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02	PCSR June 2009 update: - Inclusion of references, - Clarification of text, - Inclusion of design modifications for steam generator.	23.06.09
03	Consolidated Step 4 PCSR update: - Minor editorial changes, - Inclusion of references, - Section 2.3.1.1: addition of the 15% value for the source term improvement, - Removal of section 2.3.1.3 (Design developments being considered), - Section 2.3.1.4 is changed to section 2.3.1.3, clarification of the access to the reactor building during operation and addition of the dose uptake linked with activities in the reactor building in operation, - Section 2.3.2: correction of the EDPO definition, - Sections 2.3.2.1 to 2.3.2.7: update of the text taking into account validated modifications and dose improvements, - Section 3: update of the final EDPO.	27.03.11
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SUB-CHAPTER 12.4 - DOSE UPTAKE OPTIMISATION

1. GENERAL

The EPR dose optimisation approach aims at:

- setting radiological protection demands at the same level as those for safety, achieving an optimisation approach to radiological protection similar to that applied for safety,
- including the EPR reactor in an improvement process in relation to the best units currently operated in France, updating the EPR dose targets in line with the continuous performance improvements of these units,
- reducing the dose uptake of the most exposed groups by optimising actions of the workers groups that have the highest individual and/or collective dose uptake,
- improving the unit availability by allowing operators to enter the reactor building during power operation, while still complying with radiological protection and conventional safety rules.

In order to meet these objectives:

- optimisation studies were mainly based on recent operational feedback from the best operating units (individual dose uptake aspects, collective dose uptake, and good practices),
- the designers were the centre of the optimisation approach,
- the EPR was given an ambitious collective dose target: 0.35 man.Sv per year per unit, averaged over ten years,
- the EPR activities optimised first and foremost were those concerning the most exposed groups.

Exchange of information (documents, on-site meetings) with operating power plants and support from the organisations responsible for radiological protection have likewise allowed the designer to adopt significant best practices and specific lessons learned from the former.

German operational experience based on the design of the Konvoi units was also used for the design of specific EPR operations.

This sub-chapter describes the design measures adopted in the EPR to optimise operator dose in normal plant operations, and gives predictions for the level of collective doses expected to be achieved. The dose received by individual workers is also considered and assessed against the target for an individual worker adopted as a Safety Design Objective for the UK EPR.

2. EPR DOSE UPTAKE PREDICTION

The ALARA approach adopted for EPR design studies aims at giving the maximum benefit to the most exposed worker groups. The approach gives confidence that the ambitious collective dose target can be met, setting out the EPR design in an improvement approach compared with the best units of the French operating fleet (see Sub-chapter 12.4 - Figure 1).

2.1. METHOD

The method proposed for the detailed EPR dose prediction analysis consists in:

- collecting dose uptake statistics from French N4 and P'4 NPPs starting with the NCAD[1] codes from the best units [Ref-1], supplemented with data for maintenance, and with the data from the German facilities, for the EPR operations similar to that of the Konvoi (e.g. aeroballs maintenance),
- selecting high priority activities during outages and in operation for radiation protection optimisation, giving priority to high dose activities, and involving the designer in the optimisation initiative,
- achieving the EPR dose uptake prediction from the concatenation of available NCAD codes, taking into account the type of outage,
- deriving the annual collective EPR dose prediction over a ten years cycle.

The optimisation process is schematised on Sub-chapter 12.4 - Figure 1. In accordance with the ALARA approach, it enables iteration on the choice of activities to be optimised and on the EPR features that have an impact on radiological protection.

The method [Ref-2] used to estimate dose uptakes in the design stage of the EPR project considers that the EPR:

- is an industrial facility (to be differentiated from medical or laboratory installations),
- is in its design phase and as a result no operational feedback is available for this type of reactor.

Estimating dose uptake increases or reductions remains a complex and challenging exercise because:

- the number of exposure hours is very significant,
- the number of workers is high during an outage,
- the dose rates can vary widely depending on the water levels in the various systems,
- operation depends on the chosen design, particularly with regard to radiological protection,

[1] NCAD: New Framework for Dosimetry Analysis – NCAD code is unique and corresponds both to an elementary activity performed by a worker in a controlled area and to the access code for this worker in the controlled area.

- plant outage durations are shorter for the EPR than for the existing French NPPs and some shut-down preparation activities are carried out during power operation.

The objectives of the exercise are:

- to meet regulatory requirements,
- to provide qualitative arguments when quantitative benefits cannot be estimated,
- to involve the design teams (materials, installation, operation) in the cross-disciplinary subjects as radiological protection, human factors, and conventional safety.

2.2. ESTABLISHING THE REFERENCE DOSE

The reference dose is determined from recent statistical values for the best performing French units.

2.2.1. Assumptions

The following assumptions are made to establish the reference dose:

- use of the best up-to-date dose statistics from the recent French units (2001 to 2003, respectively; P'4[2] and N4[3] series [Ref-1]),
- 18-month EPR fuel cycle,
- dose averaged over ten years (outage cycle considered: NRO-ROO-NRO-ROO-NRO-ISIO) and including the 10 year refuelling outage (ISIO).

Dose values are classified according to the type of outage: ROO (Refuelling Only Outage), NRO (Normal Refuelling Outage), or ISIO (In-Service Inspection Outage); dose statistics for units during power operation have also been incorporated.

2.2.2. Results

Application of the above assumptions and analyses leads to the following results:

1) The calculated reference dose is 0.448 man.Sv per year per unit. This value is close to that achieved at the best operating unit of the French fleet, GOLFECH 2, which has achieved 0.440 man.Sv per year over a full cycle of ten years. The latter value was thus chosen as the reference dose. It was assumed that the percentage distribution of the dose amongst each of the basic activities was that obtained from data for the sixteen best units.

2) The dose distribution per basic activity (as a percentage) was determined considering the different types of outage (ROO, NRO or ISIO) and for the unit in operation.

3) The radiological protection high-priority activities (and the reason for set high priority) [Ref-1] are listed below:

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[2] Golfech (1,2), Belleville (1,2), Nogent (1,2), Penly (1,2), and Cattenom (1,2,3,4)
[3] Chooz (1,2) and Civaux (1,2)

- removal and installation of thermal insulation (operation involving the largest exposed population),
- opening and closing the reactor pressure vessel (high collective dose operation),
- preparation and inspection of SG primary side (high dose-rate worksite),
- site logistics (operation involving highly exposed worker groups),
- RCP [RCS], RCV [CVCS] and RIS/RRA [SIS/RHRS] valves and component maintenance (operations involving highly exposed worker groups),
- waste treatment (operation involving radiological cleanliness),
- spent fuel posting out (high collective dose operation).

These activities represent about 50% of the total annual dose uptake on operating units, (depending on the number of shutdowns a unit performs a year), but they also involve the most exposed worker groups. The results of the optimisation studies for these activities are described in section 2.3.2 of this sub-chapter. The remaining 50% of the total annual dose uptake is spread over a larger number of activities.

2.3. ESTABLISHING THE OPTIMISED DOSE

The optimised dose value is obtained by improving the parameters (source term, dose rate, and amount of exposed work) which contribute to the reference dose.

This section describes:

- the effect the developments implemented in the EPR design have on the dose uptake assessment,
- a summary of dose uptake results from the optimisation study.

2.3.1. Dose uptake assessment for the design developments

The results of the EPR dose uptake assessment for the design developments are given in section 3.

2.3.1.1. Source term and dose rate optimisation

The EPR design source term has been particularly altered by the following design changes:

- optimising the use of Stellite™ (hard-facing material containing cobalt) in the reactor vessel internals [Ref-1] and in the valves; Stellite™ has been removed from almost all the valves in contact with the primary coolant and further improvements are being sought for the reactor internals and the reactor coolant pump, as was achieved on the Konvoi plants;

- pressuriser design:
  - installation of a floor separating the spray and discharge systems at the pressuriser-dome level. This feature reduces the average dose rate, from the spray pipes in the safety valves area. Total dose uptake associated with the maintenance of the pressuriser safety valves is reduced by a minimum factor of 4, depending on the type of work;
  - monitoring the nominal pressure will be done remotely via a special pressurised line;
  - lower part of the pressuriser: the expansion line / pressuriser nozzle thermal sleeve has been modified (inverted nozzle) in order to avoid retention of active particles. Inspection of the pressuriser heaters is facilitated by removing the thermal blanket. The flanged (rather than welded) assembly of the heaters allows quick replacement.
- installation optimisation:
  - separate routing of the RCV [CVCS] pipework from the valves and pumps;
  - RRA [RHRS] operation provided by the RIS [SIS] LHSI in the Safeguard Buildings;
  - Inclusion, in the Reactor Building, of an area entirely dedicated to storing the pressure vessel head (located at +4.45 m above the operating floor, with appropriate shielding).
  - measures to limit "hot spots" in the design: elimination of pipe connections using socket welds, on most pipework carrying radioactive fluids;
  - chemistry optimisation (high flow rate purification);
  - reduction of the amount of chromium and of antimony in the primary pumps,
  - ability to dose zinc into the primary coolant.

The dose improvement associated with the source term is estimated to be 15% for all activities, except activities related to the fuel (e.g. handling and evacuation).

2.3.1.2. Limiting the Amount of Exposed Work

The amount of exposed work (subject to radiation) expected for the EPR project has been reduced in particular by the following design choices:

- large selection of equipment with bolted connections (pressuriser heaters, control rod drive mechanisms),
- increase of primary and secondary manways diameters,
- inclusion of a cylindrical section on SG channel heads (easier access to peripheral tubes),

- ARE [MFWS] line connection point in the cone-shaped shell and installation of a thermal sleeve,
- reactor vessel head heat insulation removable as a single unit,
- absence of a forced ventilation device for the RGL [CRDM]s (eliminating opening and closing operations for the RGL [CRDM] ventilation system air duct),
- improved measuring instrumentation of the reactor vessel level (allowing the elimination of removal and installation operations of the reactor vessel level piping),
- routing of the ex-core instrumentation into the reactor-vessel pit through the pool concrete wall; eliminating the opening and closing operations for the Nuclear Instrumentation system covers at the bottom of the pool,
- similar or even reduced number of large valves (nominal diameter ND > 50) as on the best French NPPs,
- optimisation of the fuel handling operation duration,
- installation of shielding around radiating equipment (shielding, full cavity decontamination, …),
- modular maintenance valves (see section 2.3.2.3 below).

2.3.1.3. Specific features of in-operation interventions

The accessibility of the EPR Reactor Building while the reactor is in operation is a significant characteristic that is scheduled particularly seven days before the reactor shutdown (to prepare the outage) and three days after restart [Ref-1]. The activities during these periods are mainly the start-up and maintenance of equipment (e.g. the polar crane, the refuelling machine), and the preparation and demobilisation of working areas.

Access for recurrent maintenance is also planned while the reactor is in operation, especially for aeroball system maintenance.

- The reactor building accessible areas in operation are the annular spaces above +1.50 m, the service floor level (+19.50m) and the polar crane. The shielding and layout of rooms are designed to ensure an overall effective dose rate (gamma and neutron) below **25 μSv/hr**, and a neutron dose rate below **2.5 μSv/hr**.
- Airborne contamination in the reactor building is due to possible uncollected leakages of primary coolant during power operation. A general design requirement of the ventilation systems aims at protecting personnel against airborne radiological hazards, by reducing to acceptable levels the concentrations of volatile nuclides in the accessible areas. To reach this goal, radiological protection studies (carried out with the designers responsible for ventilation and civil engineering) have demonstrated the need to select a "two-room" concept. A description of how the two-room concept works is given in section 3 of Sub-chapter 12.3. The two-room ventilation system design means that the risk of inhalation is nil.

Based on the shielding provisions and the design of the ventilation system, it is therefore anticipated that the operator accessibility in the Reactor Building during power operation will not have a detrimental impact on worker doses. However, this will need to be confirmed when the operations (including duration and prevailing dose rates) to be carried out in the Reactor Building during power operations are further detailed.

The dose uptake assessment for activities in the reactor building during power operation has been evaluated as 27.1 man.mSv/year.

2.3.2. High-priority activities optimisation results

For the EPR, an optimisation methodology [Ref-1] has been applied to radiological protection high-priority activities by the designers responsible for installation, materials and operation.

Prior to applying the methodology, the results of studies taking into account the proven modifications guaranteed by the EPR design have determined the Initial Predicted Dose Estimate (**EDPI**).

The detailed optimisation studies have led to the validation of new modifications to be implemented. The results of studies considering both the proven modifications and those to be implemented, have established the consolidated Optimised Predicted Dose Estimate **EDPO**) for each activity of the EPR.

2.3.2.1. Thermal Insulation Operations

The "removal and installation of thermal insulation" activity represents between 5 and 7% of the total annual dose for ROO and NRO type outages, and 13% for an ISIO type outage. It is a high dose activity in terms of collective dose as well as individual dose. Indeed, the laggers represent the most exposed worker group on the plant. Optimisation of their individual dose is based on reducing the source term and exposure time rather than increasing operator distance or shielding from the source.

The reference dose for this activity is 30.6 man.mSv/yr/unit. Taking into account the 15% dose improvement linked to the source term, the EDPI calculated is 26 man.mSv/yr/unit.

Validated radiation protection modifications are [Ref-1]:

- Operations with pipes full of water: 35% improvement,
- identification of each elementary thermal insulation piece and its associated pipework: 10% improvement,
- sufficient permanent or supplementary lighting, electrical sockets and air inlets,
- use of fast assembly-disassembly thermal insulation throughout the primary circuit (RCP [RCS]) up to the second isolation valve and throughout the entire main secondary system (MSS): 5% improvement,
- use of fast, independent assembly-disassembly thermal insulation for the SGs, the pressuriser, the welds and sensitive tap points: 5% improvement,
- use of metallic thermal insulation on primary pipes.

Considering the dose benefits which these features introduce, the consolidated Optimised Predicted Dose Estimate (EDPO) is estimated at 16 man.mSv per year per unit, which is a 38% improvement over the Initial Predicted Dose Estimate (EDPI).

2.3.2.2. Worksite logistics

The "worksite logistics" activity consists of a collection of elementary operations:

- installation of change area tenting, security arrangements, equipment preparation and monitoring (breathable air, materials, consumables), ALARA and working conditions support (remote monitoring, radio communications, general lighting…),
- "scaffolding erection and removal" operations,
- "shielding installation and removal" operations, which includes installing and removing supports and shielding devices,
- "nuclear logistics" operations for power operating conditions.

This activity represents between 13% and 16% of the total annual dose depending on the types of outages (ROO, NRO, and ISIO), and 11% of the dose for an operating unit.

It is a high dose activity in terms of collective and individual doses. Logistic personnel represent one of the most exposed worker group, after the laggers.

The reference dose for this activity is 57.2 man.mSv/yr/unit.

Optimisation of the individual dose of this worker group is based on reducing exposed work time and source term [Ref-1]. Taking into account the 15% dose improvement linked to the source term, the EDPI calculated is 48.6 man.mSv/yr/unit.

Apart from the source term, the following measures have already been included in the design:

- permanent platforms installed around the SGs at +5.15 m and +8.70 m,
- decontaminable lead blankets.

Optimising this activity relies on adapting good practices currently used in operating units to the EPR. The modifications considered have been defined from the analysis of these good practices.

The main modifications to optimise logistic operations are:

- taking into account the schedule for the installation and removal of shielding
- installation of fast, movable assembly-disassembly scaffolding around the highest dose uptake activities: improvements of 5% for this operation,
- installation of permanent platforms around the SG eyeholes, handholes, and primary manways openings as well as around the SGs,
- providing fast-assembly/disassembly change area tentings,

- including sufficient lighting (supplementary or permanent), electrical sockets, and air inlets,
- during outage planning considering activities associated with the installation and removal of shields (circuits full of water),
- using containers / flasks designed to remove contaminated material,
- consideration of human factor and of conventional safety measures,
- using appropriate tools defined before the work is launched,
- defining good organisational practices,
- taking into account activities carried out by operation, radiation protection and maintenance personnel with the creation of a radiation protection supervision room,
- developing 3D software in order to familiarise workers with their environment,
- compiling zoning drawings for Non-Destructive Testing (NDT) (e.g. X-ray examinations, eddy current, ultrasound, etc),
- developing a system for managing biological shielding.

Various modifications will be implemented during operation. Identification of these improvements has estimated the dose improvement for logistic activities to be 30% for an ROO type outage, 28% for an NRO type outage and 12% for an ISIO type outage.

The consolidated EDPO is estimated at 38.1 man.mSv per year per unit, the improvement percentage being 21% compared to the EDPI.

The dose improvement generated by the creation of a radiation protection supervision room will also have a positive impact on other activities in addition to worksite logistics.

2.3.2.3. Valve activities

The valves included in the "valve activities" are the RCP [RCS], RCV [CVCS], and RIS/RRA [SIS/RHRS] valves. The activities on these valves represent an average of 8.5% of the total annual dose for units with an ROO type outage, 13% for a NRO type outage, and 12% for an ISIO outage. It is a high dose operation in terms of collective and individual doses.

The RCP-RCV-RIS/RRA [RCS-CVCS-SIS/RHRS] valves activity includes several operations performed during unit outages, mainly in the RCD (core completely unloaded) state.

The reference dose for this activity is 41.5 man.mSv/yr/unit. Taking into account the 15% dose improvement linked to the source term, the EDPI calculated is 35.3 man.mSv/yr/unit.

This RCP-RCV-RIS/RRA [RCS-CVCS-SIS/RHRS] valve activity is complex, due to the technological diversity of the installed valve equipment (gate valves, pressure relief valves, swing check valves…), and due to the range of maintenance activities carried out, such as:

- tightening the press-packing or packing replacement,
- internal valve inspection (visual examinations, dimensional checks…),

- valve-seat grinding,
- complete replacement of the valve.

These operations are diverse in terms of duration, number of workers needed, and types of worker groups involved (fitters, welders, NDT monitoring…).

The direct contact between the workers and the valve they are working on contributes to high absorbed doses.

Furthermore, the environment and accessibility to the valves located in the Reactor Building, have a significant impact on the working conditions and consequently on the workers dose uptake.

The optimisation measures relating to valve activities are the following [Ref-1]:

- Cobalt 60 is found in Stellite™, which is a material used in hard-facing valve sealing surfaces. For all the EPR valves conveying radioactive fluid, Stellite™ is prohibited. Thus, depending on the technologies and suppliers, the valves have a coating of NOREM02 (a material with a cobalt concentration of less than 0.05%), a nickel-based coating or even no coating on certain check-valves.

  Only four valves have sealing surfaces coated with Stellite™. These are the valves fitted to the severe accident relief lines on the pressuriser. However, given the conditions of use, especially the high temperatures, the resistance of NOREM02 is not guaranteed. In addition, there are some Stellite™ deposits on pressuriser relief pilot valves. However, the impact on the source term and the dose rate is limited as these valves are always closed in normal operating conditions.

- Installation of a deck separating spray and relief systems on the pressuriser dome.
- Elimination of screwed-welded body-to-bonnet connections.
- Elimination of pipe seals by means of socket welding, the origin of hot spots on pipework carrying radioactive fluid: seals will be butt-welded, except for bypass-piping (nominal diameter (mm), DN < 15) fitted to gate valves and for leakage-recovery piping (DN < 15).
- Improvement of valve leaktightness: during system design, if the fluid is highly radioactive, bellow-sealed globe valves are specified. Moreover, valves with DN > 50 equipped with a stuffing box (this technology is more sensitive to the risk of leakage at the stem) and conveying radioactive fluid are fitted with a double stuffing box, including a leakage-recovery system.

  In addition, the presence of bellow-seals on some valves also contributes to dose reduction in maintenance operations, such as the repair of stuffing boxes (as the stuffing box suffers less degradation when a bellow is used).

  These measures contribute to radiological cleanliness (limiting leaks, which contaminate the plant) and to a reduction in the amount of exposed work (fewer entries for unplanned repair of leaking valves).

- Installation of globe valves with modular maintenance: all globe valves with DN < 50 and lift check valves are of modular maintenance type, i.e. they are fitted with removable cartridges that house all the valve internals (including the seat).

  Globe valves with DN > 50, are largely of quick-disassembly-type but the seat cannot be removed. Only the high head safety injection valves are fitted with removable cartridges that house all the valve internals (including the seat).

  The dose improvement generated by this design measure is 30%.

- Development of elective maintenance with diagnosis tools: depending on their technology, electrically actuated on-off valves classified F1A, F1B or F2 (see Sub-chapter 3.2) will be fitted with diagnosis tools monitoring the equipment operability and thus reducing the amount of maintenance (fewer regularly scheduled monitoring operations).

- Limitation of the number of the inverted valves: a stop-check valve is installed at the first isolation of the cold leg on the RIS [SIS], allowing a reduction in the number of valves required to drop the primary level down to the invert level.

- Layout measures: mechanical handling is facilitated by the optimised implementation of anchor points for lifting and handling of tools and valve parts. Worksite ergonomics is integrated by providing space around valves, recommending the placement of valves at head height and separating active and slightly active equipment.

- Adaptation of preventive maintenance programmes: RMA (reliability, maintainability and availability) analyses have identified the sensitive issues for each valve technology so that maintenance can be optimised.

- Taking into account the human factors in task design;

- Consideration of the characteristics of the four EPR trains:

  - the EPR is characterised by four trains for safety and support systems; these trains are independent and can be checked separately underwater, hence limiting the dose uptake,

  - RRA [RHRS] operation is provided by the RIS [SIS], which limits the number of large valves in these operations.

Thus, the consolidated EDPO of the RCP [RCS], RCV [CVCS], and RIS/RRA [SIS/RHRS] valves activity is 22.5 man.mSv per year per unit.

2.3.2.4. Steam generator worksite

In the French fleet, the "SG preparation and inspection" activity represents an average of 19% of the total annual dose for an ROO type outage, 13% for an NRO type outage, and 7% for an ISIO outage. When considering the frequency of EPR-type outages, this is an activity that represents an average of 13% of the total dose uptake for a unit's outage, two-thirds of which are for primary side activities and one third on the secondary side. It is therefore a high dose activity in terms of collective dose.

The SG preparation and inspection activity, except for non-destructive testing, is divided into two activities performed under APR (shutdown for refuelling) and RCD (core completely unloaded) outage conditions:

- primary side SG preparation and inspections, which consist principally of opening and closing the primary manways and associated maintenance,

- secondary side SG preparation and inspections, consisting primarily of opening and closing of the secondary openings (eyeholes, handholes and secondary manways) and the associated maintenance including sludge lancing.

The doses absorbed doses at a SG worksite are significant because the SG bunkers are tight spaces close to the primary circuit components. The primary circuit water level being very low in pipework during primary side operations, the primary fluid no longer fulfils its shielding function, and hot spots may appear in the system voids (SG, pipes and valves located in the SG bunker). In particular, among the highest dose activities, are those (installation of nozzle dams, humidity detectors, etc.) requiring man entry in the channel head using "jumpers". For these activities, the exposure time is measured in seconds.

The collective reference dose for "SG preparation and inspections" activities is 44.8 man.mSv per year per unit.

Special measures have been taken for the EPR steam generators in order to reduce the source term, as well as the duration or frequency of high dose activities [Ref-1]. They are considered to represent well known and proven modifications for the EPR. These measures are:

- Optimisation of the source term: In the design stage, the ALARA approach is considered to optimise the source term (TS), by limiting ^{60}Co concentrations, which, along with ^{58}Co, contributes to approximately 80% of collective doses. Several engineering options have been proposed to reduce the source term and thus reducing the dose rate. The principal options considered aim at reducing:

  - the residual cobalt content in the stainless steels making up the primary circuit,

  - Stellite^{TM}-based hard facing materials.

In the case of the EPR SG, Alloy 690 alloy was finally preferred over Alloy 800 on stress-corrosion resistance, on overall steam-generator design, and on industrial feasibility grounds. Recommendations to optimise the behaviour of the 690 alloy in terms of dose uptake have been associated with this choice.

In addition, the temperature-bypass lines, which could lead up to 13% of the area dose rate in some locations of the 1300 MW SG bunkers, have been removed.

- Optimising the quantity of exposed work: The geographic location of pipes and equipment, as well as the size of the worksites, has been designed such that the amount of time exposed is as low as possible. The objective of reducing the duration and frequency of maintenance activities has been considered in the design of the EPR steam generators in the following ways:

  - The increase in the size of the openings facilitates the access inside the SG:

    - increasing the outside diameter of the primary manways to 516 mm (instead of 450 mm on the N4 units),

    - increasing the outside diameter of the secondary manways to 600 mm (instead of 530 mm on the N4 units).

- facilitating access to the outermost tubes by modifying the geometry of the channel head: adding a cylindrical section below the tube support plate.

These improvements benefit both the workers' dose rate and the human factors skills.

- o Reducing the frequency of tube bundle cleaning operations on the secondary side through reducing the production of crud by:
  - selection of materials limiting corrosion,
  - optimisation of secondary water chemistry ,
  - re-use of the N4 units design to block water run-off and the flow partition plate (N4 operating experience currently demonstrates that with a sediment amount lower than 12 kg, sludge lancing can be performed at every two other shut-down, while it was initially anticipated for every ROO).
- o Reducing the risk of mechanical damage to the ARE [MFWS] and ASG [EFWS] systems by:
  - positioning ARE [MFWS] tapping points in the tapered shell (inclined tube sheet) in order to limit the thermal layering phenomenon and improving thus the fatigue behaviour of the points,
  - installing a thermal sleeve welded onto the ARE [MFWS] and ASG [EFWS]: the absence of leakage between the sleeve and the tube sheet is beneficial regarding fatigue behaviour and catastrophic failure,
  - limiting the use of the ASG [EFWS] system.
- o Reducing the risk of damage to the tube bundle by the use of high-permeability support plates (increasing the size of the cross-section for the passage of secondary water, reducing deposits).
- o Optimising the maintenance programme by reducing the number of inspections for the secondary side (weld inspections are performed on a single SG instead of all four) and by planning to remove, in ROO type outages, activities on the primary side, the secondary side and lancing operations.

These engineering measures are "known and proven" modifications for the EPR. The in-service inspection programme for the EPR SGs will be set up incorporating these improvements, with all the measures being included into the design allowing in-service SG monitoring and inspection.

By considering the latest available values from operating experience and incorporating the proven modifications described above, the EDPI associated with this activity is estimated at 28.9 man.mSv per year and per unit, which is 36% lower than the reference dose.

Other modifications contribute to dose optimisation:

- installation of removable platforms for the activities requiring eyehole/handhole opening (handling the gap left after the removal of the thermal insulation) and appropriate shielding protection.

- consideration of “quick installation” nozzle dams.
- improving reliability (electronic failures), simplifying (facilitating manoeuvrability), and improving performance (reducing execution times) for the opening and closing manways machine: 10% dose improvement on preparation activities on the primary side, for ROO and NRO type outages.
- optimising the design of thermal insulation (with a separate section at the eyehole/handhole level for partial disassembly): the dose improvement is integrated with the thermal insulation activity.
- taking into account supply needs for maintenance activities (hatch installation, air supply, electric power sockets, lighting): 2% dose improvement for all activities on the primary and secondary side.
- installation of a pipe network to allow the lancing of two SG in the same time: 5% dose improvement on lancing activities for NRO and ISIO type outages.
- polishing the SG channel head to reduce the surface contamination: 25% dose improvement on preparation of reactor coolant side activities.

Taking these modifications into account, the EDPO has been estimated as 23.1 man.mSv per year per unit, which is a reduction of 20% compared to the EDPI.

2.3.2.5. Worksite for Opening and Closing the Reactor Vessel

The opening and closing the reactor vessel activity, including inter-vessel work, represents an average of 8.8% of the total dose for a ROO type outage, 5.4% for a NRO type outage, and 3.8% for an ISIO outage. It is a high dose operation in terms of collective and individual doses.

The reference dose is 19.4 man.mSv.

The collective dose associated with the opening and closing the reactor vessel is mainly due to operations at the bottom of the pool at the O-ring level and to operations performed near the reactor vessel head, particularly when it is on its stand.

Vessel opening and closing is a worksite-type of activity, performed during plant outage and included in the technical work scope for integrated vessel maintenance. This activity consists of preparing maintenance, opening the reactor vessel for defuelling and closing it for re-start after refuelling. It is composed of three important phases, which are subdivided into nearly 90 basic operations.

Aside from the source term, the following improvements may be mentioned:

- Optimising the transfer of upper (EIS) and lower internals (EII) underwater:
    - o the upper internals are systematically taken out of the vessel during unit refuelling outages (ROO, NRO, and ISIO). The EPR design allows the upper internals to be transferred from the vessel to their stand while still maintaining a water level of about 2.5 metres above the control rods. This design reduces the dose rate at the pool-floor level compared with that in units at current French NPPs;

- o the lower internals are removed from the vessel during a ten-year inspection (ISIO) type outage. They are transferred and stored in one “block” along with the upper internals. This is thus referred to as handling the upper/lower internals. The design of the EPR means that uncovering the internals can be restricted to the upper part of the guide rods over a height of 190 mm.

- The addition of an area dedicated to the reactor vessel head storage. The pressure vessel head has a dedicated location for its storage on a stand after opening of the vessel. This storage area is located 4.45 m above the service floor and includes an appropriate concrete shielding. Thus it enables the increase in area dose rate from the reactor vessel head to be limited at the service-floor access routes. Furthermore, the sitting of the EPR stand will allow the dose rate due to stud cleaning and lubrication operations to be reduced during ROO type outages.

- Optimising the removal and replacement of the reactor vessel head thermal insulation: the annular section of the thermal insulation removed in order to detach the vessel studs is removable as a single unit. This development constitutes an advantage over previous designs, in which the removal of thermal insulation was done piece by piece (four to six pieces, depending on the thermal insulation stage). In addition, the top part of the thermal insulation will be reinforced to support the weight of maintenance personnel, and the provision of access and safety measures (a ladder, guardrails). This design eliminates the on-site fitting problems encountered during removal and replacement of the thermal insulation, due to the deformation of sections, and it thus reduces the amount of exposed work at the pool base. Moreover, conventional safety is improved compared to the N4 units, where a guardrail is not provided for the thermal insulation.

- Absence of RGL [CRDM] ventilation air ducts (opening and closing the RGL [CDRM] ventilation hatches). The mechanisms adopted for the EPR include coils capable of operating at higher temperatures than the coils for the N4 mechanisms, while still producing a lower Joule effect and thus not requiring forced-air ventilation on the head.

- In order to be able to open the reactor vessel within a time period compatible with the unit outage objectives, a decision was made to install a vessel head cooling system on the EPR using forced draft ventilation under the insulation. Compared with the natural cooling initially planned, this system is used to obtain a temperature on the vessel head flange and the studs that is sufficiently low and constant (around 70°C) more rapidly; from which the stress-release may be performed by the MSTM (Multi-stud Tensioning Machine) without any risk of mechanical degradation. This system includes air ducts fitted along the walls of the reactor building pool, on the same level as the four air outlets from EVR [CCVS] system. These ducts are composed of a fixed part and a removable part. The presence of this system implies elementary connection and disconnection operations for the air ducts, assigned to opening/closing reactor vessel operation.

  The dosimetry assessment related to the above operations, performed at the pool bottom by two operators (vessel head on reactor), is 0.34 man.mSv.

- Reactor vessel level measurement of the Konvoi type. The EPR design uses the in-core instrumentation of the Konvoi design, which is different from that in French power stations, particularly in the case of reactor-vessel level measurement (measured by ΔP on N4 units; measured by level probe on the EPR). One of the impacts on the EPR reactor-vessel opening and closing activities is the elimination of removal and reinstallation operations for the reactor vessel level pipe (reducing the amount of exposed work).

- Routing of the ex-core instrumentation through the pool concrete wall: in contrast to the P’4 and N4 stages, the EPR ex-core instrumentation is routed into the reactor-vessel pit through the pool's concrete wall. As a result, closure of the nuclear instrumentation covers at the pool bottom in the preparatory phase, prior to opening the vessel, is removed in the EPR (reducing the amount of exposed work).

- N4-type MSTM. The EPR MSTM will benefit from the N4 improvements, especially by reducing the risk of studs seizing during vessel opening and closing operations. In addition, all operations will be automated and monitored from the control desk located on the operating floor. The amount of exposed work at the bottom of the pool should therefore be reduced during vessel opening and closing operations.

- Routing of the in-core instrumentation through the vessel head: one of the essential differences between the EPR design and that of the P’4 and N4 series is the routing of internal core instrumentation through the vessel head. This eliminates penetrations through the bottom of the EPR reactor vessel, for safety reasons. This has also lead to the use of the aeroball system, as mobile instrumentation for measuring neutron flux. The consequences associated with reactor vessel opening and closing operations are as follows:

    - a greater number of disassembly and re-assembly operations for leaktightness at the instrumentation adapter level (17 instead of the four on the N4 units), as well as their cleaning and assessment during outage,

    - the addition of disconnection operations for the aeroball tubes, first at their connection panel located in the upper part of the pool, then at the instrumentation adapter level, during the preparation of the pressure vessel opening (reconnections during the closing phase),

    - the addition of raising and lowering operations for the platform above the head which is dedicated to the aeroball ducts,

    - the need to remove and install the aeroball nozzles respectively before the upper internals removal and after their reintroduction into the vessel, (the aeroball nozzles cannot remain connected to the upper internals during their transfer, an operation performed with the pool filled).

- Access to the bottom of the Reactor Building pool: the design of the EPR is such that access to the vessel compartment should be possible throughout the outage via a door at the bottom of the pool (in particular for individuals wearing Mururoa suits, and for equipment). In addition, the location of the access door to the vessel compartment provides improved accessibility when assembling a changing area at the bottom of the pool compared to the N4 design. The design of the EPR thus offers benefits in terms of security for the workers, accessibility, and cleanliness for all operations at the bottom of the pool.

- Increased number of control rod drive shafts and of control rods drive mechanisms (RGL [CRDM]s): the increased size of the EPR core (241 fuel assemblies instead of 205 for the N4 units) and its operating mode (increased cycle duration), lead to an increase in the number of RGL [CRDM]s (89 for the EPR and 73 for the N4 units) and hence the need to double the number of cable trays on the EPR (2 for the EPR, 1 for the N4 units). There are thus a total of three bridges to be controlled during EPR reactor pressure vessel opening/closing operations (one for the aeroball ducts and two for the electrical cables), rather than just one in P'4 –N4. Given the N4 values for this operation, the impact on dose measurements is deemed to be negligible. It should also be noted that the increased number of electrical cables will lead to more disconnection/connection operations (i.e. an increase in total exposure time). These operations are not performed on-site by employees involved in "reactor pressure vessel opening/closing" operations, but by site automation specialists subject to a specific NCAD code and are thus not taken into account in this worksite.

- like the RGL [CRDM]s, the number of control rods drive shafts increases from 73 to 89 on the EPR. This increases the amount of exposed work for the control rods disconnecting and connecting operations before and after removing the upper internals.

- Penetrations in the Reactor Building pool walls the walls of the EPR pool include penetrations. These nine penetrations are for:

    - the two connection panels (for RGL [CRDM] cables and instrumentation) located opposite the head cable trays,

    - the connection panel for the aeroball ducts located opposite the aeroball dedicated platform,

    - the six ventilation ducts blowing fresh air in the direction of the head, four of which exit at the pool wall lower level, the other two being at the same level as the electrical connection panels.

These penetrations are blocked by manually closing watertight doors prior to opening the pressure vessel, and then are reopened in the vessel closure phase. The impact of this design on outage activities is therefore the addition of in-pool doors opening and closing operations.

- Vessel head lifting beam: the lifting vessel head device for the EPR comprises a lower section which remains in contact with the vessel head during operation and a removable upper section. This upper section, which is called the vessel head lifting beam, is removed during reactor operation. This specific EPR feature is due to the fact that the pool is covered by concrete slabs, which means that the vessel head lifting beam cannot be retained during operation. This design means that an additional operation to assemble/dismantle the vessel head lifting beam is required during the preparatory phase prior to opening the vessel and after closing the vessel. Given the location of the individuals performing this operation (i.e. the same as for raising the cable bridge), the dosimetric loss is estimated to be negligible.

- Cover slabs: In order to access the Reactor Building several days before the scheduled outage to prepare for maintenance and refuelling operations, the EPR pool is covered with six removable concrete slabs which provide biological shielding for staff whilst the unit is operational. These slabs will therefore need to be removed during the preparatory phase, prior to opening, as part of reactor pressure vessel opening/closing operations. The dosimetric impact of this additional operation, performed when the unit is shut down, is deemed to be negligible.

The EDPI obtained for the pressure vessel opening and closing activity is 18.7 man.mSv per year per unit [Ref-1].

The modifications "being studied" consider optimisation of the worksite ergonomics:.

- Increasing the height beneath the vessel head: the altimetry of the vessel head flange, when the head is placed on its storage stand, is increased to facilitate human operations and, as a result, reduce exposure time during maintenance and inspection operations under the vessel head. The resulting height beneath the vessel head is 1.4 m, compared with a little less than 1 m for N4. This should lead to a reduced overall exposure time for activities conducted beneath the vessel closure head. However, it is difficult to quantify this reduction.

- Seal box directly integrated in the biological protection and assembled on runners/ slides: this measure ensures that the seals are held in position as the clips are being screwed and decreases the number of required operators from 6 to 2.

- Optimising vessel tapping cleaning machine assembly time at the bottom of the reactor building pool: with a view to limiting the overall exposure time at the bottom of the pool, N4 operators emphasised the importance of optimising the assembly time of the vessel tapping cleaning machine. The supply of this equipment, which must include vessel tapping cleaning, greasing and televisual inspections, will be the subject of a specific contract with the suppliers.

Aside from the potential dose benefit, this is in particular a gain in the human factors area. As a result, the EDPO is 18.6 man.mSv per year per unit.

2.3.2.6. Fuel Posting out Worksite

The "fuel posting out" activity at the Fuel Building transfer station represents approximately 25% of the total annual dose during power operation. It is a high dose operation in terms of collective and individual doses.

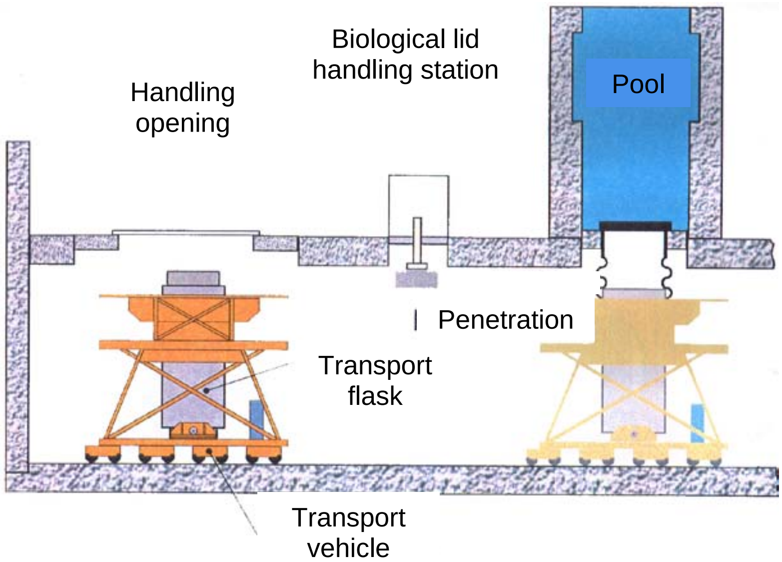
The dose rates for this activity are generated by:

- radiation from the fuel assemblies. This radiation has a significant neutron component.

- the radiation from fluid systems located above the trolley. Circulation of contaminated water leads to the formation of several hot spots above the DMK trolley (fuel building handling equipment). Radiation maps have shown that these hot spots contribute significantly to the total dose received.

In addition, the fuel posting out worksite is sensitive to radiological cleanliness. Indeed, the area and DMK trolley are vulnerable to contamination through water splashing, particularly during fluid systems disconnection operations on the cart, flask lid installation, flask skirt draining, and setting the penetration into water.

The transport flask loading principles with depleted fuel assemblies are based on below-pit loading. The flask is transferred under the Fuel Building pool and brought into contact with a penetration located at the bottom of the pool (see sketch below).



The different stages of this fuel posting out activity may be summarised as follows:

- Flask arrival: disassembly of the guards on the transport vehicle, tipping of the flask, positioning the flask above the DMK trolley, and transfer to the Fuel Building,
- Flask preparation: fitting of the valve tools, fluid connections, setting the flask in the water, adjusting the flask position, lid removal,
- Fuel loading: flask position adjusting, connection to the penetration, loading the flask, draining the penetration,
- Flask treatment: lid installation, water-tightness checks, draining and drying, flooding with nitrogen, radiological monitoring,
- Flask transfer out: transfer to the lifting station, tipping of the flask, loading onto the transport vehicle, radiological monitoring.

The collective absorbed dose during fuel posting out is 7 man.mSv on average in the P’4 units. This depends mainly on the residual activity of the twelve assemblies being removed (the neutron dose rate increases with residual activity) and on the trolley frequency of use (the trolley contamination increases with the number of fuel transfers). For the P’4 units, the fuel posting out activity corresponds to an annual dose of 24.5 man.mSv at a rate of 3.5 fuel removals a year. This value represents the reference dose for the fuel posting out activity.

The known dose reductions and increases associated with the EPR design are listed below:

- Dose and contamination optimisation: - 45%
    - fluid flow improvement,
    - design simplification,
    - valve automation,

- slow leakage fast connections,
- modification of relief tank,
- addition of valves to isolate the level measuring tank during contamination phases,
- lancing of piping emitting dose with water supplemented by compressed air,
- improvement of the 10-litre tank connected to valve tool B so as to prevent the creation of retention areas.

- Operations optimisation for preparing and monitoring the trolley: -20%
  - installation of shielding,
  - activity duration optimisation,
  - simplification of radiological controls.
- Use of MOX: The use of MOX fuel leads to an increased neutron dose rate (+ 25%),
- Increase in the number of assemblies unloaded (which produces an increase in the number of fuel shipments to be performed during one cycle): +7%.

The Initial Predicted Dose Estimate (EDPI) for the fuel posting out activity is estimated at 14.5 man.mSv, which is a 41% improvement compared to the reference dose [Ref-1].

Detailed studies have led to implementation of assisted cask positioning and a dose improvement of 6%.

The consolidated EDPO is estimated at 13.6 man.mSv per year per unit, the percentage improvement being 45% compared to the reference dose.

Additional measures, generating improvement for radiological cleanliness, have also been validated:

- Installation of a deflector to protect the cask vanes against contamination originating from penetration dips or leaks. Effluents are collected in leak pans installed on the carriage.
- Installation of a tank in the wall of the fuel handling area to increase the condensation length and thus reduce the release of contaminated steam from the DWK [FBVS].

2.3.2.7. Waste Treatment Operations

Waste treatment operations represent an important activity with regard to radiation protection. They represent an average of 4.3% of the total annual dose. The dosimetric impact is most important when plant is in operation since 0.3% of the dose is received during an ROO type outage and 0.2% during an NRO or ISIO type outage. When the plant is in operation this activity becomes dominant with respect to dose, accounting for 20% of the overall dose.

This activity is also important with regard to the radiological cleanliness of the plant.

The reference dose of this activity is 18.8 man.mSv per year per unit.

The dose improvement linked with the source term can be applied to this activity, except for the filter handling activity which represents 30% of the waste treatment activity dose. As a consequence, the EDPI is 16.8 man.mSv/yr/unit, which represents an improvement of 11% compared to the reference dose.

In respect of operational feedback, the principles retained for the EPR are therefore the following [Ref-1]:

- Mechanise and limit handling in order to reduce the effort involved and the received dose.
- Limit transfers and movements of the waste and splitting of the load.
- Permit immediate treatment in order to quickly obtain treated waste ready for transport off-site to the centre receiving the waste.
- Accelerate the treatment of technological waste produced in bags (which represents the largest volume when the reactor is shutdown) to avoid overloading the treatment chain.
- Forecast potentially overloaded situations to avoid the accumulation of waste in areas not designed for such use, thus limiting the risk of fire and the consequent dosimetric background that the waste generates.
- Ensure that distinct, identified paths are available for treating each type of waste in order to avoid errors in processing by choosing the correct stream.

For the different phases of the waste treatment, the EPR design improvements are the following:

- Processing of compactable waste bags for which the dose rate is less than 2 mSv/hr
  - A specific room is dedicated for the collection of waste from the nuclear island.

    The room will be used both while the unit is operating and during unit outages. This area is only a transit area; the objective is to continually shift the waste to the sorting and drumming area of the Effluent Treatment Building to achieve, as quickly as possible, drummed waste. Consequently, buffer stores, which act as dose rate generators and provide a significant fire risk, are avoided. This room will be equipped with:

    - Automatic dose rate and X-ray measurement equipment, which will limit the handling of waste bags and the dose uptake by the operator responsible for the waste.
    - A glove box which permits resumption of bag sorting while protecting the operator from a contamination risk. The box is shielded to limit radiation exposure.
    - Selective sorting containers for the waste which permit sorting at source and limit the amount of re-sorting upstream of waste treatment.

Layout of the compacting press room:

The room is laid out such that only the amount of waste required for the workstation is held nearby. The storage buffer room is located in the Effluent Treatment Building at +7.40 m outside a working area.

The press is linked to a depressurising device which prevents any risk of personnel contamination. The press must accept metal or HDPE (high density polyethylene) drums of 200 litres which can thus be directly incinerated at incineration centre (limiting dosimetry operations at the service provider).

Layout of the radiological inspection room:

The drums of compacted waste are transferred to the low dose rate area so that weighing, labelling and radiological checks can be carried out. They are then directly loaded in 20 foot containers and are ready for shipping, which avoids a multiplication of handling and thus unnecessary received dose.

Layout of the waste storage room

This room is considered as a clean room where only finished packages are stored. This enables the 20 foot containers, which will be used to transport the waste to the processing centre, to be placed here.

- Processing of non-compactable or special waste bags for which the dose rate is less than 2 mSv/hr
    - o The waste can be crushed, which reduces the volume of waste produced and limits the volume stored in the Effluent Treatment Building.
    - o The crushed waste receptacle is situated below the crusher, which simplifies introduction (at the height of a man) of waste at +7.40 m and permits receipt, directly and without handling of waste, into a drum at +3.70 m for possible transfer to the compacting press.

Waste for which the dose rate is less than 2 mSv/hr represents 55% of the dose for the waste treatment activity. The measures described above generate a dose improvement of 20% compared to the EDPI.

- Encapsulation of process waste
    - o The dosimetry measured for the filter crane will be reduced because:
        - The filters are transferred between the Nuclear Auxiliary Building and the Effluent Treatment Building in a specially designed and shielded machine. Replacement of the Effluent Treatment Building filters also benefits from this technology.
        - Handling and transfer distances are reduced: The filters can be suspended directly in the filter cartridge descent tube of the Effluent Treatment Building without having to insert a biological protection plug for the transfer.

- The radioactive technical waste from the Nuclear Auxiliary Building can be transferred along the floor in the special mobile trolley which will open beneath the filter cartridge descent tube.

- The activity of the withdrawn filter is measured to permit adoption of any necessary biological protection before introduction into the concrete shell in line with transport regulations (2 mSv/hr maximum at the contact surface of the final package).

o Suppression of unencapsulated shell transfers outside the controlled area and thus suppression of possible radiological risks and contamination of the road system during transport.

o Simplification of the kinematics of handling and suppression of specific activities and their associated dosimetry.

o The storage room is made entirely from concrete (walls and roofs) and is below ground at the -3.90 m level, which:

- Avoids risks of exceeding the radiological limits at the exterior of the building. The shells can be stacked in up to 3 levels without extending above ground level at 0.00 m. The roof effect is taken into account by the concrete roof.

- Simplifies handling of shells which are passing through the locking cell to the storage room at the same level (-3.90 m). This arrangement takes into account the risk of falling on an unlocked package.

Waste generated by water filters represents 30% of the waste treatment activity dose. The dose improvement linked to the measures detailed above is 20% compared to the EDPI.

Other processed waste represents 10% of the waste treatment activity dose.

On the basis of the validated modifications for the EPR, the consolidated EDPO is 14.1 man.mSv/yr/unit, which represents an improvement of 16% compared to the EDPI.

3. SUMMARY OF RESULTS FOR COLLECTIVE DOSE

The results of the analysis of the EPR collective dose are shown in the following table (values are given in man.mSv).

Predicted type	Reference dose			Initial Predicted Dose Estimate			Optimised Predicted Dose Estimate		
Dose by outage type *(average value per year)*	ROO	323	*(353)*	ROO	237	*(294)*	ROO	200	*(249)*
	NRO:	517		NRO:	445		NRO:	372	
	ISIO	1327		ISIO	1134		ISIO	972	
Dose for unit in operation per year	87			69			91		
Total average per year	**440**			**363**			**340**		

The Optimised Predicted Dose Estimate calculated for the EPR is 0.340 man.Sv per year per unit. This value is in accordance with the project target of 0.35 man.Sv per year per unit.

4. COMPLIANCE WITH OBJECTIVES FOR MAXIMUM INDIVIDUAL DOSE

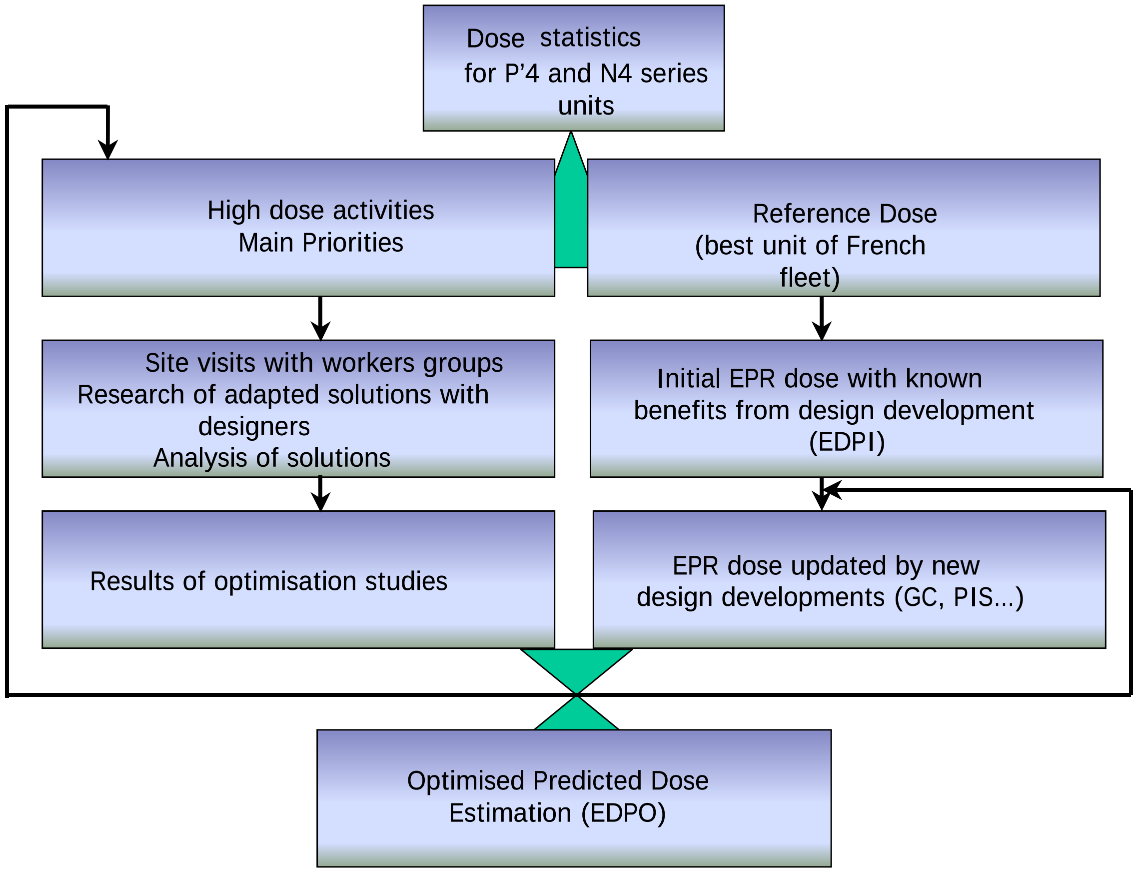
Safety Design Objective SDO-2 for the UK EPR states that the effective dose received by any operator annually should be below 10 mSv.

In practice the maximum dose received by any individual worker in a given period can be controlled by management actions during operation of the plant. For an entirely new reactor design it might be appropriate to carry out an assessment of occupancy times of rooms containing radioactive materials during proposed maintenance operations to show that the dose limit would be achievable for the required range and type of maintenance activities foreseen. However the EPR is an evolutionary development of current French and German NPP design, with improvements to both reduce the source term associated with plant operation and maintenance, and the amount of exposed work, as described in section 2 of this Sub-chapter. Therefore there is confidence that individual worker dose due to maintenance activities will be below those experienced on current operating French and German NPPs.

Consistent decrease has been achieved over the previous 10 years, in worker doses on operating French NPPs. Given the dose levels and the measures taken to reduce worker doses in the EPR compared to operating NPPs, there is confidence that the 10 mSv/yr/unit dose limit adopted for the UK EPR will be achievable.

SUB-CHAPTER 12.4 – FIGURE 1

PRINCIPLE OF THE EDF OPTIMISATION INITIATIVE ON THE FRENCH EPR



SUB-CHAPTER 12.4 – REFERENCES

External references are identified within this sub-chapter by the text [Ref-1], [Ref-2], etc at the appropriate point within the sub-chapter. These references are listed here under the heading of the section or sub-section in which they are quoted.

2. EPR DOSE UPTAKE PREDICTION

2.1. METHOD

[Ref-1] EPR - Taking into account the statistics from the best French plants – Establishment of the reference dose. ECEIG040828 Revision A1. EDF. April 2009. (E)

ECEIG040828 Revision A1 is the English translation of ECEIG040828 Revision A.

[Ref-2] EPR – FA3 – Methodology of the optimisation studies for Activities with High Level regarding Radiological Protection. ECEIG040681 Revision B1. EDF. January 2006. (E)

ECEIG040681 Revision B1 is the English translation of ECEIG040681 Revision B.

2.2. ESTABLISHING THE REFERENCE DOSE

2.2.1. Assumptions

[Ref-1] EPR - Taking into account the statistics from the best French plants – Establishment of the reference dose. ECEIG040828 Revision A1. EDF. April 2009. (E)

ECEIG040828 Revision A1 is the English translation of ECEIG040828 Revision A.

2.2.2. Results

[Ref-1] EPR – List of priority activities concerned by optimisation. ECEIG040601 Revision C1. EDF. July 2009. (E)

ECEIG040601 Revision C1 is the English translation of ECEIG040601 Revision C.

2.3. ESTABLISHING THE OPTIMISED DOSE

2.3.1. Dose uptake assessment for the design evolution

2.3.1.1 Source term and dose rate optimisation

[Ref-1] Report on the suppression or reduction of stellite hardfacing in RPV internals. NFPMRDC0004 Revision B. AREVA. October 2004. (E)

2.3.1.3. Specific features of in operation interventions

[Ref-1] EPR - Optimised dose assessment for unit at power activities planned in the FA3 EPR Reactor Building. ECEIG081619 Revision A1. EDF. November 2009. (E)

ECEIG081619 Revision A1 is the English translation of ECEIG081619 Revision A.

2.3.2. High-priority activities optimisation results

[Ref-1] EPR – FA3 – Methodology of the optimisation studies for Activities with High Level regarding Radiological Protection. ECEIG040681 Revision B1. EDF. January 2006. (E)

ECEIG040681 Revision B1 is the English translation of ECEIG040681 Revision B.

2.3.2.1. Thermal Insulation Operations

[Ref-1] Optimization of activities with radiation protection impact – chapter 2 – “Removing and fitting heat insulation and lagging”. EYRL2008FR0003 Revision D1. Sofinel. June 2010. (E)

EYRL2008FR0003 Revision D1 is the English translation of EYRL2008FR0003 Revision D.

2.3.2.2. Worksite Logistics

[Ref-1] Optimization of activities with radiation protection impact – chapter 2 – Worksite logistics. EYRL2008FR0048 Revision C1. Sofinel. February 2010. (E)

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2.3.2.3. Valve activities

[Ref-1] EPR – Optimisation of activities that impact radiation protection – RCP, RCV and RIS/RRA valves – Volume 2. ECEMA071469 Revision C1. EDF. May 2010. (E)

ECEMA071469 Revision C1 is the English translation of ECEMA071469 Revision C.

2.3.2.4. Steam generator worksite

[Ref-1] EPR – Optimisation of radiological protection activities – “SG preparation and tests” – Section 2. ECEMA070805 Revision B1. EDF. April 2010. (E)

ECEMA070805 Revision B1 is the English translation of ECEMA070805 Revision B.

2.3.2.5. Worksite for Opening and Closing the Reactor Vessel

[Ref-1] EPR – Optimizing radiation protection-related activities – “opening/closing of reactor vessel head” activity – Chapter 2. ECEMA070986 Revision B1. EDF. April 2010. (E)

ECEMA070986 Revision B1 is the English translation of ECEMA070986 Revision B.

2.3.2.6. Fuel Posting Out Worksite

[Ref-1] EPR – Optimization of activities with radiation protection impact fuel shipment – chapter 2 – YR2621. EYTM2007FR0030 Revision C1. EDF. June 2010. (E)

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2.3.2.7. Waste Treatment Operations

[Ref-1] EPR Optimisation of Radioprotection activities. Waste treatment Phases 1 and 2. D4002.92-06/123 Revision 01. EDF CNEN. March 2009. (E)