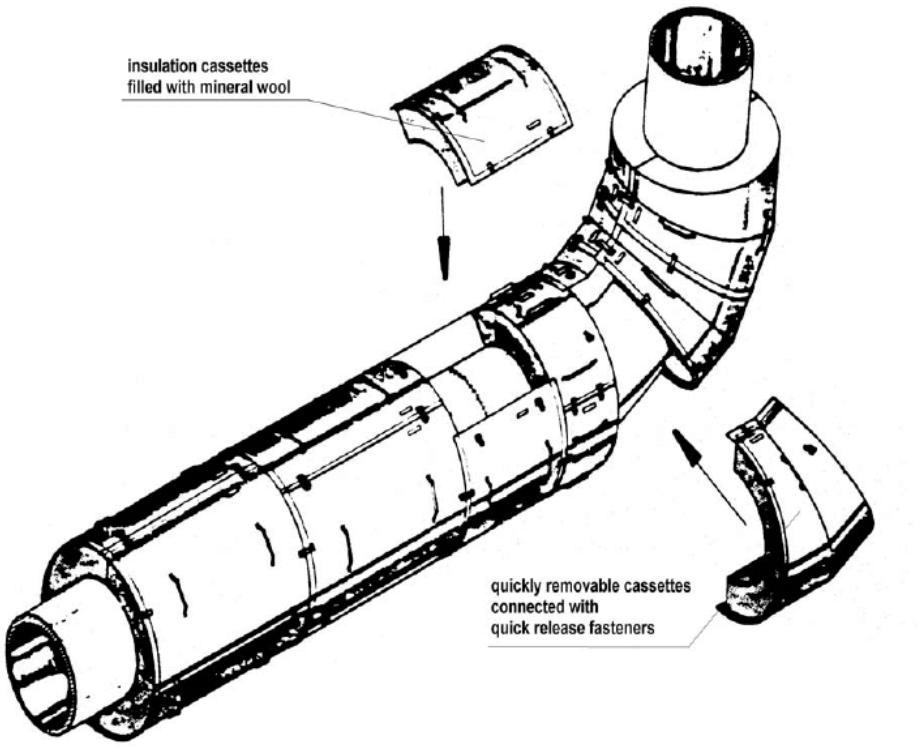


Figure 5 : Use of Heat insulator with fast use involve a profit of about 30% on the insulating



activity

Figure 6 : Reactor Building accessibility during power operation – Two rooms concept (green = accessible area ; red = non accessible area)

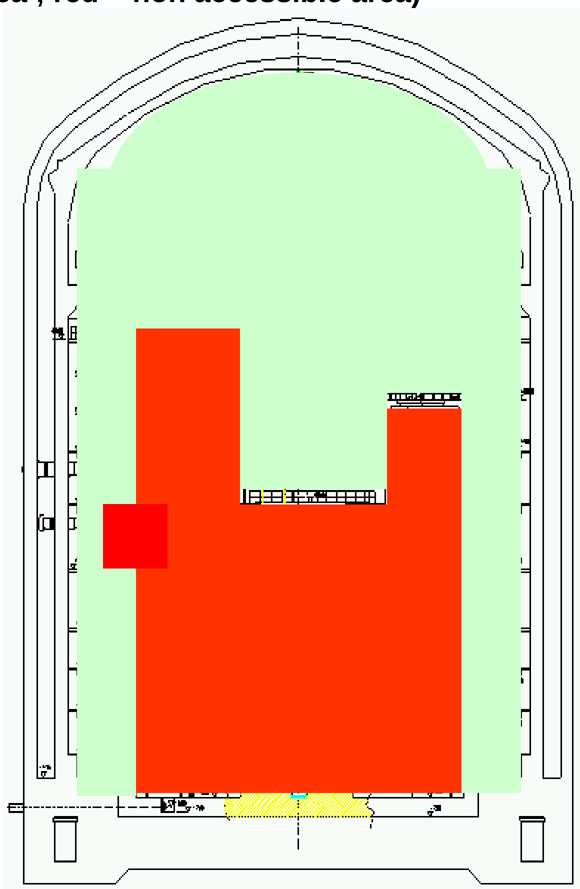


Figure 7 : cleanliness zoning in design

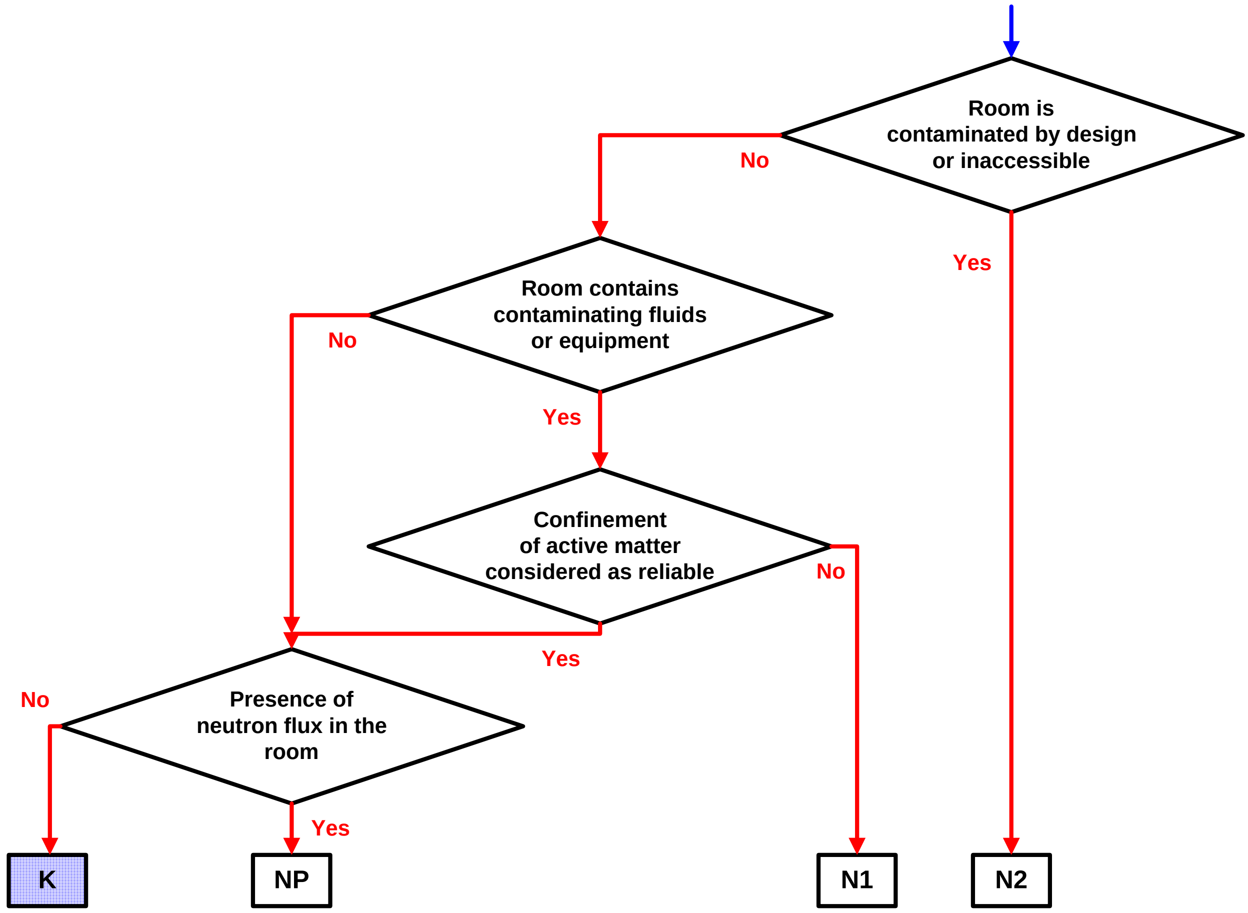


Figure 8 : cleanliness and waste zoning

Zoning	Conventional waste zone	Nuclear waste zone		
Waste zoning	Conventional : K	Nuclear : N		
Cleanliness zoning	Conventional	NP Nuclear clean	N1 Nuclear Low-level contamination	N2 Nuclear High-level contamination
Surface contamination (Bq/cm²)	< 0.4 No neutronic flux	< 0.4	0.4 < conta.< 4	> 4
Cleaning and control	Cleaning program Periodic cleanliness monitoring program			No cleaning and monitoring program

« Clean » « Unclean »