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1. INTRODUCTION

The decommissioning of the UK EPR will be the responsibility of the Licensee. However EDF / AREVA have considered at the early EPR design stage, aspects to facilitate future decommissioning in a safe and environmentally acceptable way. Description of the design improvements implemented in the EPR compared to previous generations of PWRs, and radioactive waste inventory generated by decommissioning activities are presented in the UK EPR GDA PCSR Chapter 20 (PCER Chapter 5) and supporting documents (references 1 to 5).

In addition to the information provided in the above mentioned documents, and noting that the decommissioning approach will certainly change over time, the present report intends to demonstrate that it would be feasible to decommission the UK EPR (including the interim storage facilities for Spent Fuel and ILW), using current technology, and that consideration of decommissioning issues has been made in the design. The baseline decommissioning plan covers the lifetime of the site, including achieving operational shutdown, Post Operational Clean Out, a care and maintenance period, if this required and decommissioning to a brownfield site. However it does not address de-licensing of the site.

The present report consists of eight chapters covering the following aspects:

- Chapter 1 describes the principles underpinning the EPR design, in terms of design for decommissioning and waste minimisation, operations and maintenance, and decommissioning.
- Chapter 2 describes the decommissioning logistics considered, in order to demonstrate that the plant can be decommissioned.
- Chapter 3 discusses the assumptions on the timing of decommissioning and the sensitivity of the design to any changes in those assumptions.
- Chapter 4 describes how the likely hazards and challenges associated with decommissioning are considered and how these will be controlled.
- Chapter 5 describes the assumptions on the status of the plant prior to commencement of decommissioning.
- Chapter 6 shows how the disposability assessment aligns with the assumed decommissioning processes.
- Chapter 7 shows underpinned decommissioning plans and programmes for the whole life-cycle, based upon the assumed decommissioning processes.
- Chapter 8 describes how the knowledge of the plant and associated facilities will be managed over the lifecycle, particularly knowledge pertinent to decommissioning and associated decontamination.

Although they can be considered independently, each chapter should be read in conjunction with the other chapters in order to gain an overall understanding of the strategy proposed for decommissioning the UK EPR.

2. NON TECHNICAL SUMMARY

2.1. PRINCIPLES UNDERPINNING THE DESIGN

Whilst decommissioning will be the responsibility of the Licensee, the design of the EPR provided by EDF / AREVA ensures that decommissioning of the plant will be possible in a safe and environmentally acceptable way. Moreover the design includes specific features and encourages operational philosophies which will enable suitable decommissioning solution(s).

Chapter 1 identifies the underpinning principles adopted in the design to allow the plant to be decommissioned and waste to be minimised. This includes design principles and fulfilment of IAEA requirements related to decommissioning.

The principles that should be adopted by the licensee in the operation and maintenance of the plant, in terms of the influence from or upon the baseline decommissioning approach, are presented. This covers the updating of the decommissioning plan, records, measurements, decontamination, survey, anticipation of future needs, collection of lessons learned and feedback.

The baseline principles and objectives that should be adopted during decommissioning to enable adequate management of the decommissioning process and preparation of plans and proposals for the decommissioning of an EPR are also identified. These include items such as safety of the public, and staff, safety of the plant, protection of the environment, waste management, financial provisions, maintenance of resources and records, periodic review of strategy and organisation of the activities.

Other principles are those which facilitate the operator learning from experience, industry good practice and guidance. This includes maintenance of knowledge of best practice in all aspects of decommissioning, for example through membership of adequate organisations or bodies, employment of Suitably Qualified and Experienced Personnel or participation in International Organisations.

The last parts of Chapter 1 relates to how ‘As Low As Reasonably Practicable’ (ALARP) considerations have been applied to the decommissioning aspects of the designs / philosophies. It includes discussion of some of the key design features incorporated to facilitate the application of these principles, such as building layout, choice of component material and equipment design.

2.2. DECOMMISSIONING LOGISTICS

The logistical challenges presented by the reactor design, which will have to be dealt with during decommissioning need to be understood at the design stage, in order to be able to demonstrate the credibility of the baseline decommissioning strategy and that it will be possible to safely decommission the EPR.

Chapter 2 provides EDF/AREVA strategic options, envisaged decommissioning sequence and methodology including considerations such as decontamination, space, access and infrastructure requirements. It shows how the decommissioning will proceed throughout the plant, with some focus on the primary circuit and reactor building deconstruction. In addition decommissioning principles for the ILW and SF storage facilities are provided. Immediate decommissioning of the facilities is considered i.e. after 60 years of operation for the reactor and 100 years of operation for ILW and SF storage facilities.

Safety is an important issue to be considered during decommissioning. This chapter shows:

(i) how shielding and containment design are effective during the logical sequence of the decommissioning;

(ii) how the major steps of the decommissioning sequence allow progressive reduction of the radiological hazards, the criticality risk, and contamination risks.

This chapter also shows how design and construction processes allow the preferred decommissioning scenario of the most activated and contaminated equipment to be completed in a safe manner, and the installation of dedicated dismantling sites within the premises to deal with the other components in a progressive and safe manner. Technologies associated with the baseline scenario are presented, showing that the decommissioning can be carried out using current available technologies.

Main safety systems required for the decommissioning are identified. Indication is given on how their availability will be ensured or alternatively how their safety function will be delivered by evolution / replacement of the safety system, during the decommissioning sequence.

Finally, in relation with design principles, the sequence allowing the management of the contamination risk during decommissioning is indicated.

2.3. TIMINGS OF DECOMMISSIONING

The timing of decommissioning (i.e. deferred or immediate) will have a major effect on the baseline decommissioning plan and programme, and could affect other aspects of the decommissioning, e.g. the methodologies proposed. Considering the timescales concerned it is reasonable to expect a degree of uncertainty over the time of decommissioning. At present time EDF / AREVA have set out baseline assumptions on the timing of decommissioning of the UK EPR, which are described in Chapter 3.

In particular, the preferred strategy to be adopted for the decommissioning of the UK EPR and the justification for this choice are detailed, together with the effect of changing the baseline strategy. In particular, the sensitivity to any deferment strategy is studied, and the ability to conduct decommissioning early if required is set out.

The effect on timings of the choice of interim storage technique for spent fuel are described; i.e. the time during which the spent fuel need to be stored in the at-reactor fuel pool after operations, and the effect on other decommissioning activities of storing spent fuel assemblies in the at-reactor fuel pool.

2.4. HAZARDS AND CHALLENGES

Hazards management is key in the nuclear industry during all periods of design, construction, operation or decommissioning. As such, identification of all hazards and analysis of the risk that they can present is essential before and during all decommissioning activities. Similarly, feedback and learning from experience is also essential once decommissioning activities are complete, to ensure that all hazards were identified and managed and that the controls put in place to protect against these hazards were optimised. It is important that learning is gained so that the management of hazards is improved for future projects.

The aim of Chapter 4 is to provide details on the Hazards and Challenges expected to be met during the decommissioning of the UK EPR. Details are first provided of EDF/ AREVA experience of decommissioning, participation to working groups and the type of hazards encountered.

The potentially significant hazards that could reasonably be anticipated during the decommissioning of an EPR are identified, and the protection measures implemented are provided along with the controls that have been (or will be) put in place to protect against these hazards.

Similarly, the identification and control of the likely radiological and industrial safety hazards is provided. Finally, the criteria for the use of remote-controlled equipment / techniques in decommissioning tasks are discussed.

2.5. ASSUMED PLANT STATUS AT DECOMMISSIONING

To produce a baseline decommissioning plan a suitable prediction of the plant status at the end of operations is needed. For example the radiological conditions will influence the decommissioning methodology, shielding or containment requirements.

Chapter 5 explains the basis of the plant status assumed to exist at the cessation of power operations (e.g. radiological conditions, contamination, activation) that has been established at the design stage for the purpose of defining the decommissioning plan, and the underpinned allowances made for any reasonably foreseeable abnormal operations.

It is explained how this is expected to evolve or remain unchanged until reactor cessation of operation depending on operation history. The impacts of a different decommissioning start-time compared to the baseline scenario (e.g. early plant shutdown, life extension or deferment) are then discussed.

The measures foreseen at the design stage for minimisation of activation and corrosion products, and minimising transport of those products through the plant are introduced.

Methods for confirming plant conditions in the future by the operator and through surveys and calculations at the time of cessation of operation are presented.

Finally, the design and operational measures implemented to prevent contamination of the land and groundwater are highlighted.

2.6. DISPOSABILITY ASSESSMENT

Decommissioning of the EPR and interim storage facilities generates radioactive waste, which needs to be disposed of. The aim of Chapter 6 is to show that the disposability assessment presented in the GDA submission aligns with the baseline decommissioning plans. It covers the radioactive waste generated during the decommissioning of the nuclear facilities of an EPR site (one single EPR plant and associated Interim Storage Facilities (ISF for ILW and SF)) with respect to the current UK regulatory requirements.

The baseline assumptions for the disposability assessment related to (i) the EPR decommissioning as presented in the GDA submission, and (ii) the interim storage facilities proposed by EDF/AREVA for spent fuel and ILW, are restated.

The physical and radiological inventory of the wastes, including those relating to the decommissioning of the interim storage facilities is presented, while additional information is provided on the secondary wastes during decommissioning. The sensitivity of the waste streams to the decommissioning processes is also discussed.

Waste management and waste routes from the buildings to interim storage are described. Finally disposability assessment and compliance with waste hierarchy and demonstration of BAT is presented.

2.7. DECOMMISSIONING PLANS

In order to justify the credibility of the decommissioning approach proposed, a baseline decommissioning plan is presented in Chapter 7. The plan level of detail is commensurate with the stage of the lifecycle and take cognisance of the work that is being carried out to prepare costed decommissioning plan for PWRs in France and to prepare a site specific Decommissioning Plans for an EPR which would be built in the UK.

The assumptions underpinning the plan are provided consistently with the other chapters, i.e. the baseline EDF /AREVA decommissioning scenario and techniques are considered, and the whole decommissioning lifecycle, including the decommissioning of interim waste stores is addressed.

The timescale is presented related to the operational date of the reactor, the relevant safety and environmental submission schedule and the technology choice for fuel storage. The impact on the programme of any necessary fuel storage period in the at-reactor fuel pool is also considered. Finally, consistency with Government policy and the disposability assessment is addressed.

2.8. KNOWLEDGE MANAGEMENT FOR DECOMMISSIONING

Whilst record information (baseline data, operational records etc), including the information relevant to decommissioning will be the responsibility of the Licensee, it is recognised that information pertinent to decommissioning should be specifically identified / recorded at the generic design stage of the life-cycle, in order to capture the design features which underpin the baseline decommissioning plans.

Chapter 8 identifies the types of information and knowledge, which will be required, to be preserved from the initial design stages for the EPR and associated facilities through their operational life and the decommissioning phase itself, so as to ensure that decommissioning may be undertaken safely and efficiently.

This will help the Licensee, upon handover from the designer, to understand the logic behind the baseline decommissioning plans, and ensure that specific data, assumptions and underpinning thought processes are not lost and which information needs to be acquired or generated throughout the operational phase of the station.

Differentiation is made between information which EDF / AREVA will be required to generate and retain through the design process and operational information and knowledge which the Site Licensee will be required to generate and retain.

Systems to facilitate knowledge transfers from all stages of the life-cycle, including systems to identify and retain the knowledge most pertinent to decommissioning from the design, construction and operational phases are also discussed.

3. REFERENCES

[1] "PCSR Sub-chapter 20.1 – General Principles – Regulations", UKEPR0002-201 Issue 00, June 2009

[2] "PCSR Sub-Chapter 20.2 –Implementation for the EPR", UKEPR0002-202 Issue 00, June 2009

[3] "PCER Chapter 5 – Design Principles related to Decommissioning", UKERP0003-050 Issue 03, March 2010

[4] "EPR UK – Decommissioning waste inventory", ELIDC0801302 revision A

[5] "Solid Radioactive waste Strategy Report" NESH-G/2008/en/0123 revision A

CHAPTER 1 – TABLE OF CONTENT

1. INTRODUCTION

The present chapter identifies:

- The underpinning principles adopted in the design of the EPR™ to allow the plant to be decommissioned and wastes to be minimised (Section 1).
- Principles that should be adopted by the licensee in the operation and maintenance of the EPR™, in terms of the influence from or upon the baseline decommissioning approach and (Baseline) principles that should be adopted during decommissioning;
- Principles that facilitate the operator learning from experience, industry good practice and guidance (Section 4);
- How 'As Low As Reasonably Practicable' (ALARP) consideration have been applied to the decommissioning aspects of the designs / philosophies of the EPR™ (Section 5);
- EPR™ Key design features incorporated to facilitate the principles, e.g. decommissioning enablers (Section 6).

2. UNDERPINNING PRINCIPLES ADOPTED IN THE DESIGN

The present section identifies the underpinning principles adopted in the EPR™ design to allow the plant to be decommissioned and wastes to be minimised. . These are closely related to the reduction of dose.

These principles :

- Minimise the volume of radioactive structures
- Minimise the toxicity of the waste
- Minimise the activity level of irradiated components
- Minimise the spread of contamination
- Permit easier decontamination
- Ease the access to components to dismantle
- Limit radiation dose received by workers

Dose reduction implicitly contains the sub-principles of

- Minimising the intensity of sources to which operators are exposed
- Minimising the time spent in proximity to these sources

- Facilitating the replacement and final removal of equipment.

Waste reduction implicitly contains the sub-principles of

- Maximising the recycling of materials
- Minimising the quantities of waste difficult to dispose of
- Minimising the production of secondary waste

Although these principles are identified separately their fulfilment in the EPR™ design are very often achieved by common features.

Fulfilment of these principles also requires application of BAT technology as defined by the Environmental Agency in the publication Radioactive Substances Regulation- Environmental Principles. Within the context of decommissioning this application is decided on a case-by-case basis and is featured in the decommissioning plan since future developments produce improved or alternative BAT technologies. This application is also of particular merit for waste reduction as outlined in the document GDA UK EPR – Integrated Waste Strategy Document (reference [4]).The above design principles are in line with IAEA TECDOC documentation in preparation; EPR design takes particular account of the following factors:

- Provision in the design for easy and safe access for maintenance and for final dismantling
- Provides access to very large items in the plant to allow intact removal
- Ensures design and installation of pipes and ductwork to minimise hold-up and deposition of radioactive crud and dust particulates

Provides ease of chemical decontamination of primary circuits and other contaminated piping systems

These principles and design principles closely align to those described and recommended in IAEA and in the latest OECD publications (see references [1], [2] and [3]).

3. INFLUENCE OF OPERATION AND MAINTENANCE ON THE BASELINE DECOMMISSIONING APPROACH

The present section identifies the principles that should be adopted by the licensee in the operation and maintenance of the plant, that could influence from or upon the baseline decommissioning approach.

Design of the EPR^{TM} provides for optimal operation and maintenance work of the reactor. This will then be beneficial for later decommissioning tasks. However, in addition to these design features (provision of space, minimisation of doses, minimisation of waste...), operators have to adopt principles during the operation and maintenance tasks in order to prepare for the unit's future decommissioning.

An “all inclusive” approach is considered as the correct approach:

It starts with the availability of the required information about plant design by feasible knowledge and data transfer between the designer and the utility;

Next, is a comprehensive training programme for the future operator of the EPR to facilitate the development of knowledge, skills and attitudes required for the safe operation of the EPR. These programs are in accordance with IAEA methodologies. (Further details are provided in Chapter 8 of the present report)

Further considerations are given to:

- the needs of plant configuration management
- complete and accurate records keeping (e.g. physical and radiological configuration, leaks and other contamination incidents) on an ongoing basis (more details are covered in Chapter 8 of the present report.)

As a result, updates of the decommissioning plan have to be based on:

- changes to the plant as recorded in the documentation of the EPR
- records of environmental monitoring (especially for the soil and groundwater),
- site history from regular surveys,
- maintenance works (identification of modifications/improvements to the initial design),
- incidents (e.g. spills or releases).

Preservation of the records of the physical configuration during the whole life of the plant requires clear definition of the storage media for records and of long-term responsibilities for maintenance of the records.

More details relating to preservation of knowledge and records are provided in Chapter 8 of the present report.)

In addition, involvement of some of the operating team in the preparation of the decommissioning plan and in future decommissioning needs to be considered and anticipated.

In order to complete these records, plant operators need to give special attention to the collection and preservation of the information, in particular for contamination events that could have an impact on the demolition of the concrete structure. In addition, good working practices have to be considered in order to deal immediately with contamination from spills and leakage, and to respect delineation of zones and barriers.

Moreover, principles adopted for the reactor design have to be adapted to the operation and maintenance work and during the design and implementation process of modification of the facility; indeed these tasks have to be completed having in mind to address material selection for reduced dose rates, good surface finishing to facilitate decontamination of materials and keeping accessibility for removal of plant components.

Baseline of the decommissioning approach is to remove dose and contamination as soon as possible by proceeding from removal of high activity to low – this takes account of the building layout by starting from the reactor building and advancing to the outside to the safeguards and auxiliary buildings, for instance. Facilities such as workshops for repairs, decontamination, cleanliness zoning and ventilation are used for this purpose.

Such a baseline takes account that the EPR and auxiliary facilities are designed and operated to enable safe decommissioning. The decommissioning strategy will be harmonised with other on-site strategies, if relevant, and performed as soon as is reasonably practicable by considering pertinent factors. The decommissioning plan must be prepared and regularly updated to demonstrate continued safe decommissioning, which also includes the records mentioned above.

Finally, dismantling lessons from other similar plants should be incorporated during the whole lifecycle of the plant (see Section 5). The operator organisation (in charge of the updates of the decommissioning plan) has to be managed in order to allow, through systematic approaches, collection, analysis and recording of dismantling experience.

4. BASELINE PRINCIPLES TO BE ADOPTED DURING DECOMMISSIONING

The baseline principles for the decommissioning activities of a UK EPR are similar to those for the decommissioning of any other reactor. As such, in order to adequately manage the decommissioning process and to prepare plans and proposals for the decommissioning of an EPR, the following baseline principles should be adopted:

i) The safety of the public, staff and plant, and the protection of the environment are of paramount importance throughout all decommissioning activities.

ii) Decommissioning wastes will be managed in accordance with the Corporate Radioactive Waste Management Strategy, with particular focus on recycling and reprocessing of the nuclear wastes in order to reduce disposal volume.

iii) Full cognisance will be taken of all relevant environmental and decommissioning legislation (radioprotection, safety, wastes, environment), regulations and guidance in the management of decommissioning.

iv) Financial provisions for decommissioning will be made in accordance with the liabilities management agreements.

v) Required resources will be maintained and records taken during decommissioning the EPR. (See Chapter 8 of this document).

vi) Strategies, plans & programmes for decommissioning will be prepared, developed and periodically reviewed. In particular, plant management systems will be designed to include, in addition to records directly relevant to operation, other records that might be important for decommissioning. Relevant decommissioning experience should be built into the development of these aspects (see Section 5).

vii) The organisation of the decommissioning activities and the responsibilities involved will be clearly identified. In addition, items such as the following will be clarified as soon as possible before or at the beginning of the decommissioning activities.

- The end-state of the site will be identified before the beginning of the decommissioning activities;
- Reuse of existing buildings for potentially different purposes (rather than construction of new facilities) will be encouraged when possible;
- Progressive reduction and suppression of radioactivity to reduce hazards will be planned; the radiological inventory will be reduced as far as possible by removing the most irradiating equipment first;
- Handling and movements of waste packages will be planned to be minimised and to be separate from movements of personnel;
- Conventional rubble will be reused as far as possible as reinstatement material.

viii) Records (including technical specifications) and samples of the original composition of steel and concrete materials used in the plant (in particular aimed at pin-pointing such impurities creating critical radionuclides for future disposal like Cl36 or C14) will be kept to facilitate better management of radionuclide inventories.

Part of the initial design stage is to ensure retention of samples of concrete, steel and other structures specified for the internals and structures around the reactor in order to facilitate analysis for predicting the future inventory and to compare with the final status.

ix) Decommissioning activities will be planned and anticipated as soon as possible before the end of the operating life of the facility. In particular, it is estimated that the decision on the strategy prior to definitive shutdown of the unit must be taken at least 10 years before the estimated date of the final unit shutdown. This is particularly relevant regarding the calculation of the last fuel cycles and treatment of objects stored in the pool of the EPR fuel building prior to removal.

x) Dose to workers during decommissioning activities are reduced by limiting time spent in or near contaminated areas or active items by the use of shielding, if deemed necessary. Dismantling principles are:

- In contact /remotely in air/ under water

- dismantling of strongly and moderately activated components remotely under water

- dismantling of contaminated components in contact with air –possibly after decontamination

o Cutting according to separation requirements with respect to radiological classification and packaging

o Use of proven technologies applied worldwide at the time of decommissioning for similar operations.

Currently available techniques are applicable to the EPR design but are subject to adjustment for future evolution of technologies prior to reactor dismantling.

5. OPERATOR LEARNING FROM EXPERIENCE

During the whole lifecycle of the facility, principles will be in place to encourage and facilitate the operator to learn from experience, to exercise industrial good practice and to obtain guidance. These principles can include (but not only) some or all of the following:

- Employment of Suitably Qualified and Experienced Personnel (SQEP). In particular, suitable and sufficient capability to allow the Utility to function as an intelligent customer will be demonstrated for work that is to be carried out by external contractors. Competence needs for personnel responsible for undertaking decommissioning activities, including contractors, will be identified and personnel will receive suitable training for carrying out their duties. Special attention will be paid to train the personnel regarding awareness of working in a nuclear environment, radiation protection, required caution concerning dose, contamination and reduction of exposure to these.

- Maintenance of knowledge of best practice in all aspects of decommissioning, in particular by:

  o Being members of collaborate organisations sharing good practice and experience (such as WANO and/ or EPRI)

  o Participating in membership of collaborative R&D organisations, such as the NDA lead Nuclear Waste Research Forum (NWRF)

  o Undertaking information exchange visits to other decommissioning sites

  o Employing suitably qualified and experienced suppliers to undertake studies and implementation of decommissioning

  o Participating in national and international conferences, seminars and workshops including other operators

  o Participating in International Organisations such as IAEA and/ or OECD for example

- Maintaining awareness of National & International Publications including OECD, IAEA, NEA, WENRA, USNRC, HMNII, EA/SEPA, NDA and Institution Journals.

- An Operational Experience Database will be maintained to record lessons learned within the organisation and internationally during the operational life of the site

Dismantling experience will be collected, analysed and recorded so that lessons learned during decommissioning activities will be incorporated in the future, in particular for the other UK EPR units.

6. ALARP CONSIDERATION

The ALARP approach for decommissioning has the objective to keep the radiation exposure of personnel during operations to a as low as reasonably practical level.

This objective is fulfilled by the following basic principles:

- Justification
- Optimisation
- Limitation (doses below regulatory values)
- Minimisation

The EPR™ design has been the result of combining the proven features of the French N4 and German Konvoi plants. As such all practical measures installed to keep doses ALARP were investigated as to their effectiveness as based on experience in these plants. Design features were retained to reduce the dose to operators and to minimise waste, when proven to be effective. In cases where no significant dose saving was apparent then this feature was removed for the EPR™ design. Only those features judged as being practical remained.

One example of this process was the thinning down of certain shield walls whose design source term had been too conservative. This had the positive effect of providing easier access to the components during maintenance and for decommissioning without incurring a dose penalty and reducing the final volume of waste at the time of decommissioning. Improved accessibility is usually linked with dose reduction. This applies to both operational maintenance and decommissioning alike.

The EPR™ operational design itself is of paramount importance in achieving doses ALARP during the entire decommissioning period.

The main philosophy behind the ALARP design is that the features reducing or avoiding operational dose due to maintenance are also those features, which assist decommissioning processes. Design provisions specific to decommissioning alone include designing structures for long-term integrity and including features aimed at minimising infiltration, containing spills and releases, and attenuating contaminant transport. All of these are features of the EPR™ design and will contribute to the ALARP consideration.

Chapter 1 - Table 1 provides information of how ALARP has been introduced into the EPR™ design on a step-by-step basis from plant generation to plant generation. The last column provides information on some of those ALARP features, which have been incorporated for the EPR™ design.

As can be seen some of those features to keep doses ALARP are lifting devices, separate access paths, platforms and widened routes.

Further examples are to be found in PCSR Chapter 20 (PCER Chapter 5).

7. KEY DESIGN FEATURES

Key design features incorporated to facilitate the principles, e.g. "decommissioning enablers" are identified in this section.

Implementation of the underlying principles is to be found in many of the key design features of the UK EPR™ that facilitate decommissioning. These are also discussed in PCSR Chapter 20 (PCER Chapter 5), sub-section 4.1.

The following information provides an overview of many key design features of the UKEPR that facilitate decommissioning:

- Building Layout
  - Non-radioactive and radioactive components as well as system trains are separated by shield walls
  - Large vessels, their pumps, and their valves are separated (three room concept)
  - Compartments are designed to make components readily accessible with clear openings (> 50 cm) around large components
  - Work/service platforms are provided at access levels and provision for lifting gear is made.
  - Compartments with potential radioactive spills are provided with decontaminable coatings to prevent liquid ingress
  - Floor loadings designed to accept contingency temporary shielding
  - Rigorous zoning according to radiation level.
  - Hot and cold leg separation walls for reactor cooling system
  - Access floor to pressuriser discharge valves
  - Access pathways and handling ability of large components
  - Provision of installation openings which may be re-opened later
  - The reactor and nuclear auxiliary building are on a separate foundation raft from that of the turbine hall

- Choice of component materials
  - Minimisation in the level of impurities, notably Co, in steel alloys which are prone to neutron activation.
  - Use of high strength Zircalloy for fuel assembly cladding
  - Limitation on the use of Stellite™ for valve seats
  - Exclusion of Ag and Sb in seals and bearings
- Equipment design
  - One piece removal of main primary components
  - Ability to remove equipment without demolition work or prior removal of other components
  - In-core instrumentation through RPV head
  - Use of modular thermal insulation
  - Use of bolted support flanges instead of welded ones
  - Reduction of retention zones, improved drainage
  - Decontamination nozzles are provided on large components

Some detailed examples are provided in Chapter 1 - Figures 1 to 6, to illustrate some of the above key layout design features. Other examples will be found in Chapter 2 of the present report, in the sections dealing with decommissioning logistics.

8. REFERENCES

[1] TRS no. 382 1997, Design and Construction of Nuclear Power Plants to Facilitate Decommissioning.

[2] OECD 2010, Decommissioning Considerations for New Nuclear Power Plants, NEA No. 6833

[3] OECD 2010, Applying Decommissioning Experience to the Design and Operation of New Nuclear Power Plants, NEA No. 6924

[4] EDF/AREVA, GDA UK EPR – Integrated Waste Strategy Document, UKEPR-0010-001

CHAPTER 1 - TABLE 1

Essential Improvements of Building Construction relevant to Radiation Protection

Improvement steps in older designs			N4/Konvoi	EPR
- SG separated from RCP motor - loop valve compartment - loop-specific stairwell - separated access paths - separated transducer compartment - HP cooler separated from recuperative heat exchanger	- separation of hot leg of loop from cold leg	- residual heat removal pumps separated from valves	- tanks/vessels usually set separately (e.g. liquid waste, coolant) - shielded safety injection pump - improved shielding for HP cooler, recuperative heat exchangers, fuel pool and residual heat removal pumps (accessibility after accidents) - additional pipe ducts	- provision of a core catcher for the severe accident - creation of safeguards building to provide protection and allow accessibility after an accident - provision of APC shell - provision of IRWST
- High-radioactive tanks/vessels set up separately (e.g. Ion-exchanger) - Medium-radioactive tanks/vessels set up in pairs (e.g. coolant tanks) - Separation of medium low-level waste	- separate access for high radiation tanks (shield brick openings	- avoidance of shielding block openings (labyrinths, shield doors)	- separate access paths of many levels (avoidance of ladders) - no shield block walls - widened transport and construction routes - stationary platforms in the auxiliary building (large tanks/vessels)	- removable slabs to enable large component replacement - increased separation of highly active components, e. g in the region of the pressuriser where a new concrete floor is provided
- common access to tank rooms				-
- mostly ladders for internal stairs				-
	- fixed installed platforms at SGs and loops	- increase of inspection platforms in the auxiliary building		-

CHAPTER 1 - FIGURE 1

Example of accessibility

{ CCI removed }[a]

CHAPTER 1 - FIGURE 2

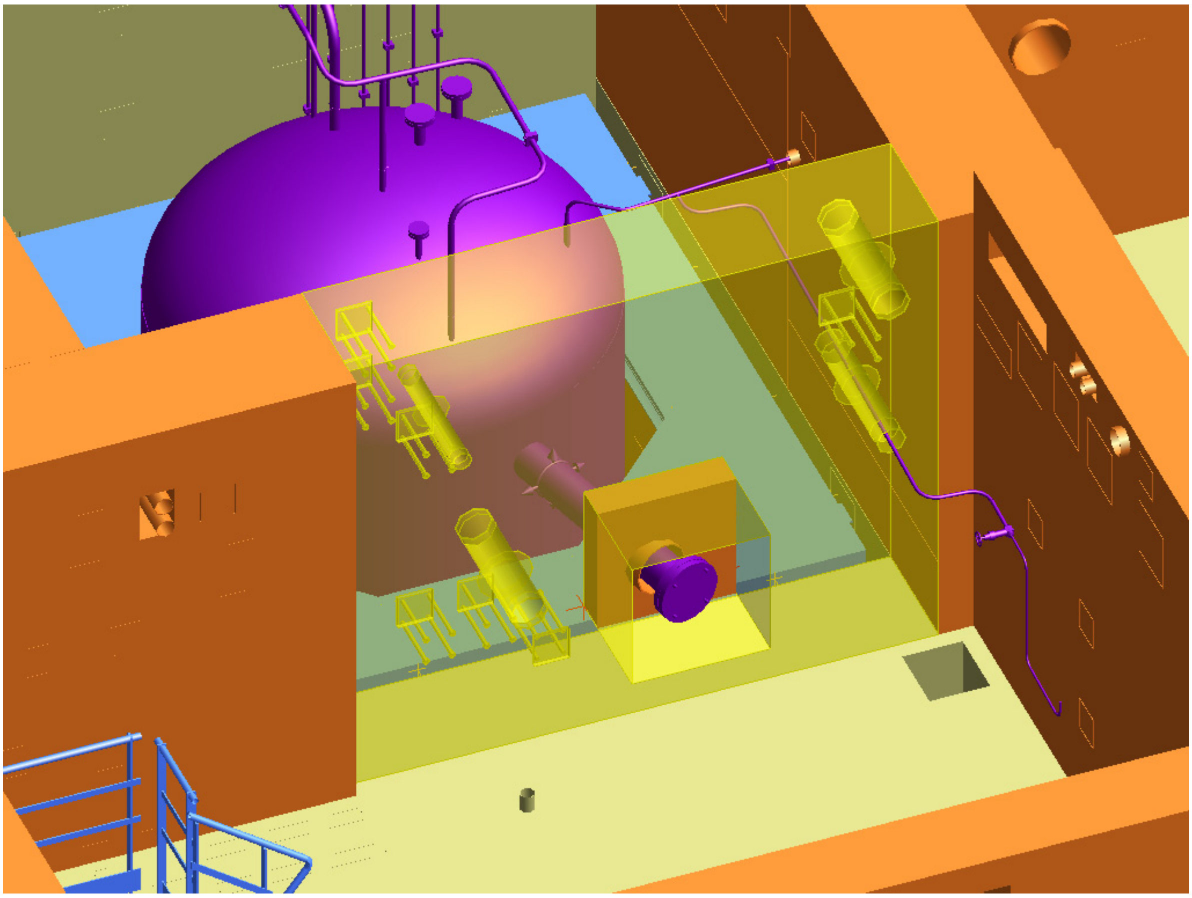
Example of accessibility:

{ CCI removed }[a]

CHAPTER 1 - FIGURE 3

Examples of decontamination nozzles

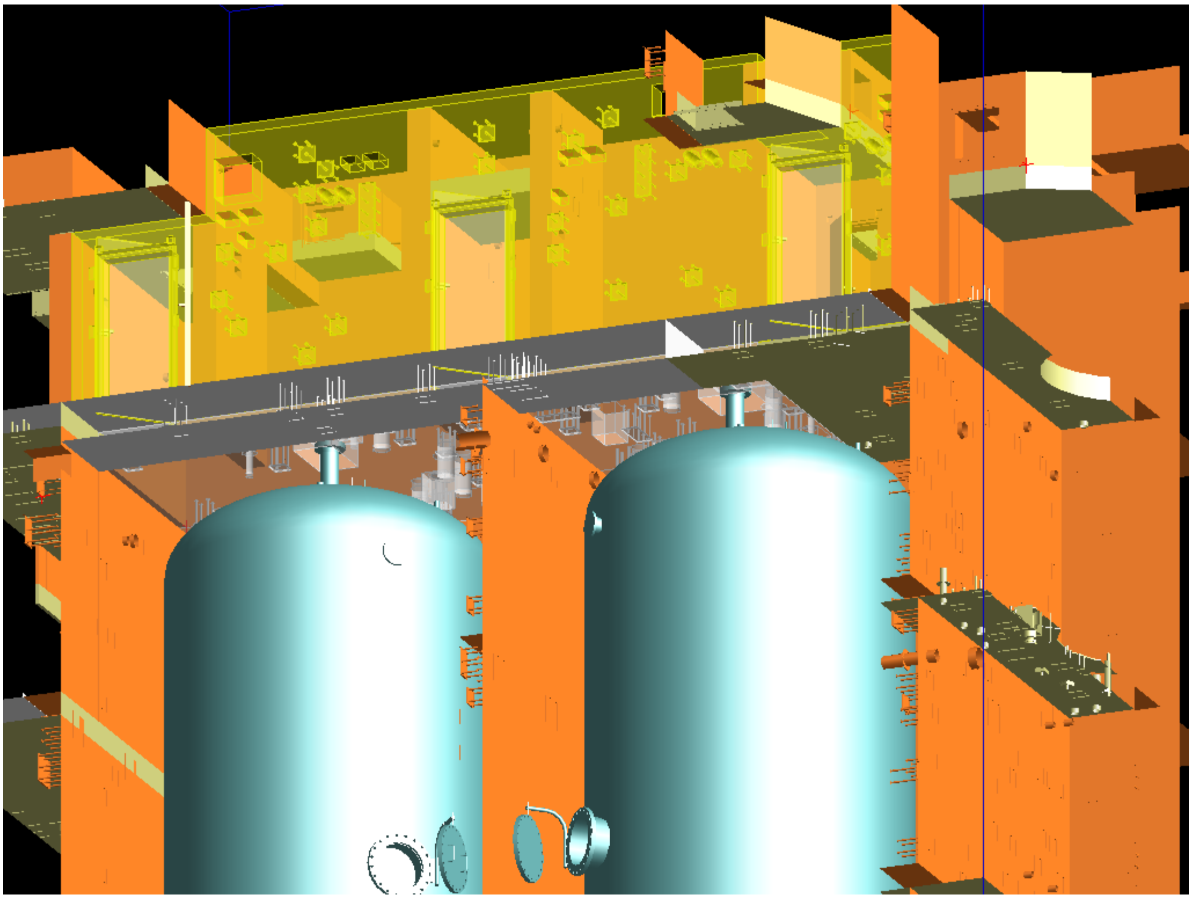
The following pictures (Chapter 1 - Figures 3 and 4) have been taken from a 3D model for some of the large vessels



Decontamination nozzle on the Volume Control Tank
(Large lateral pipe)

CHAPTER 1 - FIGURE 4

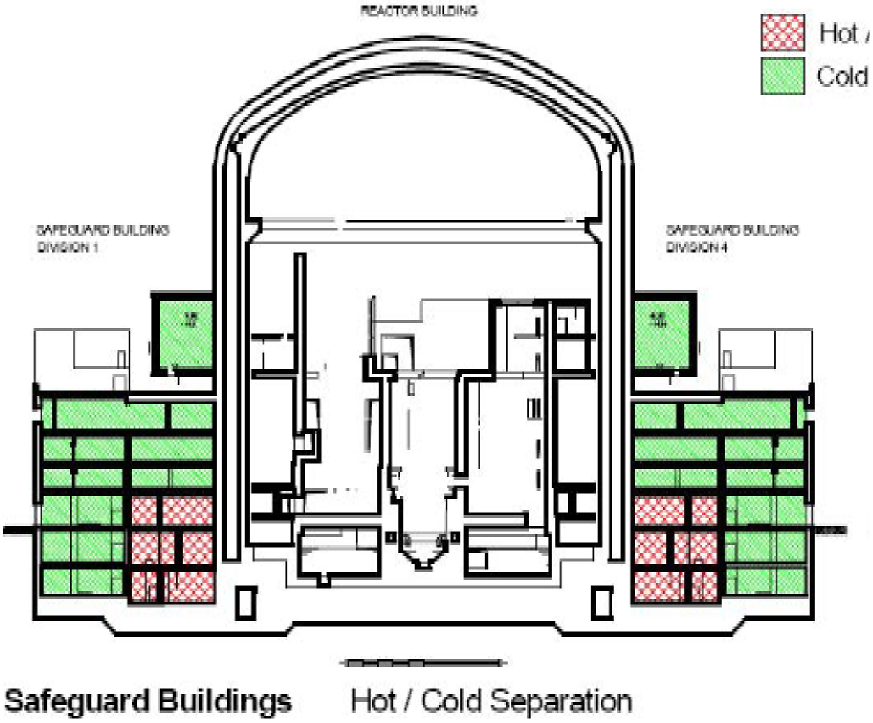
Examples of decontamination nozzles



Decontamination nozzles on the boric acid storage tank (Vertical pipes)

CHAPTER 1 - FIGURE 5

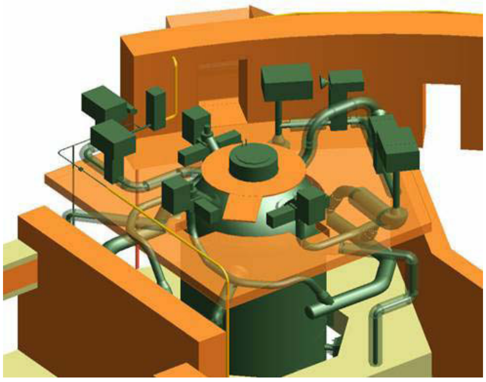
Hot and cold separation

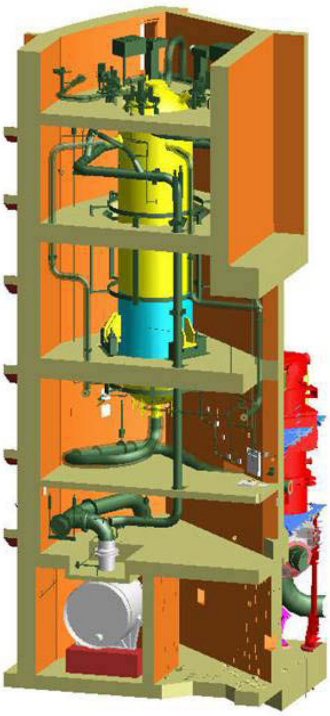


This illustrates the strict separation within a building complex of the non-radioactive systems and radioactive systems. This facilitates dismantling, in this case, of the safeguards building.

CHAPTER 1 - FIGURE 6

Access floor to pressuriser discharge valves





The excerpt clearly shows the direct access to allow easier removal of these relatively highly contaminated valves.

CHAPTER 2 – TABLE OF CONTENTS

1. INTRODUCTION

This chapter provides EDF/AREVA strategic options, envisaged decommissioning sequence and methodology including considerations such as decontamination, space, access and infrastructure requirements (Section 2). It shows how the decommissioning will proceed throughout the plant, with some focus on the primary circuit and reactor building deconstruction. In addition decommissioning principles for the ILW and SF storage facilities are provided. Immediate decommissioning of the facilities is considered i.e. after 60 years of operation for the reactor and 100 years of operation for ILW and SF storage facilities.

Safety is an important issue to be considered during decommissioning. This chapter shows (i) how shielding and containment design are effective during the logical sequence of the decommissioning (Section 3); (ii) how the major steps of the decommissioning sequence allow progressive reduction of the radiological hazards, the criticality risk and contamination risks (Section 4).

This chapter also shows how design and construction processes allow:

- the preferred decommissioning scenario of the most activated and contaminated equipment to be completed in a safe manner,
- the installation of dedicated dismantling sites within the premises to deal with the other components in a progressive and safe manner (Section 5).

Technologies associated with the scenario are indicated, showing that the decommissioning can be carried out using current available technologies (Section 6).

Main safety systems required for the decommissioning are identified; indication is given on how their availability will be ensured, or alternatively how their safety function will be delivered by evolution / replacement during the decommissioning sequence (Section 7).

Finally, in relation with design principles, the sequence allowing the management of the contamination risk during decommissioning is indicated (Section 8).

2. DESCRIPTION OF THE DECOMMISSIONING SCENARIO

2.1. INITIAL STATUS OF THE PLANT

The initial status of the plant is defined in Chapter 5 of the present report.

2.2. DECOMMISSIONING SEQUENCE

The decommissioning of a nuclear facility comprises several technical operations and administrative processes which end point is return of the facility to a ‘brownfield site’.

The following decommissioning sequence applies and may proceed following regulatory consent to proceed:

- Removal of fissile materials and radioactive liquids; post shutdown but with the nuclear systems still operational, and in-situ decontamination of primary circuit. The removal of fissile and radioactive materials, radioactive liquids and most of the contamination eliminates the largest part of the radiological hazard.

- Depending on the technical requirements, demolition or refurbishment of the conventional facilities of the unit and construction of decommissioning specific service facilities.

- Dismantling of the activated and contaminated equipment and structures.

- Demolishing and removal of what remains of the facility to a pre-defined end state, which has been discussed and agreed with the Regulators and local planning officers (partial or total de-licensing). In the current strategy the end state (brown-field) is assumed to include the radiological decontamination of all buildings and their demolition to one metre below ground level, then backfill and grading of voids.

Generally speaking, the overall decommissioning scenario takes into account the "Cleanliness/Waste" zoning of the units defined initially for the reactor operation (in line with reference [2] as explained in Chapter 5). This zoning will be amended with operation historic using events records collected.

The status of this zoning at the end of plant operation (corresponding to the beginning of plant decommissioning) will be reviewed in order to define the detailed decommissioning sequence. First priority will be given to work in conventional rooms/areas in order to avoid contamination risk arising from external works and to free space for the access, circulation and installation of decommissioning sites in the active areas.

2.3. DECOMMISSIONING METHODOLOGY

The scenario for the complete reactor site dismantling is based on:

- Use of currently practiced, realistic and achievable operations and techniques, which enable the control of the dismantling. Feasibility is demonstrated through the use of techniques and/or scenarios validated in projects both ongoing and completed worldwide.

- Technical choices and operation modes reducing radiation doses to operators and members of the public:

- Minimisation of doses to operators (limitation of required personnel, limitation of work at contact, minimisation of the duration of operation, use of mobile radiological shielding protection, decontamination),

- Use as far as practicable of service such as static and/or dynamic containment to minimise contamination risks,

- Limitation of technical risk by using existing and proven technologies at the time of decommissioning,

- Management of the waste and minimisation of secondary waste generated.

Strategic options for decommissioning will be developed and refined during the operational phase of the EPR through dialogue with the relevant regulators. The experience gained from other decommissioning and dismantling projects will also be taken into account.

The wastes produced by these operations will be removed from the site, possibly after interim storage on site. This will be the case for ILW produced during the decommissioning of the reactor and stored in the ILW Storage Facility on site prior to their transport to the GDF. No significant quantities of ILW should be generated during the decommissioning of the Interim Storage Facilities (spent fuel and ILW). LLW and VLLW potentially generated (depending of storage technology – see Chapter 6 of the present report) will be removed from site without the need for interim storage.

The dismantling of the EPR is based on the following methodologies:

- Remote dismantling of highly and moderately activated components under water. The reactor core components, especially the neutron shield, have been designed for ease of dismantling and removal (see here after).

- Dismantling of contaminated components and slightly activated components in contact with air.

- Dismantling will make maximum use of the EPR static and dynamic containment. The access routes to the reactor containment building have been designed to allow import of dismantling equipment and export of large components.

- Use of auxiliary buildings refurbished especially for the dismantling (and complying with the safety requirements). Once the reactor has been shut down and fuel removed from the Nuclear Island, redundant auxiliary buildings can be refurbished to support decommissioning and waste management; this will be the case for the Turbine hall.

- Cutting of components in order to separate and categorise waste with respect to waste classification and to provide size reduced pieces, which are compatible with the designated packaging while minimising the packed waste volume.

- Main Coolant Pipes and Reactor Coolant Pumps are removed from their location inside the Reactor Building to a workshop at the building floor service or in auxiliary buildings in order to be size reduced for packaging.

- Removal of the Steam Generators as complete units from their respective shielded enclosures (“pillboxes”) to a waste processing facility outside of the Reactor Building (possibly in the Turbine Hall). The design and installation of large components, particularly the steam generators, reactor coolant pumps and the pressuriser, allow their reverse handling and transportation operations; thereby providing the possibility of removing them from the Reactor Building in one single piece, if that strategy is adopted.

- The polar crane within the reactor building has been designed for the handling of heavy equipment and reactor components during decommissioning. Lighter components can be handled by other means specific to the task and potentially added during the decommissioning stage.

In term of decontamination, the following methodology is envisaged:

- Preliminary decontamination process as scheduled for the full primary circuit, using for instance a process known as CORD-UV. The process will be performed on the intact primary circuit after defuelling.

- Item specific decontamination will be performed either in-situ or in a workshop in order to allow some reclassification of waste and potentially recycling or release as exempt waste (on a case-by-case basis).

2.4. DECOMMISSIONING SCENARIO

At the present time, the baseline scenario for decommissioning and dismantling can be defined as follows (for more information, see Chapter 7 of the present report):

- Pre-decommissioning studies (preparation studies and application for final shutdown/ demolition order) in support of safety and environmental submissions to the regulators.

- Final shutdown activities focused on the last updates of records and inventories, the preparation of functional simplifications (an iterative process which has to be repeated during the whole decommissioning sequence) and the planning of the removal tasks for the spent fuel present in the reactor and in the Fuel Building.

- Chemical decontamination of the reactor coolant system immediately after the reactor shutdown and removal of fuel from the reactor vessel, while reactor's safety systems are still fully operational.

- Preparatory works within the Conventional Island and non-nuclear part of the plant starting immediately after permanent plant shutdown. Existing buildings and systems are re-used for decommissioning activities when possible, in particular:

    - After dismantling of the electromechanical equipment, the Turbine Hall could be converted into a workshop (size reduction and characterisation of large components) and an interim buffer storage area for LLW and VLLW.

    - Use of the IRWST for Reactor Building dismantling.

- Decommissioning of the nuclear island (NI) mainly constituted of the Reactor Building (RB), Fuel Building (FB), Nuclear Auxiliary Building (NAB), Safeguard Building (SB) and the Effluent Treatment Building (ETB) in the following sequence:

    - Within each building, dismantling of the electromechanical equipment before clean-up and final demolition,

    - Between dismantling of the different buildings, the following sequences have to be considered:

    - Dismantling of the RB, followed by dismantling of the NAB if the following conditions are reached:

        - All the spent fuel has been removed from the FB and transported to the Interim Storage Facility on site,

- Completion of under water dismantling (reactor vessel),
- Completion of final dismantling of the SB (safeguard then electrical part).

o Dismantling of the FB to parallel of the dismantling of the RB after completion of spent fuel removal.

o Dismantling of the ventilation, filtration and gaseous discharges treatment systems of the NAB and of the ETB after completion of dismantling and clean-up of all the buildings of the NI.

o Once dismantling operations have been completed, demolition of the Nuclear Island buildings will take place in parallel.

- After their interim storage on site, export of the ILW packages and SF from their Interim Storage Facilities to the dedicated geological depository.
- Decommissioning of each ISF as soon as the corresponding last package has been exported.

This baseline scenario can be adapted to include additional options that can be considered as shown in the SRWSR document (ref. [1]). They are not discussed in the present report.

The dismantling scenario for the primary circuit, where components have the greatest potential to become activated or contaminated, is as follows:

- Preliminary decontamination of the primary circuit (e.g. with CORD-UV type process) in order to:
  - o Reduce the dose rate and exposure to decommissioning workers in later decommissioning steps.
  - o Reduce dose rates to allow contact (“hands-on”) dismantling of many of the primary circuit components.
  - o Minimise volume of packed waste (reduction of required biological shielding) by removal and concentration of activity, taking account of the production of secondary waste (e.g. ion exchange resins).
- Preparation of primary circuit dismantling, dismantling of last auxiliary pipes;
- Export of the steam generators out of the RB for dismantling in a dedicated workshop;
- Export and dismantling of the reactor coolant pumps;
- Dismantling and export of the main coolant pipes;
- Export and dismantling of the pressuriser;
- Preparation and dismantling of internals in the reactor pool under water:
  - o Removal of reactor vessel head before filling the reactor pool

- Water level adjusting,
- Dismantling of upper core internals on its storage stand,
- Dismantling of thermal shield,
- Dismantling of lower core internals on its storage stand,

- Dismantling of reactor pressure vessel;
- Dismantling of reactor vessel head (if not removed and packaged in one piece);
- Dismantling of activated part of the reactor pit (approx. the first 60cm at the level of the reactor core);
- End of primary circuit dismantling
- Radiological decontamination and demolition of the buildings.

In order to complete the dismantling of the primary circuit, after the decontamination phase which requires maintaining the reactor fully operational, it is necessary to maintain (or make available through preliminary decommissioning tasks) the following nuclear installations and systems:

- The RB ventilation system in order to fulfil the needs of ventilation and dynamic containment of the in-situ workshops,
- The necessary handling devices used during operation of the reactor (in addition to the required temporary devices discussed previously): polar crane, fuel loading machine, various lighter handling devices,
- Space on the RB service floor (level 19.50m) necessary to install dismantling and packaging workshops,
- The treatment (purification, cooling) of the water of RB pool,
- The various utilities, such as breathable air, compressed air, electricity.

In order to illustrate this dismantling scenario, a focus is made here after on 3 particular and representative operations:

- Primary decontamination of the full primary circuit,
- Removal of SGs from the RB (for later dismantling in a dedicated workshop installed potentially within the turbine hall premise),
- Dismantling of reactor vessel internals under water,
- Dismantling of the reactor vessel under water.

2.4.1. Preliminary decontamination of the full primary circuit

Currently the HP/CORD-UV process, which is used worldwide, is envisaged for this operation. Operational experience worldwide will be taken into account in making the final choice of the decontamination technique that is used. The principles of this process are the following:

- Chemical decontamination process which removes the oxide layers present by controlled dissolution of a layer of base metal material, using:
  - Permanganic acid as oxidising agent,
  - Organic acids to dissolve corrosion products and associated activity.
- Use of UV wet oxidation (decomposition of the organic decontamination chemicals by UV-light source) and ion exchange (by-pass clean-up by ion exchange resins during the decontamination step) minimises the amount of secondary waste produced.
- Completion of the entire decontamination with only one fill of water as the circulation water is cleaned by ion exchange.
- Multi-cycle process: cycle sequence of the decontamination (pre-oxidation, reduction, decontamination, chemical decontamination) may be repeated until the activity is removed and fixed on ion exchange resins (Number of cycle adjustable - typical 1 or 4 – adapted to the decontamination targets) - See Chapter 6 of the present document.

The advantages of CORD process are the following:

- Details of applied process are developed site specific,
- Regenerative process with minimum waste generation (very important especially for large scale decontaminations with high system volumes) ➔ about 35 m^3 of resins / 370 drums produced to decontaminate primary circuit of one EPR on an assumed basis of 4 cycles,
- Reduction of the individual and total doses for decommissioning work with high decontamination factors achievable➔ Typical decontamination factor achieved: 30 (auxiliary systems), 75 to 750 (primary loops), 160 to 1400 (SG tubes),
- Operation duration limited to some days to few weeks depending on the number of cycles,
- Use of plant equipment (i.e. reactor coolant pumps) for heating and circulation of decontamination solution),
- CORD components are modular, skid mounted, and adaptable to space requirement.

{ CCI removed }[a]

2.4.2. SGs removal from the RB

Removal of the SGs from the RB requires some preparatory works in order to manage access routes and position handling devices.

Indeed, some of the handling equipment used during the erection of the reactor is not maintained in place during the 60-year operation of the reactor.

{ CCI removed }[a]

{ CCI removed }[a]

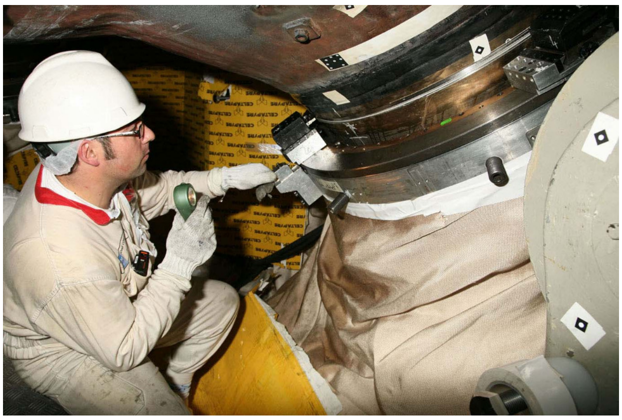
{ CCI removed }[a]

In addition, some civil works are necessary in order to:

- Re-open the access wall to the level 19.50m of the material lock,
- Remove the upper part of the concrete biological wall blocks constituting the SG pillboxes.

The operation to remove each SG from the RB comprises:

- Cutting of the primary pipes (hot and cross-over (U) legs) after the positioning of the same system as the one used for SG replacement completed for currently operated plants (see figure below),



- Removal from top to bottom of the successive floors,
- Wedging of the SG and bracing of its vertical supports,
- Removal of SG lower and upper horizontal restraints,
- Freeing of the SG from its vertical supports,

- Lifting of the SG,
- Extraction of the SG from its pillbox,
- Tipping from vertical to horizontal position within the containment,

{ CCI removed }[a]

- Transfer through the material lock, the SG being positioned on skidding saddles,
- Lifting down of the SG and positioning on a trailer,
- Transport to the dismantling workshop.

2.4.3. Dismantling of reactor vessel internals

Reactor vessel internals, located in the vicinity of the core, comprise the most activated parts of the reactor.

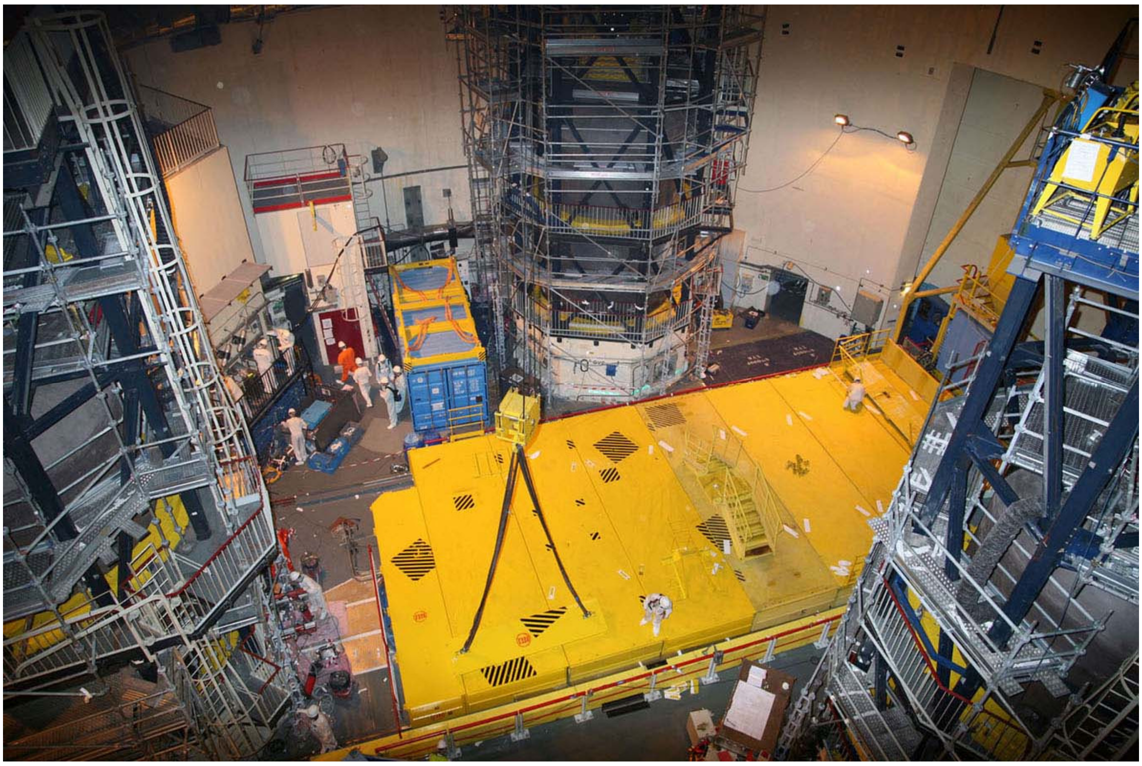
The dismantling of the reactor vessel internals is completed under water in the reactor building pool, in the internals compartment, using cutting systems operated from the fuel loading machine platform or from a dedicated transborder.

The envisaged scenario makes use of cold cutting techniques (with disassembly operations if possible) enabling the limitation of the spread of contamination and associated risks. Similar dismantling projects completed by AREVA in Germany are proof of the technological feasibility of this approach.

The cutting sequence allows the segregation of the waste by class (ILW for the bottom part of upper internal and central part of the lower internal, LLW for the rest of upper internal and the bottom and the higher part of lower internal) while producing waste compatible with the corresponding packaging (size reduction, limitation of waste volume). ILW is packaged under water, LLW in an area installed on the reactor service floor (level +19.50m). In order to illustrate the availability of adequate space for dismantling, the plan below shows specific areas to perform dismantling activities. Additional space along with adequate worker protection is provided for dismantling and installing waste processing workshops on the operating floor above the reactor pool and close to the materials hatch. The set down area behind the equipment hatch provides working areas and a direct exit to the site.

{ CCI removed }[a]

In addition, for other dismantling operations within the Reactor Building, working floor can be installed on the reactor pool itself in a similar manner than the one applied for SGs replacement as shown one the following picture (taken during an operation in a 900MWe PWR).



Prior to the dismantling of the vessel internals, corresponding upper and lower internals storage stands (used during plant operation) are modified in order to be able to support the component during the whole cutting sequence.

The first operation is the dismantling of the upper internal. After transfer from the vessel to its storage stand with the internals lifting device (as during plant operation), the cutting sequence can begin. One possible scenario is the following:

- Cutting of the guide tubes and columns with an alternating saw (freeing from the whole structure), then a band saw (sizing prior packaging); a compactor can also be used for waste volume minimisation.

- Cutting of the upper support plate and the upper core plate using a very high pressure abrasive water jet technique installed in a containment tank in the pool; a water treatment system is associated with this tank.

After completion of the dismantling of the upper internal, the scenario continues with the dismantling of the lower internal. After transfer from the vessel to its storage stand with the internals lifting device (as during plant operation), the cutting sequence can begin. One possible scenario is the following:

- Cutting of core barrel shell and heavy reflector using a band saw, heavy reflector being partially disassembled (constituted of 12 slabs).

- Cutting of lower support plate using water jet cutting technique.

- Complementary cuts are made with alternative saw and shear.

2.4.4. Dismantling of reactor vessel

{ CCI removed }[b]

{ CCI removed }[b]

2.5. FINAL STATUS OF THE PLANT

The final status of the plant corresponds to the demolition and removal of what remains of the facility to a pre-defined end state which has been discussed and agreed with the Regulators and local planning officers. In the current strategy the end state is assumed to include the radiological decontamination of all buildings and their demolition to one meter below ground level, i.e. return to brown-field site.

Depending on future use of the site, the final status environmental monitoring could be defined as similar to the baseline characterisation of the site completed during construction. A baseline survey of the facility will then be undertaken prior to operation, to facilitate, following completion of decommissioning, verification of compliance with the site release criteria established by the regulatory authorities.

3. SHIELDING AND CONTAINMENT REQUIREMENTS

The decommissioning scenario described in the previous section takes advantages of the EPR reactor design to provide most of the shielding and containment requirements. Additional light means or adaptation of systems used during operation of the reactor will be potentially needed and put in place on a case by case basis for some specific dismantling operations. Additional means correspond to a set of mobile devices (local ventilation/filtration, shielding, and containment) that will be moved in the building, following the progress of the decommissioning.

Effective shielding and containment will then be provided throughout the decommissioning sequence by means for:

- Shielding requirements:
  - Dismantling of the most activated components (reactor vessel internals) under water in the reactor pool.
  - Concrete walls separating equipment will provide shielding to protect operators from dose present in the vicinity of the area where the decommissioning operations are in progress.
  - Additional mobile shielding e.g. steel plates will be provided if needed, on a case-by-case basis (using an ALARA approach), depending on the specific radiological situation of the decommissioning activity in progress. Similarly, decontamination tasks will be completed when adequate prior to the decommissioning task itself.
- Containment requirements:
  - As far as possible, the containment and ventilation systems used during the operational life of the plant will be reused, sometimes after adaptation to the specific risks. In particular, the static containment provided by each nuclear building will be kept operational till the end of its clean-up following the dismantling of its electromechanical equipment. Indeed, demolition of the building is scheduled at the latest.
  - Dedicated working areas will be installed, within the room/area being decommissioned, on a case-by-case basis (ALARA approach) to create the necessary containment, either for static requirements (vinyl tents...) or dynamic ones (mobile ventilation and filtration unit). Similarly, decontamination will be completed when appropriate prior to the decommissioning task itself to minimise internal radiation exposure of the operators and the spread of contamination.
  - Containment within the buildings or the galleries of any radioactive liquid substance resulting from leaks and from internal flooding is ensure by the design of the EPR; this allows the completion of the dismantling operations in particular for the reactor internals under water in the reactor pool while managing suitable effluent treatment.

In addition, regular surveys are scheduled during the operation of the EPR; they will allow, by extrapolation prior to decommissioning:

- Verification of the adequacy of shielding and containment requirements,
- Identification of the potential needs of modification/improvement or of decontamination.

4. REDUCTION OF HAZARDS DURING THE DECOMMISSIONING

During operation of a nuclear facility, and particularly in the case of a nuclear power plant, the primary hazards are associated with the nuclear fission process. Safe operation requires careful control of the reactor core operation and cooling, prevention of accidental criticality and avoidance of exposure of operators to the high levels of radiation associated with these activities.

After a nuclear facility is shut down for the last time, the next steps involve reducing the sources of hazard in a systematic and progressive way. This involves removal of as much of the nuclear material as possible. In the EPR, for example, it involves removal of irradiated fuel from the reactor and from spent fuel pools, the drainage of equipment containing radioactive materials and removal of any residual radioactive waste. The removal of fuel from the reactor is the most significant step in hazard reduction as the inventory of radioactive material present is reduced to less than 1% of the operational level. In addition to reducing the major source of radiological hazard, other hazards such as those associated with operations at high temperatures and pressures are also reduced.

Although the main source of radiological hazard is substantially reduced and the associated risk is correspondingly lower, rigorous radiological control and worker protection is still necessary during decommissioning.

However, it is necessary to recognise that the inherent need to remove safety systems from service progressively and to destroy confinement barriers, in order to achieve the long-term reduction in hazard, can temporarily increase the short-term hazards. These hazards are assessed and managed as part of the decommissioning process.

The key issue in the decommissioning of nuclear facilities is the progressive removal of hazards, by way of a series of decontamination and dismantling activities that have to be carried out safely and within the boundaries of an approved safety case; during the dismantling phase, the required safety functions to be ensured are the containment of radioactive materials and the minimisation of radiation doses to members of the public.

It is clear, therefore, that the activities connected with the process of decommissioning are rather different from the day-to-day activities on an operating plant in steady state. Moreover, they vary and change progressively as the decommissioning process progresses.

One of the major changes associated with transition from operation to decommissioning is the need for additional emphasis on non-radiological hazards. This is because many of the decommissioning activities are typically industrial processes, and the hazards associated with them are the conventional hazards of fire, explosion, toxic or hazardous materials, and the electrical and physical hazards associated with dismantling plant and with lifting and moving large structures or items of equipment – See Chapter 4 of the present report.

Compared to those considerations, which are related to the EPR, the decommissioning of the ISF for the SF and ILW is relatively simple. Indeed, the radiological hazards are dramatically reduced after the export of the stored packages, which contained the radioactive material in safe conditions. Depending of the storage technology considered (See Chapter 6 of the present report), the radiological hazards, if any, are then limited to the presence of contamination The main hazards requiring protection against will be the conventional hazards.

4.1. CRITICALITY

There is no possibility of an accidental criticality in a shutdown nuclear reactor from which the fuel elements have been completely removed, including from associated stores.

The criticality risk is thus removed in the RB after last fuel transfer to the FB, and in the FB after the last export to the Spent Fuel Interim Storage Facility.

The design of the SF ISF (with associated racks, packages or canisters) will ensure safe operation of the storage on site e.g. by preventing criticality incident prior to the final export to the final repository.

Safety management will ensure appropriate measures are taken until the fuel leaves the site.

4.2. EXPOSURE TO DIRECT RADIATION

As a general requirement, the established dose limits must be fulfilled and applicable dose constraints should restrict the projected individual doses. The magnitude of individual doses, the number of people exposed, and the likelihood of incurring exposures should be kept as low as reasonably achievable, economic and social factors being taken into account (ALARA principle).

In situations where remote handling systems cannot be used and after all practicable steps have been taken to decontaminate an area or equipment, the exposure of staff undertaking dismantling activities from external sources should be minimised.

Some important strategic options have been taken in defining the baseline decommissioning scenario in order to address the fundamental requirement to minimise radiation doses. These are:

- Preliminary decontamination of the primary circuit in order to reduce dose rates to allow contact dismantling of many of the primary circuit components,
- Dismantling of the most activated components (reactor vessel internals and vessel) under water, in order to take advantage of the protection given by the water.

Once these operations have been completed, the exposure to direct radiation will come primarily from the contamination of equipment and installations: various local decontamination operations will be performed as soon as required either in-situ or in workshop on a case by case basis.

4.3. CONTAMINATION

As discussed previously, decontamination phases will be completed in order to facilitate access to working areas and dismantling activities and to reduce the volume of radioactive waste. This typically involves various chemical, mechanical or electrical processes or some combination of them.

Decontamination will allow the removal of removable superficial surface contamination; after decontamination, the potential for internal radiation exposure of the operators by ingestion or inhalation is minimised.

As dismantling operations progress, working areas will be installed to create the necessary containment (static and dynamic). Indeed, the possibility of inadvertent loss of containment of the radioactive materials present at a facility must be taken into account in all decommissioning tasks. This is particularly important in the retrieval of radioactive materials from the various radioactive systems of the plant, in the dismantling of its systems and in the later cleanup of areas where they were located. The containment and ventilation systems used during the operational life of a facility may be not sufficient/suitable for the all dismantling operations, and special systems/adaptations will be set up to contain and ventilate work areas, if they are required. The safety features of such special containment systems must match the hazards and radionuclides present in each area.

Additional personal operator protection will be used on a case-by-case basis, considering the level of the risk.

Finally, before any nuclear island building demolition, inducing to a loss of containment, clean-up of the building will be completed and validated by adapted measures and controls.

5. PREVENTION OF EARLY FORECLOSURE OF OPTIONS

The design of the EPR can be considered as facilitating options for decommissioning and waste management and it is important that such options are not prematurely foreclosed. The design and construction processes of the EPR will enable the preferred decommissioning scenario to be completed in a safe manner, especially for the most activated and contaminated equipment of the primary circuit located in the RB. Examples of where the design of the EPR presents a number of options are presented below:

- The design of large components to be removable in one piece for use in areas which are inaccessible because of radiation levels (see removal sequence for the SGs). This implies the use of handling processes, appropriately designed/adapted openings and access that enable the removal in a single piece and its subsequent processing in a more suitable environment. This provides the option of ex-situ size reduction in addition to in-situ size reduction.

- The design of the RB pool allows the transfer under water of the reactor vessel internals from the reactor vessel to the internals compartment. This compartment allows further dismantling of the internals under water. This provides the option of remotely operated in-situ size reduction in addition to other options such as deferred decommissioning followed by non-remotely operated size reduction once radiation levels have decreased.

- The layout of roofs, roof hatches, and building walls provides the ability to remove contaminated equipment and tanks thereby minimising the need to conduct in-situ size reduction and enabling the option of ex-situ size reduction.

It can thus be seen that the design of the EPR facilitates the provision of options by enabling prompt decommissioning as well as deferred decommissioning and in providing choices such as the ex-situ size reduction of large components. The design does not prematurely foreclose options and can be considered as providing additional options in comparison with earlier reactor designs.

The measures adopted (e.g. see Chapter 1 of the present report) to enable maintenance during operation facilitate the removal of waste. These measures, associated with an approach to decommissioning which is based on starting from the access points, provide the necessary areas for the deployment of machinery, the disassembly, the placement and processing (decontamination, cutting, etc.) of the components, and the implementation of waste measurement, packaging and characterisation facilities. This will enable:

- Installation and operation of lifting, moving, size reduction, etc equipment necessary for decommissioning activities,

- Installation of temporary systems for worker and environmental protection, such as moveable shielding, airlocks and mobile ventilation and filtration equipment, together with provision of protective personal equipment such as air suits, breathing equipment and masks. This will be achieved having in mind necessary radiological protection provisions such as:

    - Effective containment for preventing the movement and dispersion of residual contamination in facilities undergoing decommissioning. As long as possible after shutdown, dismantling activities will be organised in such a way that the original containment barriers remain operative. Otherwise, effective temporary barriers will be installed and maintained for as long as necessary to contain any residual radionuclides.

    - Ventilation systems will be continuously adapted so as to ensure, on the one hand, the integrity of the structures and equipment after permanent shutdown and partial dismantling, and, on the other hand, the containment of contamination during dismantling operations.

    - Provision of means of containment of the worn component for disposal (e.g. vinyl bag, metal container).

    - Compliance with the radiological zoning regime of the facility, where rooms, cells or areas are classified according to both contamination and radiation hazards.

    - Compliance with the principle of multiple containment barriers, for the protection of site workers and members of the public against contamination spread.

    - Sizing of circulation routes and openings in the facility appropriately so as to avoid any release of radioactive material during the removal of the worn components (and the introduction of new items).

6. TECHNOLOGY USED (CURRENT OR TO BE VALIDATED)

Decommissioning studies for the EPR decommissioning have to take into account feedback of all representative decommissioning operations completed worldwide, especially the ones related to PWR decommissioning. Indeed, even if the decommissioning conditions are not always exactly the same and directly transposable, they present some important similarities. If no typical scenario emerges, the current feedback indicates that various dismantling techniques are available and can be used, on a case-by-case basis, to perform the whole decommissioning operations.

In particular, various cutting techniques are currently available to reduce the size of the equipment. The most appropriate technique will be applied after appropriate feasibility reviews for the individual decommissioning step depending on specific physical characteristics of the piece (size, thickness, and type of material) and intervention principles.

6.1. TECHNIQUES FOR THE DISMANTLING OF THE PRIMARY AND AUXILIARY COMPONENTS

The following techniques can be used for the dismantling of the primary circuit:

- Steam generators: thermal (plasma, torch), mechanical (circular saw, band saw),
- Reactor coolant pump: thermal (plasma, torch), mechanical,
- Main Coolant Pipe: thermal (plasma), mechanical (tool used for SG replacement)
- Pressuriser: thermal (torch),
- Reactor pressure vessel internals: thermal (plasma), mechanical (circular or band saw), very high pressure/abrasive water jet,
- Pressure vessel / pressure vessel head: thermal (e.g. plasma), mechanical (e.g. circular saw),
- Reactor pressure vessel supporting ring: circular saw.

These techniques are typical also for auxiliary systems decommissioning.

Generally speaking, for all the necessary works, techniques are currently available; the issue is then to choose the most appropriate one (BAT approach) and to determine how this technique should be implemented for each specific configuration.

Should a new technology become available, appropriate feedback collection, feasibility reviews, inactive test and trials programme will be arranged to qualify the technique prior to validate its use for the decommissioning works.

In addition, various decontamination techniques are also currently available and can be used on a case-by-case basis. These will need to be adapted to the particular circumstances of the application to each EPR. For example, if the full system decontamination (as scheduled for the primary circuit) is transposable from some completed decommissioning projects, adaptations of the technique to the reactor specificities will still be required so as to adapt to the design, the contamination levels and the defined decontamination targets that are applicable to the UK-EPR and which have arisen from the operation conditions.

6.2. TECHNIQUES FOR DISMANTLING CONCRETE STRUCTURES

6.2.1. General case

Clean-up of buildings will be facilitated by the use of wall linings in the more sensitive areas. The clean-up is then completed by removal of the paint or decontamination of the steel liners. For any other non-protected concrete walls for which contamination in depth can have occurred, removal of a layer of concrete may be necessary (categorisation of the walls, floors and ceilings prior to decontamination and dismantling is detailed in Chapter 5 of the present report). Available mechanical techniques are impact breaking, mechanical chisels, shavers, high-pressure water sprayers or shot blasters. Laser is another technique currently developed.

For the cutting of concrete, various techniques can be used; the choice will be dependent of the developed demolition plan which will take into account safety, dust emission, noise reduction and, storage requirements. Demolition of the concrete structures will begin after dismantling and clean-up of building internal structures. Heavy concrete structures are typically dismantled using diamond wire cutting techniques. A structural study will be carried out before demolition to validate the demolition plan and the chosen sequence of actions. As an example, the anticipated demolition methodology for the aircraft shell, a reinforced concrete protection covering the reactor building, the fuel building and safeguard buildings 2 and 3, is the following:

- Demolition of the upper part of the aircraft shell either by a power shovel fitted with a hydraulic rock breaker, or by diamond wire sawing followed by removal of sawn blocks with a crane.
- Removal of the steel bars by oxyacetylene or by mechanical cutting.
- Demolition of the walls of the aircraft shell by a power shovel fitted with a hydraulic rock breaker or a hydraulic crusher; in this case, ramps will be constructed to reach the upper part of the structure.
- Diamond wire sawing is likely to be used to the walls into blocks of transportable size, which would then be removed by a crane.

Final complete building demolition will involve use of mechanical demolition (e.g. power shovel fitted with hydraulic rock breaker or hydraulic crusher) and some use of explosives (e.g. by micro-mining).

The same kind of approach and techniques will be used for the demolition of all the buildings.

6.2.2. Techniques for dismantling the reactor pit

For the specific dismantling of the reactor pit, experience feedback (in particular gained from sites in the US) has shown that concrete activation calculations and early characterisation surveys are very valuable prior to carrying out the decommissioning activities of the pit. In addition, feedback from the Connecticut Yankee decommissioning site in the US has shown that the presence of a Neutron Shield Tank around the active fuel region of the Reactor Vessel was effective in reducing the activation of the concrete outside of the tank. The presence of a heavy reflector in the design of the EPR reactor vessel should lead to a similar conclusion.

Depending on the levels of activation of the concrete, different methods can be envisaged for the dismantling of the reactor pit, ranging from shallow remediation techniques (concrete shavers, media blasters) to more aggressive remediation techniques such as pneumatic jackhammers, hydraulic hammers (such as the Modified Brokk Demolition Machine with Remote Control) or diamond wire cutting which is particularly effective when the concrete is very thick and when complete removal of the structure is planned. An advantage of this technique is also the preparation of the cut pieces for shipment. This technique was for example used for the dismantling of the concrete reactor vessel at Bugey in France (AGR reactor), where concrete blocks 1.1m high x 2.1m wide x 0.8m thick were produced using diamond wire sawing techniques before being directly placed into waste containers: this is consistent with what has been proposed in the EPR disposability assessment, (i.e. ILW concrete cut in blocks and placed in 4 metre boxes).

During all the cutting activities, containment will be provided to ensure that negative pressure will be maintained around the work area where cutting activities will take place. Negative pressure will be applied to the containment structure by the use of suitable ventilation system.

6.3. USE OF CURRENT EXPERIENCE

Feedback on dismantling (such as Stade, BR3, Chooz A, Würgassen, Trojan, Main Yankee, Yankee Rowe) and heavy maintenance projects show the international capabilities already available to manage the challenge represents by the decommissioning.

Feedback analysis that will be developed during the lifecycle of the facilities in parallel to the preparation of the various update of the decommissioning plan, will allow:

- Clarification of the main technical decommissioning options in terms of scenario, cutting techniques, use of radiological shielding and decontamination;
- Consideration of the evolution of usable techniques in order to control and optimise the works; in particular, these techniques should be designed in order to facilitate operations and minimise operator doses considering as far as possible, for works at contact, the following general approach:
  - Design of lightweight tools composed of subsets handled by an operator,
  - Use of systems with quick and reliable fittings,
  - Automation of tools and control devices in order to avoid presence of operators near the contaminated equipments using today’s technologies.

Taking account of the current existing technologies mentioned before, we can confirm that decommissioning of the EPR can be completed.

7. STRATEGY FOR SAFETY SYSTEMS

When a facility is shut down, the following step involves reducing or eliminating high energy sources, removing hazardous and nuclear materials, immobilising contamination to prevent uncontrolled migration, and otherwise creating a set of facility conditions that are safe and stable.

Thus, systems and major components can be viewed in three ways:

- Many will be permanently shutdown, isolated, made inoperable, and left in place waiting for their dismantling.
- Some will need to remain operational.
- A few may be mothballed for later use. The primary example is major cranes that may be useful when equipment is removed prior to demolition.

Indeed, it is essential that the machinery and facilities required for decommissioning operations are maintained (and if necessary refurbished or replaced) over the decommissioning period to ensure that operations can be carried out safely and with operational efficiency. In accordance with good engineering practice, routine maintenance, refurbishment and component replacement schedules will be determined on the basis of an understanding of the failure behaviour and useful operational lives of specific systems and will adopt an anticipatory and preventative approach.

Most importantly, these systems will be designed and installed to remain operational as long as needed and to be sufficiently maintained (or to be replaceable) and integrity and reliability commensurate with their importance to safety.

It will also be essential to maintain the availability on the facility site of:

- Diagnostic and testing facilities for equipment known to show wear-out failure mechanisms,
- Suitable workshop facilities for repair, refurbishment or replacement of faulty or age-degraded components,
- A spare parts management system with the maintained stock of items based on an understanding of the failure behaviour and useful operational life of the item and its operational and safety importance.

When a facility is decommissioned, several systems and equipment will remain operational as long as required, for example:

- Draining, filling and filtering of the spent fuel pool,
- Draining and filling of the steam generators,
- Transfers between the Reactor Building and the Fuel Building,
- Treatment of solid, liquid and gaseous waste,
- Ventilation, fire surveillance and protection,
- Radioactivity and anoxia controls, monitoring of the environment,
- Draining of cavities and floors,
- Power supply, compressed air and raw water.

The measures implemented for the related circuits and systems mean that they can be kept in service and maintained after the permanent shutdown of the reactor.

For the specific context of the Interim Storage Facilities, in addition to maintaining the condition of the waste packages over the extended storage period, it is essential that the machinery and facilities required for the handling operations are maintained (and if necessary refurbished or replaced) over the interim store's lifetime to ensure that final retrieval operations can be carried out safely and with operational efficiency. In accordance with good engineering practice, routine maintenance, refurbishment and component replacement schedules will be determined on the basis of an understanding of the failure behaviour and useful operational lives of specific systems and will adopt an anticipatory and preventative approach.

The necessity of refurbishment of the various systems will have to be determined through the analysis of the needs and the study of possible functional simplifications. The aims of these functional simplifications are:

- To allow the progress of the decommissioning operations while keeping as far as necessary existing systems and structures and minimising costs (operational, maintenance and repair costs),

- To fit with specific needs of the decommissioning works,

while permitting the progressive freeing of rooms/areas and fulfilling the safety functions required for the successive steps of the decommissioning scenario.

Functional simplifications will have to follow the sequence below:

- Analysis of the various systems/structures/components and their safety classification considering their importance in terms of decommissioning tasks; after fuel removal, this classification is mainly based on containment.

- Modification of the various operational procedures in order to take into account the functional simplifications of the related systems.

- Resizing of plant systems and structures in relation with the identified needs for the decommissioning, keeping sufficient and safe working conditions.

- Determination of the control, instrumentation and driving means necessary during the decommissioning works.

These functional simplifications will be based on the detailed decommissioning scenario that will be developed during the 60-year operation of the reactor. It is not possible to anticipate what these will be at the current stage of development of the EPR and only indicative information can be provided.

Some examples of systems/installations which are anticipated as being likely to be subject to functional simplification are given below:

- RB ventilation

  If ventilation inside the RB will be necessary for decommissioning works, global ventilation requirements will be different (in terms of flow, dispatching...) from those that were required for operation. In addition, the requirements for the decommissioning will vary in with the progress of the decommissioning activities and with the location of decommissioning workshop/areas.

It will then be necessary to adapt the ventilation system to the specific requirements of the considered task (in relation with the safety analysis and the contamination risk). In this aim, means of adaptation, connecting, adjustment, etc should be available.

- Pool water treatment

  Pool water treatment and cooling system is another system able to evolve from its initial operational function, cooling and purification of the water from the RB and the FB pools; and its could be adapted in order to separate treatment of the 2 pools (uncoupling in order to proceed to the dismantling of the equipments within these 2 buildings) and to fit with the reduced cooling and reactivity control requirements resulting from the removal of spent fuel.

- Fire surveillance and protection

  This system has to evolve in order to fit with the change in terms of risks (initiator element, calorific potential) and to be adapted to the progress of the decommissioning works and displacement of decommissioning workshop/area.

  The same approach has to be scheduled for radiological protection systems, health and security measures.

  These evolutions have to be integrated by the operators at each step, with training being provided as necessary.

- Liquid effluent treatment

  Liquid effluent treatment systems operated during the 60-year operation of the reactor will be kept operational during almost the whole decommissioning of the reactor but will have to be dismantled at the appropriate time: as the equipment composing these systems are contaminated, they cannot be used during the whole decommissioning sequence. Moreover, these equipments are sized to fit with operation waste streams and are not adapted to the decommissioning needs. Their replacements have to be scheduled in the final decommissioning plan.

  The new systems should be if possible installed in a new area (or based on mobile unit) in order to free the rooms/areas used during operation and then allow clean-up and demolition of the building.

- Electrical distribution

  Electrical distribution has to be redesigned: from a reactor producing electricity to the network, the reactor becomes an installation consuming power to supply the dismantling machines necessary for its decommissioning and to fit with the progress of the decommissioning works and displacement of decommissioning workshop/area.

In addition, the experience from permanent facility shutdown work on other nuclear plants reveals that the uncertainties related to the actual state of the electrical cabling, and thereby the ability to isolate them, can present considerable difficulties. To take account of this issue the EPR has been designed with four safety trains. The allocation of one cabling system to each safety area improves the clarity and ability to uniquely identify the systems. In addition, this design allows the dismantling works to be phased train by train, while keeping in-service the auxiliary systems housed in the Fuel Building and the Nuclear Auxiliary Building.

8. PREVENTION OF LAND CONTAMINATION

The EPR is designed in order to ensure, during its operation, the containment inside the buildings or the galleries of any radioactive or dangerous liquid substance, resulting from leaks and from internal flooding.

Several levels of preventive measures are implemented in the design in order to achieve the containment of radioactive and dangerous substances. The combination of all the techniques used for the design and operation of the circuits, equipments and structures containing radioactive or dangerous substance constitute the best available techniques for the prevention of ground/groundwater contamination. For example, the following measures can be mentioned:

- The manufacturing of the equipments and their installation in buildings or galleries with protected floors and walls wherever confirmed necessary;
- The monitoring of potential leaks from the pools, tanks and sumps;
- The information to the operator;
- The periodic inspection of pipes and the monitoring groundwater.

More details on prevention of contamination in the design of the EPR are provided in Chapter 5 of the present report.

If contamination is detected:

- Measures will be immediately taken to find its source, to stop the contamination and to limit spread of it.
- In parallel, an assessment will be carried out in order to determine whether this contamination could be treated (and then scheduled decontamination work) or the decontamination postponed to the decommissioning phase.
- In any case, precise records of this event and its subsequent treatment will be collected in order to supply the definition of initial status of the facility prior to its decommissioning.

Generally speaking, systems for collection, detection and monitoring of potential leaks will be kept operational as late as possible throughout the decommissioning operations.

In particular, the position of the in-containment water storage tank (IRWST) under the reactor vessel allows the collection of any water leaks during the dismantling of the reactor internal components.

9. REFERENCES

[1] Solid Radioactive Waste Strategy Report (SRWSR)" NESH-G/2008/en/0123 Revision A, AREVA NP, November 2008.

[2] "Cleanliness / waste design guide for the building of the EPR FA3", ECEIG060879 rev B1

CHAPTER 3 - TABLE OF CONTENT

1. INTRODUCTION

This chapter provides details on the Timings of Decommissioning for the UK EPR design. In particular, the preferred strategy to be adopted for the decommissioning of the UK EPR and the justification for this choice is detailed (Sub-sections 2.1 and 2.2 of this chapter). The effect of the need to store spent fuel in the at-reactor fuel pool after operations are complete, the assumption of the baseline scenario, the requirements for storing spent fuel in the fuel pool and the effect of storing spent fuel assemblies in the fuel pool on other decommissioning activities are detailed in Section 3. Finally, the effect of changing the baseline strategy is detailed in Section 4. In particular, the sensitivity to any deferment strategy is studied in Sub-section 4.1, and the ability to conduct decommissioning early if required is demonstrated in Sub-section 4.2.

This chapter should be read in conjunction with the other chapters of the present report in order to gain an overall understanding of the proposed strategy for decommissioning of the UK EPR.

2. STRATEGY CHOSEN FOR THE DECOMISSIONING OF THE UK EPR

2.1. BASELINE SCENARIO

The main technical and safety issues involved in decommissioning the EPR are not significantly different from those encountered during the dismantling programme for any other PWR plant, and cover the following operations:

- The disassembly of electro-mechanical equipment
- The clean-up of civil engineering structures
- Waste management
- Buildings demolition
- Reconditioning of the site (which is outside of the scope of the GDA)

The issue of decommissioning has been an area of interest for EDF and AREVA for many years. In particular, provisions have been made in France and Germany since the 1970s to fund the future decommissioning of existing plants. In subsequent years, studies were carried out in order to study the different possible decommissioning strategies.

Two main strategies can generally be considered for the decommissioning of Nuclear Power Plants: Early Site Clearance (ESC) or deferred decommissioning. The first strategy (ESC) implies that decommissioning activities take place as soon as possible after final shutdown, i.e. without waiting for a period of decay of the activated structures. The second strategy (deferred decommissioning) implies that a deferral period, usually referred to as Care and Maintenance (C&M), and generally lasting several tens of years, is included as part of the decommissioning strategy. This deferred strategy (also referred to as “safestore strategy”) implies that the plant is brought to a “safestore” status (i.e. primary coolant has been removed from the primary circuit, and all spent fuel has been transported out of the fuel pool which has been emptied) and decommissioning activities on site resume at the end of the deferral period. This strategy is usually chosen where there is a clear benefit to the dose reduction by waiting for decay of the activated structures.

The outcome of the studies mentioned above showed that, in the context of PWRs, early decommissioning is preferable to deferred decommissioning, in particular due to the following elements:

- A similar level of reduction of the activity to that obtained with a deferral period can be achieved by performing decontamination of the Primary Reactor Coolant System as soon as the unit is shut down
- The impact on the activated structures (vessel and vessel internals) of a deferral period for decay is negligible (for PWRs, the dose from activated structures is still too high after the deferral period to avoid the use of remote handling equipment for decommissioning activities, and it is not possible to declassify the waste produced from these structures)
- The development of off-site (when or if possible) or remote-controlled operations, instead of on-site human intervention, means that activated structures can be handled.
- Availability of a functional infrastructure

The preferred decommissioning strategy for PWR is therefore Early Site Clearance (ESC) with reactor dismantling commencing as soon as practicable after the end of generation. This strategy is now widely preferred for PWRs internationally, and it is generally recommended by international bodies (IAEA and NEA) as well as national authorities that decommissioning should be carried out as soon as reasonably practicable. In particular, ESC has been chosen as the current preferred strategy for PWRs in a number of countries including Germany, South Korea, the USA, Japan and Sweden. This strategy is in addition supported by recent studies undertaken in 2008 and 2009 by EDF/AREVA considering the feedback available on decommissioning activities in France, Germany and elsewhere in the world, and is therefore the current preferred strategy for the UK EPR.

This strategy is based on the assumption that there will be adequate solutions available for waste disposal systems during decommissioning activities of the UK EPR. The choice could however be reviewed and adapted to the specific context if this was not the case. In addition, this strategy takes account of the specific characteristics of the EPR design (and more generally PWR design) and may not be the most suitable to other situations.

In summary, the chosen baseline scenario for the decommissioning of the UK EPR is to commence decommissioning activities without waiting for a decay period. The schedule for the decommissioning of the plant will take into account the technical, industrial, administrative and financial constraints that will apply to the decommissioning programme.

It may also be noted that, while the baseline decommissioning scenario for the UK EPR is assumed to be Early Site Clearance, it will be a matter for the future operator to define the final decommissioning strategy taking all relevant factors into account.

2.2. JUSTIFICATION OF THE CHOICE OF IMMEDIATE DECOMMISSIONING FOR THE UK EPR

In addition to the points already set out in Sub-section 2.1 which argue in favour of Early Site Clearance of the UK EPR (i.e. similar level of reduction of the activity can be achieved by decontamination of the Primary Reactor Coolant System as soon as the unit is shut down; the impact on the activated structures (vessel and vessel internals) of a deferral period for decay is negligible; and the development of off-site (when or if possible) or remote-controlled operations, instead of on-site human intervention, means that activated structures can be handled), other benefits are expected from this strategy, which include:

- **Preserving knowledge of the installation (conditions of construction and operation) over a shorter period**: knowledge about the installation and its operation among the operators working on-site when the unit is shut down may be transferred during the final years of operation and at the start of the dismantling of the EPR unit. This can occur as the workforce is renewed (transfers or retirements) thus ensuring that there is continuity in the transmission of knowledge and expertise (see also Chapter 8 of this report).

- **Reducing risk related to the ageing and obsolescence of installations, and the disappearance of skills as employees who know the installation leave/move on:**

    - Continuing the operations and maintenance of some equipment during the dismantling phase, ensures continuity with the operation of the unit and means that employees can keep using equipment that they are proficient in operating (e.g. ventilation systems, cranes/hoists and other handling equipment, power supply devices, instrumentation and control systems, surveillance equipment, etc.).

    - The use of available technologies where there are spare parts and robust management of spare parts stocks will minimise the risk of obsolescence of installations. This is especially true for instrumentation and control systems and electronic parts, where technological development occurs very rapidly.

    - Where possible, not replacing equipment can save time and can minimise the waste that would otherwise be generated by dismantling existing equipment and replacing it with new equipment, which will subsequently need to be dismantled.

- **Generally speaking, the risks related to the safety, security and environmental impacts of the installation are eliminated earlier:** for example, quicker cessation of the discharge of effluents.

- **There can be a positive socio-economic impact of keeping employees in position:** dismantling operations allow employment levels to be reduced gradually compared with the operating phase and to prepare affected regions to move away from energy production towards other sectors of the economy.

- **Sustainable development:** the direct transmission of knowledge from the longest serving employees who have run the unit to the younger employees who are set to dismantle it during their professional careers, and the short-term completion of this process, enables the operator to demonstrate to the public and future generations that dismantling a unit is possible over a short timescale. Generation n+1 will see the end of the dismantling of a unit that has been operated during the working lives of generation n.

3. CURRENT SCHEDULE OF OPERATIONS AND EFFECT OF STORING SPENT FUEL IN THE AT-REACTOR FUEL POOL

The current decommissioning plans considered for the decommissioning activities of the UK EPR are described in Chapter 7 of the present UK EPR document. The plans prepared have been derived from the scenario considered by EDF in France, but also took account of UK-specific considerations, such as the on-site presence of ILW and spent fuel interim storage buildings. However, the baseline strategy for both fuel storage scenarios is that the strategy should be Early Site Clearance (i.e. no period of Care and Maintenance) as explained in Section 1.

3.1. MAIN ASSUMPTIONS FOR THE BASELINE SCENARIO

The baseline scenario as provided in Chapter 7 considers an overall decommissioning scenario of the UK EPR. This scenario is based on the following main assumptions:

- Immediate defuelling of the reactor into the fuel building then transfer of the spent fuel from the fuel storage pool as soon as possible to the SF ISF commensurate with the safety case.

- Preparation, submission and approval of appropriate regulatory documents in a timely manner to enable the prompt commencement of decommissioning.

- Dismantling work to commence as soon as possible while maintaining safety, to systematically reduce the hazards as quickly as reasonably possible.

- Conventional waste and LLW is removed as and when it is produced at the same time as the dismantling of the facilities where the waste has been generated. ILW is sent to the suitable storage or disposal facility depending on availability. All waste produced during the decommissioning of the ILW and Spent fuel Interim Storage Facilities will be removed as and when produced and sent to the adequate disposal facility available.

- Size of the storage/ disposal facilities and facilities built for particular decommissioning activities (i.e. workshops) is optimised

- During decommissioning operations, it is preferable, wherever appropriate, to make use of the systems (ventilation), equipment (handling), and buildings (for on-site storage of waste to be removed) previously deployed in the operating phase. This is so as to limit, as far as possible, the cost and duration of both preparatory and final shutdown work.

- The chemical decontamination of the reactor coolant system is implemented as soon as possible after shutdown of the unit, when all of the facility's safety systems and operating staff are present on site at full availability.

- The UK EPR baseline scenario assumes that in the first phase of decommissioning the spent fuel assemblies will be transported to the on-site spent fuel storage building after three years of cooling (“Short Term Pool Storage”); a longer cooling period of 10 years is also considered (“Long Term Pool Storage” scenario) to allow more thermal decay.

3.2. REQUIREMENTS FOR STORING SPENT-FUEL IN THE AT-REACTOR FUEL POOL

The presence of spent fuel in the fuel building cooling pool requires that both the reactivity and the cooling function of the pool remain, but also that safety measures and containment of the building are maintained. In order to ensure that the above requirements are satisfied, it is essential that functions providing the following items are available:

- Sufficient capacity to provide boronated water make-up to the fuel building cooling pool

- The temperature control of the cooling pool. This requires the maintenance of the cooling pool heat exchangers to remove the residual heat. In particular, this is electronically controlled and requires a supply of cooling water, which subsequently has an impact on:

    - The size of the backup diesel generator required

    - The presence of a cooling water supply circuit

    - Water purification and treatment systems

- The dynamic containment of the building because the fuel building ventilation system must remain operational

- The maintenance of environmental monitoring systems

3.3. EFFECT OF STORING SPENT FUEL IN THE AT-REACTOR FUEL POOL ON OTHER DECOMMISSIONING ACTIVITIES

In addition to the points identified in Sub-section 3.2, the duration of the cooling time of the fuel in the spent fuel building can impact the overall schedule of activities. In particular, the effect of maintaining fuel in the fuel pool after 3 years of cooling will require that operational and monitoring staff remain in the building while the fuel is present.

{ CCI removed }[b]

In summary, changing the cooling time of the fuel assemblies in the fuel pool will only have an effect on the schedule of the decommissioning of the EPR and will have no effect on the decommissioning of the interim storage buildings (Interim Spent Fuel storage facility or Interim ILW storage facility).

4. IMPLICATION OF CHANGING THE BASELINE STRATEGY

4.1. SENSITIVITY TO DEFERRED DECOMMISSIONING

The reasons for the choice of baseline strategy for the UK EPR (Early Site Clearance) have been detailed in Section 2. This section examines the impact of changing the strategy from Early Site Clearance to deferred decommissioning and covers the following:

- The work performed prior to the dismantling of nuclear systems: final shutdown operations, work performed in preparation for the dismantling of nuclear systems and the dismantling of non-nuclear systems.

- The provision of systems which ensure that safety functions are maintained during the Care and Maintenance period.
- The systems used in nuclear dismantling operations.
- The preservation of records and the maintenance of skills and knowledge (see also Chapter 8).

4.1.1. Impact on final shutdown operations

The change in decommissioning strategy (from Early Site Clearance to deferred decommissioning) has little impact on final shutdown operations, which are restated below:

- Specific Reactor Building (RB) work;

{ CCI removed }[b]

- Work carried out on the Fuel Building following unloading of fuel to the FB pool;

{ CCI removed }[b]

- Functional simplification works.

{ CCI removed }[b]

- Identified items of equipment taken permanently out of service in Turbine Hall
- Identified items of equipment taken permanently out of service in the Nuclear Auxiliary Building (NAB) and the Waste Treatment/Effluent Treatment Building (ETB). Only the systems treating effluents generated during the C&M phase (rain or run-off water, condensation in the ventilation systems, etc.) would be operated in the deferred scenario.

4.1.2. Impact of C&M period on work performed in preparation for dismantling

{ CCI removed }[b]

Disassembly of the electro-mechanical equipment in the Turbine Hall is a non-nuclear and relatively straightforward operation. This transformation shall therefore be performed as soon as the Turbine Hall power generation ceases whether the scenario chosen is ESC or deferred decommissioning.

In the case of deferred decommissioning, the technical and economic advantages and disadvantages of keeping the Turbine Hall to create workshops and a temporary storage area will be assessed, taking account the duration of the C&M period.

The assessment will consider the cost of maintaining this building compared with demolition of the Turbine Hall and construction of a new facility for processing of decommissioning wastes.

4.1.3. Impact on the dismantling of non-nuclear systems

For the same reasons as stated above for the Turbine Hall electro-mechanical equipment, the change in strategy from Early Site Clearance to deferred decommissioning has no impact on the dismantling of non-nuclear systems and any systems not required to fulfil safety functions. Non-nuclear systems can be dismantled as soon as they are no longer required.

4.1.4. Impact on systems ensuring safety functions are provided:

The ‘containment’ safety function is the only function required once the spent fuel has been removed from the fuel building. To achieve this, ventilation and discharge monitoring systems, and related support functions (mainly power supply) must be available. The functions of these systems are simplified during the final shutdown phase. A maintenance programme is operated to ensure they remain available during the entire deferral period.

Similarly, a monitoring and maintenance programme will be operated for the NAB, ETB and RB civil engineering systems that are involved in static containment during the deferral period. The civil engineering works will be inspected periodically, and appropriate action will be taken if needed (e.g. cracks in concrete or corrosion reported).

4.1.5. Impact on systems used during dismantling operations

During the dismantling of the RB, the following functions are required:

1. Ventilation function, but to a much lower level than in the operating phase –

   { CCI removed }[b]

2. Back-up electrical circuits to provide power to the radiological protection measurement monitoring channels (in the NAB stack), fire protection and detection systems.

   { CCI removed }[b]

3. Effluent treatment system. It is expected that the operational effluent treatment plant will be modified (or replaced) to suit the needs during the decommissioning phase (after decontamination of the primary circuit)

4. Electrical circuits required for dismantling (site power supply)

5. Breathable air system and working air system resized in accordance with the needs of dismantling.

6. Handling equipment (e.g. steam generator- manhole opening machine, RPV multi-stud tensioning machine)

7. Water volume makeup: provided by the IRWST and related systems (e.g. Reactor Cavity and Spent Fuel Pit Cooling and Treatment System) in the Early Site Clearance strategy.

8. RB polar crane.

Functions 1 to 3 are also required during the C&M phase and will therefore be maintained during this phase. According to the duration of the C&M period and the age of the equipment, renewal of this equipment may be required. The effluent treatment system must be altered to enable water used during dismantling of the vessel to be treated and the ventilation system must be adapted to enable dismantling operations to go ahead.

The change of strategy also affects functions 4, 5, 6 and 7 which may require installation of replacement systems. Specific studies will assess the possibility of reusing some circuits or systems, particularly in terms of the duration of the C&M period.

Lastly, the RB polar crane structures (runway tracks, beams) are mechanical components that are difficult to replace and for which damage is not acceptable. A maintenance programme will be implemented for the C&M period, as will be the case for the civil engineering works. The RB polar crane is not required to operate during this C&M period. Maintenance would therefore not be expected to be performed on non-static elements (bearings, cables, instrumentation and control systems, etc.). These systems will need to be renewed and the full crane will have to undergo regulatory qualification before dismantling operations may begin again after the C&M period.

4.1.6. Impact on preservation of skills and knowledge

One of the advantages of Early Site Clearance is preserving knowledge of the installation over a shorter duration (conditions of construction and operation, state of the installation when operations ceased) and that it enables the knowledge of the operational teams to be transferred to the dismantling engineering teams.

Deferring dismantling means that teams must take over the installation information again and update their knowledge, in particular in terms of any changes that have taken place in regulatory reference systems between the dismantling studies and the end of the deferral period (additional characterisations in terms of the requirements of the waste removal systems, for example). The change from an ESC to deferred decommissioning strategy therefore may result in a greater requirement for engineering staff resources.

In addition, deferring dismantling means that operating and maintenance skills must be kept on-site to ensure the "containment" safety function is fulfilled throughout the C&M period.

4.1.7. Conclusion: sensitivity to deferred decommissioning for the UK EPR

A change in strategy from Early Site Clearance to deferred decommissioning for the UK EPR is expected to have limited impact on the final shutdown phase and on the dismantling of non-nuclear systems.

The overall main impacts are expected to be:

- Maintenance of an operating and maintenance team to ensure the "containment" safety function is fulfilled.
- Maintenance and retrieval of records and longer time required for knowledge transfer.
- Prior to dismantling, the renovation or installation of new handling systems, water treatment or ventilation systems due to the potential obsolescence of operational equipment.
- Depending on the length of the deferral period, new facilities may also be required to e.g. accommodate some workshops.

4.2. ABILITY TO DECOMMISSION UK EPR EARLY IF NEEDED

4.2.1. Decommissioning of the EPR will be possible with currently available equipment

Internationally, complete dismantling of PWR-type power plants has been proven and presents no major technical difficulties. Review of experience feedback, especially in the United States, shows that there has been an ongoing reduction in the time taken to decommission nuclear plants.

In France, the Chooz A PWR plant is currently being dismantled. Other projects are ongoing in other countries in particular Germany (e.g. Würgassen and Stade nuclear plants). At the current stage, no technical problems have been identified that would compromise EDF or AREVA's ability to dismantle PWR power plants.

Several NPP have been decommissioned to brown field internationally using mature and widely available technologies. Early decommissioning of an EPR is therefore possible using the currently available technologies.

The decommissioning scenario for the EPR Primary Reactor Coolant System has been established on the basis of the decommissioning scenario of a PWR Primary Reactor Coolant System. This scenario shows that the dismantling of a Primary Reactor Coolant System of a PWR unit may be achieved with currently-available technologies and equipment. This demonstrates the feasibility of dismantling an EPR unit that has been shut down ahead of schedule.

In conclusion, the EPR decommissioning scenario could be performed if it needed to be applied ahead of schedule, and the management of decommissioning waste will be examined taking account of the general context at the time of decision.

4.2.2. Radiological inventory expected to be lower

The radiological inventory of an EPR unit has been assessed after 60 years of operation. By that point, and considering the half-life of Co60 (about 5 years), Co60 has reached equilibrium. However, not all of the other radionuclides of interest, especially the long lived radionuclides, will have reached equilibrium. Despite this, and because it is assumed in the radiological calculations carried out that the cooling period remains the same in the case of an early shutdown as is in the "Short Term Pool Storage" baseline scenario, an early shutdown of the unit will not change the assumptions considered in the radiological calculations.

However, operating over a shorter period will result in reduced activation and contamination of the equipment and structures, which will have a positive effect on dismantling operations, work performed on equipment and on the dosimetry of employees. The radioactivity of the long lived radionuclides is indeed linearly linked to the length of operation before the definitive shut down, and therefore a reduction the operating time will reduce the activity of the long lived radionuclides by the same factor.

In summary, an early shutdown of the facility will have no impact on the radiological inventory for the short lived radionuclides, and a positive impact on the radiological inventory of the facility (reduction of the activity) as regards the long-lived radionuclides.

5. CONCLUSION

Both deferred and Early Site Clearance strategies can be envisaged for the decommissioning of the UK EPR. However, Early Site Clearance is the preferred baseline decommissioning scenario on the basis of the benefits identified.

This choice takes account of a number of relevant factors including (but not restricted to) safety, easier access and preservation of operational knowledge of the installation, availability of equipment and socio-economic impact. In addition, this strategy is encouraged by several international bodies such as the IAEA and NEA, and has been chosen as the preferred strategy in a number of countries around the world, including the USA, Germany and Sweden. The preferred strategy for EPR is therefore in line with National and International recommendations.

However, EDF and AREVA acknowledge that decommissioning activities are not due to commence for several decades and therefore new drivers may potentially arise in favour of a deferred decommissioning strategy.

As such, the present document identified a number of main differences that would be encountered if a change of strategy was to be envisaged, but also provided confidence that, if necessary, either early or deferred decommissioning of the UK EPR would be technically achievable.

TABLE OF CONTENTS

1. INTRODUCTION

This chapter provides details on the Hazards and Challenges expected to be met during the decommissioning of the UK EPR. In particular, details of EDF/ AREVA experience of decommissioning, participation to working groups and the type of hazards expected to be encountered are provided in Sections 2 and 3. The potentially significant hazards that could reasonably be anticipated during the decommissioning of an EPR have been identified in Section 3.1, and the protection measures implemented have been provided in Section 4 along with the controls that have been (or will be) put in place to protect against these hazards. Similarly, the identification and control of the likely radiological and industrial safety hazards is provided in Section 4 and Appendix 1 of the current chapter. Finally, an identification of the tasks for which remote-controlled equipment could or may be used has been provided in Section 5.

Overall, this chapter should be read in conjunction with the other chapters of this UK EPR document in order to gain an overall understanding of the proposed strategy for decommissioning of the UK EPR.

2. OVERVIEW OF EDF/AREVA OPERATIONAL EXPERIENCE AND FEEDBACK IN DECOMMISSIONING

The decommissioning of Pressurised Water Reactors (PWRs), such as the UK EPR, are multi-disciplinary projects and as such a large range of hazards, whether conventional or specific to the nuclear industry, could be encountered. Hazard analyses are carried out in order to ensure the safety of decommissioning operations. Operational experience and feedback is a significant input in the hazard analysis process, allowing hazards to be identified prior to the start of the decommissioning activities and enabling mitigating measures to be identified and implemented. In the case of the EPR, consideration of decommissioning has also been taken into account at the design stage as is discussed in Chapter 20.2 of the PCSR.

As there are no operational EPR units and the decommissioning of PWRs in France is an ongoing process, it is relevant to consider the decommissioning of nuclear reactors outside France and other nuclear facilities more generally. The following subsections provide brief information on EDF/AREVA involvement in national and international working groups relating to decommissioning.

2.1. EDF/AREVA INVOLVEMENT IN NATIONAL AND INTERNATIONAL WORKING GROUPS

Considering the lifetime of the existing nuclear facilities, relatively few decommissioning projects have already reached completion, although many projects are currently ongoing. Given the technological diversity of the installations to be decommissioned it is essential that experience is shared between those involved in decommissioning activities all over the world. In particular, EDF liaises with the NEA/OECD, IAEA and various US groups, such as EPRI.

2.1.1. EDF/AREVA involvement in OECD/NEA activities

EDF/AREVA are involved in a number of international exchange groups, for example the NEA Co-operative Programme on Decommissioning [1]. In November 2005, the programme of international dialogue in which EDF participated through the OECD and the IAEA comprised 26 reactor dismantling projects and 16 fuel fabrication or reprocessing decommissioning projects.

EDF is also involved in the international Technical Advisory Groups (TAG) of the OECD's Nuclear Energy Agency (NEA).

Decommissioning activities are overseen by the Working Party on Decommissioning and Dismantling (WPDD), which is a sub-group of the Radioactive Waste Management Committee (RWMC). This working party includes members of the authorities, regulators and industry from the leading member countries of the NEA, representatives of the EC (DGTREM) and IAEA. Its purpose is to exchange information and experience between its members, as well as to provide the authorities with opinions concerning policy, strategy and the regulatory aspects of nuclear facility decommissioning.

A Working Party on incorporation of decommissioning regulations and experience feedback into the design of future power reactors has been established. An initial meeting took place in 2009 in order to define the scope that will be presented to the WPDD and the first part of this study included information collected about the design of 4 to 5 new reactors, including the EPR.

This working group produced a recent OECD document "Decommissioning considerations for New Nuclear Power Plants" [2].

2.1.2. EDF/AREVA involvement in IAEA activities

Current activities relate to:

- revision of safety standards for the decommissioning of nuclear facilities;
- creation of an international network of experts to facilitate the exchange of information between the entities (regulatory and industrial) involved in decommissioning;
- follow-up of the International Project on evaluation and demonstration of safety for the decommissioning of nuclear facilities;
- organisation of an international conference on management of contaminated scrap.

2.1.3. Bilateral cooperation agreements

EDF has also signed bilateral cooperation agreements (for example: EDF – SOGIN, EDF - ENRESA, etc).

The discussions have mainly been related to the following topics so far:

- decommissioning of Gas Cooled Reactors;
- decommissioning of PWRs;
- graphite management;

- management of nuclear waste, interim storage, deep disposal;
- processing of soils and ground water;
- delicensing.

Although a large part of the decommissioning activities are common to all projects, some specific activities are only relevant to specific reactor types. Decommissioning experience is shared, taking account of the specificities of each reactor type.

2.2. INTEGRATION OF OPERATIONAL FEEDBACK AND EXPERIENCE IN DECOMMISSIONING ACTIVITIES

Learning from previous experience such as that gained in national and international working groups is essential to the improvement of decommissioning strategies and methods. Decommissioning experience and feedback is taken into account in new projects. The EPR is a PWR and EDF/AREVA thus have a particular focus on operational experience and feedback from PWR decommissioning projects. This includes the feedback from decommissioning of the Chooz A unit, which is the first French PWR unit to undergo decommissioning, and from decommissioning of other PWRs across the world.

EDF and AREVA have both short and long-term objectives in terms of learning from experience. In the short and medium term, the objectives are related to the current activities of the unit, i.e., completion of the decommissioning programme of the “first generation” plants and the operation of the various disciplines and management, including the implementation of processes and the management of resources.In the longer term, the objective is to gain a better knowledge of decommissioning activities to facilitate the future decommissioning of the EDF NPPs in operation. The aim is therefore to build on the experience gained in all areas: technical, methods, costs, organisation, contractual, industrial policy, and to ensure that this knowledge is retained and disseminated.

2.3. THE LESSONS LEARNT FROM NATIONAL AND INTERNATIONAL OPERATIONAL EXPERIENCE AND FEEDBACK

Although the projects studied vary and differ widely in international dialogue between operators undertaking dismantling projects, the dialogue that has taken place over the past 20 years has led to the following lessons being identified, as set out in the NEA report which reviews Reference [2]:

- Dismantling can and has been done in a safe and cost-effective manner with protection of the environment;
- Current technologies have proven their effectiveness and robust performance in a large number of decommissioning activities;
- Knowledge and feedback of experience of design, construction and operation is a considerable advantage when planning, costing and carrying out decommissioning operations;
- Consideration and dissemination of international experience feedback provides a good basis for effective cooperation and support on decommissioning projects;

- Radiological risks are considered to be small in comparison with non-radiological risks during decommissioning.

2.4. INTEGRATION OF EXPERIENCE FEEDBACK IN DECOMMISSIONING ACTIVITIES

Learning from experience is essential to improve decommissioning activities. Decommissioning experience feedback is included into new projects by using usual methods for collecting, analysing and sharing the previous experiences. These methods are particularly developed to implement the programme of decommissioning, since many programmes are currently ongoing in France and around the world, but only a few have reached completion.

2.5. HAZARDS/CHALLENGES ENCOUNTERED DURING INTERNATIONAL EXPERIENCE OF DECOMMISSIONING PROJECTS

A number of technical challenges and issues have been identified as a result of review of international experience of decommissioning (Reference [1]) and which are relevant to the decommissioning of the EPR. Brief information is presented in the following sub-sections.

2.5.1. Decommissioning of large components

Cutting up large components such as heat exchangers, steam generators and tanks, before placing them in containers for final disposal, is often time-consuming and carried out in cramped conditions when implemented *in situ*. Segmentation *in situ*, where ambient dose rates are generally higher inside containments, can also lead to significant radiation doses to operators.

In some projects, the choice has been made to take these components out in a single piece and cut them up in special installations outside the containment (for example MZFR/Germany). This has had a significant impact on the hazard analysis of operations in terms of duration, associated radiological risk and physical hazards.

2.5.2. Use of remote-controlled equipment

In the early days of technology development for the decommissioning of nuclear facilities it was envisaged that there would be extensive use of robotics for the dismantling of radioactive components, particularly in high radiation areas in fuel cycle facilities.

However, experience and feedback indicates that industrial robots may have only limited applicability in decommissioning due to the non-repetitive tasks and the unstructured and changing environments of decommissioning projects. More emphasis is placed on the optimisation of proven and commonly available industrial techniques, which are adapted for use in nuclear environments. The use of remote-controlled equipment thus tends to be limited to the use of articulated arms which are particularly well-suited to tasks that are often repetitive and carried out in different environments such as decommissioning but which maintain the control of the operator of the task.

Both of these key learning points have been taken into account in the design of the EPR and the development of the baseline decommissioning plan.

3. IDENTIFICATION OF SIGNIFICANT HAZARDS ASSOCIATED WITH DECOMMISSIONING OF THE UK EPR

3.1. IDENTIFICATION OF SIGNIFICANT HAZARDS ASSOCIATED WITH THE DECOMMISSIONING ACTIVITIES

IAEA Safety Standard WS-G-5.2 (Reference [3]) provides a list of relevant hazards and initiating events associated with the decommissioning of facilities using radioactive materials. This is presented in Chapter 4 - Table 1 together with information on the likely relevance of the hazard to the decommissioning of the UK EPR.

Chapter 4 - Table 1: Potential significant hazards associated with the decommissioning of nuclear facilities (from Reference [3])

HAZARD	RELEVANCE OF HAZARD FOR DECOMMISSIONING OF THE UK EPR
Radiological Hazards	
Criticality	Relevant while fuel is stored and handled in the Fuel Building during the early stages of decommissioning of the Nuclear Island. However, this is a routine operational activity. Criticality is an issue for the design and operation of the Spent Fuel Interim Storage Facility.
Spread of contamination	Relevant to decommissioning of all areas in which radioactive materials have arisen and where contamination may have spread or where the decommissioning method used provides the potential for the suspension of radioactive particulate or gases/aerosols into the air.
External radiation exposure	Relevant to the decommissioning of areas and equipment containing activated materials and the management of wastes arising from treatment of radioactive liquids (e.g. filters and ion exchange resins).
Internal radiation exposure	Relevant to the decommissioning of contaminated areas and equipment where there is a risk of ingestion, inhalation or wounding.
Contamination, corrosion	Relevant to decommissioning of areas where contamination and corrosion products may be present.
Non-radiological hazards	
Fire	Relevance depends on the use of thermal cutting techniques, decontamination processes, accumulation of combustible materials, the presence of ignition sources and the presence of flammable gases and liquids.
Explosion	Relevance depends on the presence of explosive substances, use of compressed gases and dust and the decontamination processes applied.
Flooding	Relevant to storage of liquids (e.g. drains, bunds, sumps, etc.)
Toxic and hazardous materials	Relevant. Decontamination processes may use toxic materials and some residues of toxic materials used during operation may also be present (e.g. hydrazine, amines, oils, etc.).
Electrical hazards	Relevant to decommissioning of electrical systems and the use of electrical equipment during decommissioning operations.

HAZARD	**RELEVANCE OF HAZARD FOR DECOMMISSIONING OF THE UK EPR**
Physical hazards	Relevant to decommissioning, such as the movement of heavy loads such as large components (e.g. steam generators, pressuriser, pump motors), the fall of loads on to structures, systems and components important to safety or on to radioactive materials, collapse of structures and demolition activities. There will also be hazards to personnel such as noise, working at height and possibly confined spaces.
External events	
Earthquake	Relevant to decommissioning and the operational phase of the reactor. Seismic issues need to be addressed in the design and construction of the interim storage facilities for spent fuel and ILW.
External flooding	Relevant but is a site-specific issue.
External fire	Relevant but depends on site-specific circumstances
Extreme weather conditions	Relevant to decommissioning but will have been largely addressed in the design and assessment of decommissioning methods. This issue will need to be addressed for the interim storage facilities for spent fuel and ILW.
Human and organisational events	Relevant. Examples include operator error, accidental disabling of services and ergonomic conditions. These issues will need to be addressed in the detailed hazard analyses for specific decommissioning tasks.

Chapter 4 - Table 1 provides the list of hazards that are potentially significant for all decommissioning operations. Before carrying out any specific decommissioning operation on site, the operator will go through this list and each of the above hazards will be considered in the context of the operation to carry out. This will enable identification of the hazards relevant and significant for a given operation. For each of those hazards identified as relevant, mitigation measures will be put in place before the operation can begin.

Given the specific nature of the decommissioning activities, the use of a systematic approach (such as described above: analysis of each hazard in Chapter 4 - Table 1 and identification of the relevant significant hazards) to analyse the potential risks can ensure that the significant hazards have been identified and that suitable protective measures have been implemented.

The experience feedback of completed decommissioning operations shows that the hazards that are most frequently encountered in decommissioning are associated with conventional safety. This is due to the fact that, during decommissioning, the facility is in permanent evolution (removal and cutting of materials, handling openings, civil engineering structures demolition, operations on electrical circuits, heavy loads movement or removal, etc) and hence conventional hazards are most likely.

The radiological hazards remain significant for some operations, such as operations associated with the cutting of contaminated compounds. Section 4 of this document provides specific information on how potentially significant hazards identified for an activity have been taken into account and mitigated as soon as the design stage. In particular, the hazards considered are as follows:

- Physical hazards (i.e. slips, trips, falls, dropped loads, crushing, entrapment, etc), primarily during the removal of major process components (e.g. steam generators) and the handling and access to components and materials during decommissioning.

- External radiation exposure, mainly associated with the handling of plant that has become activated and/or contaminated with corrosion products or from waste management activities;

- Internal radiation exposure, associated with an uncontrolled spread of contamination into the working atmosphere;

3.2. PREPARATION OF THE DECOMMISSIONING SAFETY REPORT

The hazards identified above will be reviewed in the preparation of the Decommissioning Safety Report in order to identify the specific hazards associated with decommissioning of the UK EPR.

The Decommissioning Safety Report will be prepared as soon as the decommissioning design studies start, which is carried out as part of the Pre-Closure Preparatory Work (See Chapter 7 Decommissioning Plans), which starts five years before reactor shutdown. The Decommissioning Safety Report contains:

- **Definition of the high level decommissioning methodology**: Definition of the major steps involved in reaching the agreed end state. The sequence of decommissioning is discussed in Chapter 2 – 'Decommissioning Logistics' of this document.

- **Preliminary risk analysis of the major steps of the decommissioning methodology**: This is a preliminary qualitative analysis of radiological, conventional, environmental and "cross-category" hazards, where cross-category hazards include human factors and work-specific hazards such as parallel activities and interfaces. Generic arrangements are described for managing these hazards.

- **Preliminary demonstration of safety based on bounding scenarios**: The consequences of bounding scenarios are calculated to demonstrate that they are acceptable. Specific safety analyses are subsequently carried out which incorporate the specific activities and interfaces.

In addition to the Decommissioning Safety Report, analysis of hazards for each activity and task operation is carried out in order to determine the required control measures. For each category of hazards identified, safety, security, radiation protection or the environment, this approach is based on the optimisation of the activity or task by using the Best Available Techniques and to ensure that the risks are reduced to a level which is ALARP.

A hazard analysis is carried out for each successive step of the life of an operation, as follows:

- preliminary hazard analysis;

- design and performance hazard analysis;

- site hazard analysis: Before an operation is carried out, the hazard analysis is checked to ensure it is appropriate for the site-specific circumstances and may modify it depending on the particular circumstances.

This approach enables the identification of the potentially significant hazards identified in Chapter 4 - Table 1 that are actually applicable to each of the decommissioning operations.

4. THE PROTECTION AND CONTROL OF HAZARDS IN THE DECOMMISSIONING OF THE UK EPR

The hazards identified in Section 3 have been taken into account in the design of the UK EPR and will be taken into account during operation and decommissioning.

Chapter 4 - Table 2 provides information on the main aspects of the design that are relevant to the control and minimisation of the three potentially significant hazards identified in Section 3.1: physical hazard and external and internal radiation exposure. This takes account of the information in Sub-Chapter 20.2 of the PCSR (Reference 4) and the Solid Radioactive Waste Strategy Report (Reference 5).

In addition to the aspects that have been specifically taken into account in the design of the UK EPR, a number of other measures will contribute to the control of hazards during operation and decommissioning. These include in particular:

- Control of primary coolant chemistry to minimise corrosion in the primary circuit and the protection of the integrity of the fuel cladding. This contributes to the reduction of radiation doses during operation and during decommissioning.

- The decontamination of the primary circuit after reactor shutdown. This removes activation and corrosion products from the primary circuit and transfers them on to filters and ion exchange resins which are dealt with using the same procedures as during operations. This reduces the radiation doses to workers during subsequent dismantling of the primary circuit plant.

- The management of the information on operational history. Operational records, post operational on-site and off-site surveys and information from ongoing decommissioning activities are particularly important for the identification of additional contamination of buildings, structures and systems above or below the ground, as well as contamination of land (including surface or groundwater) as a result of incidents, accidents or due to structures buried on the site (see also Chapter 8)

Chapter 4 - Table 2: Aspects of design relevant to the control of potentially significant hazards during operation and decommissioning of the UK EPR

Design feature/aspect	Specific measures identified	Hazards addressed by measures	Benefits in control of hazards during operation and decommissioning
Choice of materials of construction to minimise activation	Use of low cobalt steels Elimination of cobalt Limitation of antimony and silver containing seals	External radiation	Reduced activation will reduce radiation doses to workers during operation and decommissioning.
Optimisation of neutron shielding	Use of heavy reflector around the core Neutron shielding is modular to facilitate removal.	External radiation	This reduces irradiation of the steel and reactor compartment, thereby reducing radiation doses to workers during operation and decommissioning.
Reactor system design	Reactor systems designed to facilitate decommissioning and minimise creation, movement and deposition of contamination.	External radiation Internal radiation Contamination, corrosion Spread of Contamination	This is designed to minimise activation products and circuit contamination hereby reducing radiation doses to workers during operation and decommissioning.

Design feature/aspect	**Specific measures identified**	**Hazards addressed by measures**	**Benefits in control of hazards during operation and decommissioning**
Ease of removal of major process components	Design of major components (e.g. steam generator) to be removed as single items to enable size reduction and waste processing elsewhere.	External radiation Physical hazards	This is of benefit in minimising the time taken to remove major components from high radiation areas during operations if required. This will also reduce the need to carry out size reduction in high radiation areas thus reducing radiation doses to workers carrying out decommissioning. Removal of single large items for processing outside the reactor containment will reduce the physical hazards associated with size reduction of large items in the containment. The physical hazards associated with the movement of large or heavy loads will remain but these are addressed by means of the facilities which are installed for movement of heavy loads during operation (e.g. steam generator replacement) and in the detailed design of dismantling tasks.
Use of modular thermal insulation	Modular thermal insulation can be removed in sections.	External radiation Physical hazards Hazardous materials	Ease of removal will reduce the time taken and thus reduce radiation doses to workers incurred as a result of working in high radiation areas. This will also reduce the handling of thermal insulation materials by workers, thereby minimising worker exposure to the materials (which may be hazardous, e.g. man-made mineral fibre)
Prevention of contamination spread	A number of measures including containment, the zoning of rooms, ventilation and segregated drainage systems. Maximisation of leaktightness.	Spread of contamination External and internal radiation	This will minimise external and internal radiation doses to workers as a result of the spread of contamination.

Design feature/aspect	**Specific measures identified**	**Hazards addressed by measures**	**Benefits in control of hazards during operation and decommissioning**
Design for decontamination	Provision of coatings and linings of walls. Positioning of seals, drainage lines and tanks to aid post-operational clean-out. Minimisation of use of porous materials. Minimisation of voids.	External radiation Internal radiation Spread of contamination	Design to facilitate decontamination will reduce external and internal radiation of workers during decontamination and dismantling and will minimise the spread of contamination during decommissioning.
Submerged disassembly of reactor pressure vessel	Reactor compartment is designed to allow the pressure vessel to be filled with water to allow underwater disassembly of reactor internal components	External radiation Spread of contamination	This will reduce radiation doses to workers during decommissioning as a result of the shielding provided by the water (see also Chapter 2) and enable prompt decommissioning
Fuel cladding integrity	Improved fuel cladding through the use of Zircaloy M5 fuel	Internal radiation External radiation Spread of contamination	Improved fuel cladding integrity will reduce contamination of the primary circuit with fission products, thereby reducing external and internal radiation doses from caesium-137. This will be beneficial in both operation and decommissioning.
Optimisation of access routes to nuclear areas	Design of access points, handling equipment and access routes	External radiation Physical hazards	The layout of the primary circuit plant takes account of handling and access routes for decommissioning. This will reduce physical hazards during decommissioning by ensuring that there is sufficient space to move items safely and will reduce radiation doses as a result of reduced duration of tasks. This is also of benefit during operations in the event of the need to replace major components.

Chapter 4 - Table 2 indicates that measures being implemented in the UK EPR do address the hazards identified. Also the decommissioning also takes account of the lessons learnt from international experience of decommissioning as discussed in Section 2, such as the removal of large components in one piece. Further information on some of the key measures to reduce radiological hazards during decommissioning is presented in the following sub-section while information on the control of non-radiological hazards is presented in Appendix 1.

4.1. CONTROL OF RADIOLOGICAL HAZARDS

Radiological hazards can be reduced if the activation of material and/or contamination can be reduced. This involves limiting the presence of materials in the components of circuits or structures that could be activated and also susceptible to corrosion thereby resulting in contamination by activated corrosion products.

4.1.1. Choice of material

With regard to the reduction of dose rates associated with external exposure, the measures adopted at the design stage principally include:

- elimination wherever possible of cobalt, for example, by reducing wear through design modifications, and by replacing materials with a high cobalt content level (stellites) by alloys without cobalt. Activated cobalt constitutes the main source of external radiation dose during decommissioning;

- the use of alloy 690 for the steam generator tubes minimises the quantity of cobalt in the corrosion products circulating in the primary system;

- limiting the amount of silver and cobalt in steel and alloys and the replacement of seals coated with silver by graphite seals (an isotope of silver represents a significant source of dose during the first few years after the shutdown of a unit);

- limiting seals and bearings made with antimony.

4.1.2. Provision of neutron shielding to minimise activation of components

The reactor design includes neutron shielding. This shielding reduces the activation of materials and thereby facilitates the clean-up of the structures while reducing the volume of active waste. This involves:

- the neutron shield (also referred to as 'heavy reflector' in other chapters) surrounding the core, made of a dozen circular elements joined together by vertical tie-rods;

- the slab positioned above the vessel, made of removable concrete plates.

This shielding is unavoidably activated during reactor operation to a significant degree, but is designed to be dismantled in sections. This makes it possible to remove it once operation of the reactor has ceased, while minimising the doses of operators.

4.1.3. Provisions facilitating decommissioning by reducing worker intervention and duration of radiation exposure

The objective is to reduce the dose to workers by reducing the time they spend near highly activated components and increasing the speed with which these components are removed.

The following are some of the main measures adopted:

- The design of many items of equipment (e.g. core instrumentation, steam generators, reactor coolant pumps, pressuriser, heat exchangers, evaporator-degasser, particularly) facilitates their decommissioning;

- A review of the installation of some large components, particularly the steam generators, reactor coolant pumps and the pressuriser, has been complemented by a review of their disassembly, including their reverse handling and transportation operations, thereby ensuring the possibility of removing them from the reactor building in one single piece, if appropriate. Feedback from the replacement of steam generators in the PWR plants provides guidance and is taken into account in the design. For example, a protected area behind the equipment hatch is created in which an entire steam generator can be handled. These measures will also be of benefit in controlling the physical hazards associated with the dismantling of large components

- For the majority of the above components located in inaccessible areas due to the level of radiation, disposal in one piece was investigated; this implies the implementation of handling processes, appropriately designed openings and access that enable removal in a single piece and its subsequent processing in a more suitable environment;

- The position of the in-containment water storage tank (IRWST) under the reactor vessel allows the collection of any water leaks during the dismantling of the reactor internal components;

- The thermal insulation on the main primary circuit is easy to remove from around the welds due to its modular design;

- The reactor design facilitates access at minimal dose rates within the controlled area as much as practicable. As such, the active components have been enclosed in bunkers or isolated behind screens. Examples include:

  - the floor separating the pressuriser spray function from the pressuriser pressure relief function;

  - the walls separating the hot legs from the cold legs;

  - the bunkers in which the most active valves are placed.

Furthermore, measures have been taken to facilitate access to equipment and to create protected working and emergency shutdown areas, for example:

- the strengthening of the biological shielding of the annular region;

- the implementation of shielding baffles in front of the reactor coolant pumps;

- the implementation of shielded doors in front of the steam generators;

- the operating floor above the cavity (pool), permitting the installation of an in-situ dismantling workshop;
- the access areas introduced around the main components.

All of these measures help to reduce the exposure level and time of staff undertaking manual operations.

4.1.4. Measures to limit the contamination of systems

Specific measures have been taken to eliminate retention areas that are likely to attract radioactive deposits and be a possible source of corrosion, particularly once the power unit ceases to operate. These include in particular:

- a failed fuel assembly fast detection system, which is an essential factor in limiting contamination of waste with alpha emitters;
- processing facilities (e.g. reactor coolant chemistry control and particulate filters) that limit both corrosion and deposits in the systems;
- the design of systems and tanks avoiding, as far as possible, vortex areas, undrained low points even of a small volume (e.g. in valves), low velocity areas and dead cavities;
- the complete drainage of systems, facilitated by an adequate slope, as well as the appropriate provision and positioning of drainage valves and vents;
- ventilation systems, designed according to segregated zones, to limit the spread of contamination, the minimisation of air ducts likely to transport contamination, the removal of contamination from as close as possible to its source, and the mounting of filters as far upstream as possible.

These measures limit the deposition of contamination in the systems and tanks, as well as the transport and deposition of activated material. In both cases, the main aim is to reduce the dose. During decommissioning, these measures reduce the dose to workers, the risk of internal exposure and the activity of the waste.

4.2. MANAGEMENT OF CONVENTIONAL HAZARDS

The management and controls in place for non-radiological (conventional) hazards, including fire, lifting and manual handling, working at heights and slips, trips and falls, electrical hazards, mechanical hazards from machines and tools, hazards from toxic and hazardous substances, noise, asphyxia/anoxia is of great importance during decommissioning activities. This is presented in Appendix 1.

Similarly, management measures for hazards that may have an environmental impact, and the controls in place to mitigate these hazards such as hazards providing from discharges of liquid or gaseous effluents, dust emission, noise, odours or visual nuisance, or from human factors are also described in Appendix 1.

5. CONSIDERATION OF REMOTE-CONTROLLED DECOMMISSIONING TASKS

External and internal radiation exposures have both been identified as being potentially significant hazards that need to be controlled during the decommissioning of the UK EPR. One of the means by which these hazards can be minimised is by the use of remote-controlled equipment. This section provides information on the criteria taken into account in deciding whether to use remote-controlled equipment, a brief overview of the types of remote-operated equipment used in decommissioning and information on the key tasks in the decommissioning of the UK EPR that are expected to be carried out remotely.

5.1. CRITERIA FOR DECIDING ON THE USE OF REMOTE-CONTROLLED EQUIPMENT IN DECOMMISSIONING TASKS

The criteria to consider for the use of remote-controlled equipment include:

- Radiation levels: If it is evident that radiation levels in the work area are high, to the extent that an operator cannot enter then the use of remote-controlled equipment or a robot will be required.

- The dose received: an operation in a place with a very low dosage rate may, if very repetitive, require the use of remote-controlled equipment or a robot. An example of this is the characterisation of waste packages. Although each package may have relatively low radiation dose rates or radioactivity levels, characterising a package requires standardised wipe samples to be performed on several surfaces, which means remaining near to the source for some time. If there are a large number of packages to be characterised, then remotely operated characterisation of the packages may be justified.

- Ambient air quality: If the area for dismantling is a long way from a ventilated area (low point), then the use of remotely operated equipment, which does not run the risk of anoxia may be considered as an alternative to extension and augmentation of the ventilation system.

In addition to these criteria there are also general criteria such as:

- The available space: it may be possible to fit a remotely operated tool into a confined area, whereas an operator would not be able to enter;

- The repetitiveness and/or simplicity of the task: the simpler the elementary task is to perform in a similar fashion, the more suitable a robot may be. An example is the cutting of exchangers containing thousands of tubes to be cut to the same length for the preparation of waste packages.

- Difficulty of the work: The improvement in safety to be achieved by using remotely operated equipment needs to be analysed.

The use of remote-controlled equipment does have its limitations, as is noted in Section 5.2. There can be disadvantages to the use of remote-controlled equipment, such as:

- Cost: unless efforts are made to reuse robots already available in "aggressive" industrial settings (chemicals etc.), these tools are costly to develop. In addition, the environment in which they are used could transform them into radioactive waste.

- Possible breakdowns: the possibility of mechanical equipment breaking down must always be taken into account, meaning that there must be the option of taking the equipment to an area of reduced radiation/contamination area to carry out maintenance. The effect of radiation may have an adverse effect on the electronics of the equipment.

5.2. REMOTE-CONTROLLED TASKS IN THE DECOMMISSIONING OF THE UK EPR

At the current stage of development of the UK EPR the major task that is planned to be carried out remotely is that of dismantling of the reactor vessel internals. These are located in the core and comprise the most activated parts of the reactor. It is envisaged that dismantling is completed under water in the reactor building pool, in the internals compartment, using cutting systems operated from the fuel loading machine. This is discussed in more detail in Chapter 2 of the present report. This method reduces the hazard presented by external radiation and takes the benefit of the shielding provided by the water. The segmentation of reactor pressure vessels under water using remote techniques is well-established and has been carried out in Europe and the USA. This method will be used in the decommissioning of the Chooz A PWR.

The use of remote techniques for other decommissioning tasks on the UK EPR will be decided on a case-by-case basis on the basis of the review of radiation levels and the complexity of the specific task, taking account of the criteria listed in Section 5.1.

Most of the current robots used in dismantling activities are remotely controlled tools to which commands are passed through a cable link between a control station and the tool. The operator is located in a console protected from radiation and the tool is fitted with cameras that allow the operator to guide it. These robots are tool carriers suited to the operation in question such as:

- Pliers for the mechanical cutting of tubes;
- Electro-hydraulic jackhammer for removal of concrete;
- Laser beam.

These robust pieces of equipment are already developed and have been used internationally and at the CEA (French Atomic Energy Centre) and will be considered for future use in PWR decommissioning.

6. CONCLUSIONS

This chapter identified the potential significant hazards encountered on a regular basis during decommissioning activities. This identification has been based on experience feedback gathered from previous activities and participation to international decommissioning programmes, as well as international guidance.

The safety approach used for the hazard identification for each decommissioning operation has also been presented. For each relevant hazard, mitigations measures must be put in place.

The design of the UK EPR has taken account of the significant hazards associated with decommissioning and provides measures to control them.

The main control and protection measures that can be implemented to limit the radiological and non-radiological hazards during the decommissioning of a UK EPR have been identified.

Lastly, it has been proven that the use of remote-controlled equipment can help reduce the hazards during decommissioning. More specifically, this document presented some examples where the use of remote controlled equipment could be envisaged for the decommissioning of an EPR.

7. REFERENCES

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APPENDIX 1: HAZARDS MANAGEMENT MEASURES

This appendix presents information on hazards management measures for the hazards that have been identified for the decommissioning of radioactive facilities. They apply to all hazardous situations in which these hazards occur and are applicable to EPR Design.

MANAGEMENT OF RADIOLOGICAL HAZARDS

1. Dispersion of radioactive material

- The principle adopted for decommissioning and clean-out operations is the containment of dispersible radioactive materials as close as possible to their source. This principle minimises the contamination of radiologically clean premises. The means of containment put into place needs to be appropriate for the physical/chemical nature of the radioactive materials present in the area being decommissioned – this includes consideration of:
  - the radiological inventory present in the area being decommissioned;
  - the processes and tools used;
  - the physical/chemical nature of the radioactive waste produced.

Containment for decommissioning is implemented through a combination of:

- static containment: airlock and/or wall;
- dynamic containment: ventilation.

Additional measures may be taken to reduce the requirements concerning static-dynamic containment, or even to obviate the need for them:

- collection at source (local extraction);
- depressurisation of the system on which the work is carried out;
- implementation and management of radiological cleanliness zoning.

Processes and procedures are defined to maintain the containment of radioactive materials during the course of each phase of the works (installation of airlocks, depressurisation, etc.). Compliance with these procedures will control the risk of the dissemination of radioactive materials. Monitoring equipment will be positioned close to the work areas in order to check for the presence of contamination.

2. External/internal exposure of workers

Preventing the risk of exposure of personnel is first of all based on the design of the decommissioning project or task. The organisation of the work is based on the optimisation method (ALARA principle) and the control of individual and collective doses to personnel. Radiation protection zoning and the corresponding access and circulation rules will be defined for all the areas in the installations being dismantled. This zoning will change as the dismantling operations progress, according to the increase/reduction (temporary or permanent) in the radiological inventory of the defined zones.

- Following radiological surveys, a map of the most significant radiation hot-spots is made and used to define these areas. These points are identified and biological protection is installed whenever possible and appropriate in the zones with a high dose rate. For certain operations in the decommissioning of reactors, some of the most active structures are decommissioned under water;
- In zones with high dose rates, remote-operation equipment may be used, to minimise worker exposures.

Depending on the hazard analysis specific to each operation, the personnel and worksites will be given mobile equipment for radiation protection checks:

- devices for monitoring irradiation and the presence of atmospheric aerosols;
- portable radiation meters;
- surface contamination inspection devices with manual probes;

Radiation protection also involves the following devices:

- measurement equipment for checking the radiological environment of the premises;
- means for checking personnel and equipment leaving the zone.

During normal operating conditions, technical means supplementing those of the installation are used:

- mapping and marking out of hot spots. Biological protection screens are positioned, if necessary, at the hot spots that cannot be eliminated at the beginning of the decommissioning work;
- checks on doses received by means of an operational dosimeter against the task dose constraints;
- provision of devices for checking atmospheric contamination, with triggering of a local alarm if the threshold is exceeded (portable monitors);
- wearing of protective breathing apparatus or suitable respitatory protection (filtering or isolating) when the contamination exceeds 1 DAC (Derived Air Concentration), in order to prevent any internal contamination.

Specific measures are taken where there is a risk of exposure to alpha contamination:

- appropriate site management concerning signage, tooling, waste, checks, working methods;

- collective protection (containment appropriate to the scale of the risk);
- individual protection (ventilated leak-tight suits or breathing apparatus);
- training area for practising undressing;
- medical monitoring protocol based on relevant regulations;
- site events register;
- supervision of all participants.

MANAGEMENT OF NON-RADIOLOGICAL (CONVENTIONAL) HAZARDS

1. Fire

Prevention and monitoring of fire hazard during the work is based on fire risk assessment and compliance with relevant regulations. Measures expected to be taken include:

- personnel training;
- management and monitoring of the calorific potential;
- the non-flammability and non-propagating characteristics of the materials making up the airlocks and workshops;
- the use of electrical cables that do not propagate fire;
- electrical appliances equipped with earthed equipotential links to avoid a build-up of static electricity;
- limiting the amount of combustible material present by regular cleaning of the site and removing combustible materials that are not being used,
- switching equipment off when not in use;
- where practicable, opting for the use of cold cutting tools (no activation energy);
- installation of approved spark arresters.

Work involving thermal hot spots (grinding, cutting, welding, etc.) is only authorised if there is an authorisation procedure ("hot permit" or operating procedure), the aim of which is to identify the risks and adopt prevention, monitoring and intervention measures accordingly. They will be recorded in the hazard analysis associated with the document.

Generally speaking, the fire risk assessment will take account of the risk of thermal bridging in the work premises, their walls and the adjacent premises.

The main control measure is the regular inspection of work sites, carried out by the operator or the regulatory body.

2. Lifting and Manual Handling

The lifting equipment to be used will be sufficiently strong and stable for the specified use and marked to indicated safe working loads. It will be positioned and installed to minimise any risks and their use will be planned, organised and performed by competent personnel. The lifting equipment will be subject to ongoing examination and testing by competent people Handling and lifting equipment will include safety devices. Only equipment appropriate to the load are used. The lifting and handling equipment will be regularly inspected and maintained.

The handling and lifting systems will be suitably designed to be adapted to the potential consequences of a falling load.

Safety instructions are specified and followed, for example lifting zones and circulation routes. The personnel will be suitably qualified and experienced in the use of the lifting equipment.

3. Working at height and slips, trips and falls

For work at height, collective protection measures (guard rails, secure working platforms, etc.) are generally preferred to individual protection systems. If these collective protection measures are considered to be unsatisfactory or impossible to install, individual protection equipment is used. Scaffolding will be used in accordance with the regulations.

During the course of work at height, tools and objects must be kept to the strict minimum and an exclusion zone marked out on the ground. The tools used will be attached to the operator's belt. Protective netting will be installed around the scaffolding where appropriate.

All waste will be removed from the working platforms as and when produced, in order to limit this hazard. The workers will be trained in work at height

Personnel will ensure that the working zones remain clean and tidy. The worker circulation zones will be marked out and well lit. No storage will be allowed in these zones.

The floors will be kept clean and in good condition to minimise the risk of slipping.

These hazards will be controlled by site visits and inspections.

4. Electrical hazard

Work will be carried out to ensure that electrical installations are safe. Personnel will be provided with safe and suitable equipment, with alternatives to electrical tools (e.g hydraulic tools) being used where practicable and use of the lowest possible voltage equipment.

Electrical equipment will be checked by an approved organisation. Safety devices will be provided such as circuit-breakers on electrical cubicles, which will be earthed. The personnel involved will possess electrical qualifications appropriate to the nature of the work carried out. The safety instructions will be followed (in particular the tag-out and power-off procedure before intervening on an electrical installation) and preventative maintenance of electrical equipment will be carried out.

5. Mechanical hazard from machines and tools

In order to protect all the personnel in the vicinity of work areas using machines and tools, the workstation will be marked out to minimise the risks of spraying/projection reaching personnel outside this work area.

Machines and tools used in these areas will comply with the relevant regulations and codes of practice. Personnel will be trained in the use of the various tools, which may present hazards (e.g plasma, cutting, grinding, welding). Personnel will follow safety instructions, the manufacturer's recommendations and will wear individual protection equipment appropriate to each tool. These tools will be tagged out when not in use.

6. Toxic and Hazardous Substances

The preliminary risk analysis will involve the determination of:

- the list of chemical products used;
- the way in which they are used (REACH European directive), which allows the operating procedure's suitability for the product to be verified;
- the measures implemented to limit the risks.

Recommendations for the use and storage of chemical products will be followed. These products will be clearly identified. These products will be delivered in the quantities strictly necessary. When choice is available, the least hazardous material for each particular activity will be preferred.

The personnel will be trained in the procedures to be followed in the event of an incident or accident involving these products (splashing, spillage, leak, etc.). The instructions for use and the safety data sheet for each product will be made available to the user and followed.

When handling chemical products, the personnel will be given appropriate individual protection equipment.

Specific measures will be taken as necessary for particular hazardous substances for which there is separate legislation (e.g. lead).

7. Noise-related hazard

For building demolition operations, special measures will be taken on a case by case basis.

Equipment will be used which complies with regulatory requirements. Where high work noise levels are possible, a risk assessment will be undertaken in accordance in order to identify measures to minimise noise exposure.

8. Asphyxia/Anoxia

Work involving this risk (use of equipment with a supply of breathable air for example) will only be possible if there is a supervisor (with visual contact at least) located outside the work zone.

The equipment installation will comply with the safety requirements (clearly marked hoses, connections). An appropriate air supply will be used (with safety bottles), equipped with filtration and permanently monitored (air quality and flow rate: audible and visual alarm, etc.). Only equipment in good working order will be used (check on expiry dates, check on equipment condition).

The personnel will be regularly trained in the use of the various equipment with an air supply. They will also follow the safety instructions and instructions for use of this equipment.

MANAGEMENT OF ENVIRONMENTAL IMPACT RISKS AND CONTROLS IN PLACE

1. Hazards from discharge of liquid effluents

The liquid effluents resulting from decommissioning operations will be treated if necessary and checked prior to discharge. They will comply with the values of the environmental permits in force.

The condition of the liquid effluent collection systems will be periodically checked to ensure that they are leak-tight.

Controls will be put in place prior to discharges in order to prevent any risk of the unwanted release of material into the environment.

2. Hazards from discharge of gaseous effluents

During operations on the work areas (in particular cutting), gases and aerosols are generated. These discharges will be collected in the work areas by ventilation extraction and are filtered using high efficiency (HEPA) filters.

Gases and aerosols will be checked and discharged into the atmosphere via the site's discharge stacks. Aerosols will be filtered on HEPA filters.

The discharges generated by the decommissioning work will comply with the values authorised under the environmental permit.

3. Dust emission

The main cause of dust is demolition of the conventional buildings made of concrete. Given the limited duration of the building demolition work, dust emissions caused by this demolition work are expected to be relatively minor. In the event of large-scale emission of dust, mitigation measures will be taken: for example, water spraying and mist curtains.

4. Noise, release of odours or visual nuisances

Most of the decommissioning operations take place inside the buildings, which will diminish their impacts on the environment. Steps will be taken on a case-by-case basis for outdoor operations, in particular demolition work. Whenever possible, the work will be carried out during the day. Noise will not exceed the authorised levels.

MANAGEMENT OF HUMAN FACTORS

1. Parallel activities and interfaces between work areas

Several activities can be carried out at the same time. These various work areas can share the handling machinery made available (e.g crane and gantry). All the operations will be planned in advance (examination of parallel working) and regularly monitored. These aspects have an impact on the safety and organisation of each work site during EPR decommissioning. With regard to safety, the contractors will follow the instructions, in particular for:

- cessation of activities in the zone during handling phases;
- cessation of the activity on a work site during maintenance operations.

During the planning phase of decommissioning It is important to ensure that the organisation of the work sites is not too rigid (in terms of planning and organising the work) and takes account of operational constraints, while complying with safety instructions, with minimal disruption and delay.

2. Working conditions

The approach to the working situation enables the operator working conditions to be envisaged, in particular:

- the physical environment (thermal, lighting, noise, etc.);
- the radiological and chemical context, which may require the wearing of specific clothing and individual protective equipment. Particular attention will be given to ventilated suits or the use of breathing apparatus;
- manual handling - the aim will be to limit the carrying of loads by the operators and to recommend the use of mechanical handling means;
- postural recommendations for performance of tasks, their repetitiveness and their duration;
- the conditions for moving around congested or tight spaces, etc;
- gathering information and documentation required for performance of the tasks;
- the choice of tools.

These factors will influence the choice of scenarios whenever possible, in order to optimise the work conditions and minimise the risks.

3. Preparation of the premises

Most work sites require a preparatory phase prior to the actual decommissioning work. The aim is to organise the premises in which the various decommissioning related activities are to take place. The premises concerned are the rest/changing areas, the cold and hot airlocks, the cutting and packaging workshops, the storage and loading areas, etc.

The aim is to take account of the actual activity of the operators on the site in order to offer optimum working conditions and enhance their performance, thus optimising management of the safety, security and radiation protection risks. In order to validate the design of these workspaces, consideration must be given to the following:

- the tasks and activities that are to take place in these premises (who? how? what individual protective equipment? what tools? etc.);
- the number of people and duration of tasks;
- waste management;
- regulatory compliance;
- the risks envisaged;

- the techniques used and their constraints;
- the general organisation and its constraints.

This approach requires study of the procedures, operating experience and feedback and if possible the involvement of the various disciplines that will be working on the site. On the basis of these elements, scenarios can be run on 3D or 2D mock-ups as necessary.

CHAPTER 5 – TABLE OF CONTENT

1 INTRODUCTION

This chapter explains the basis of the plant status assumed to exist at the cessation of power operations (e.g. radiological conditions, contamination, activation).

Section 2 presents how the status has been established at the design stage for the purpose of defining the decommissioning plan, and the underpinned allowances made for any reasonably foreseeable abnormal operations, and how it is expected to evolve or remain unchanged until reactor cessation of operation depending on operation history.

The impacts of the time of decommissioning on this status compared to the baseline decommissioning (e.g. early plant shutdown, life extension or deferment) are discussed in Section 3.

The measures foreseen at the design stage (selection and treatment of material, reactor chemistry) to minimise the production and transport of activated products in the plant is introduced in Section 4.

Finally, the methods for confirming plant conditions in the future through surveys and calculations at the time of cessation of operation are presented in Section 5, and the design and operational measures implemented to prevent contamination of the land are highlighted in Section 6.

2 PREDICTED PLANT STATUS AT CESSATION OF OPERATIONS

2.1 GENERAL STATUS OF THE NUCLEAR ISLAND AT CESSATION OF OPERATION

At the EPR design stage, the radiological and cleanliness/waste zonings have been performed conservatively enough so that, provided that the operators take all the measures required to maintain them, they will remain valid during the overall plant life. Through the design, the zonings aim to ensure the habitability of rooms, so that the maintenance and potential replacement of the components situated in the Nuclear Island, is feasible with ALARP doses.

2.1.1 Radiological status

The Design Radiological studies of the EPR are performed on an effective dose assumption, which includes both irradiation and contamination sources. They are performed on the basis of the Biological Shielding (DPB) source term. { CCI removed }[b]

Since the N4 model does not incorporate the evolution in the EPR design related to the materials selected, and in particular the reduction in the use of stellite™ (see Section 4) which will induce lower activity levels in the source term, the EPR design source term is considered to be conservative and to remain valid over the 60 years operation of the EPR.

Nevertheless, it will be the operator responsibility to keep up dated records of radiological plant status, taking into account the occurrence, if any, of incidents that may impact a particular room or group of rooms. For example, in the case of any hot spot creation, it is the operator's responsibility to identify and manage it, within the framework of the radiological zoning.

The assumption is therefore that the radiological status of the plant should remain the same at cessation of operations as at the plant start-up.

2.1.2 Cleanliness / waste zoning

In addition to the radiological zoning, a cleanliness / waste zoning is implemented within the Nuclear Island buildings of the EPR. This zoning is performed at the design stage
{ CCI removed }[b]:

- The rooms description and the activities and facilities likely to be found in those rooms,
- The operational feedback from French fleet plants,
- The radiological classification of the EPR buildings,
- A conservative approach for the equipment: it is considered that all the valves, pumps, exchangers that contain fluid under pressure and elevated temperature are likely to leak,
- The personnel movements, with the rule that a non-contaminated zone cannot be accessed through a contaminated one,

The goals to be achieved by means of this zoning are mainly:

- To define the air transfers from the less contaminated rooms to the most contaminated ones,
- To limit, during the operating phase, transfers of contamination and to ease the classification of waste as conventional waste even when originating in controlled areas, reducing the volume of waste which would otherwise have to be considered as radioactive waste,
- To facilitate maintenance of plant cleanliness, noting that this is the operator's responsibility.
- During decommissioning, to reduce the decontamination work and the volumes of waste classified as radioactive.

Zoning for the reference EPR is based on a principle of classification of the rooms and areas as follows:

- A "K" room (area) is a room (area) where the waste produced may be directed to a non-nuclear waste route. The room must be free of unfixed contamination; air supplied is clean (fresh inlet) air; and the stored waste or waste transiting this room is clean or appropriately packaged. In addition, a “K” room is necessarily a room without any neutron flux;

- A "Np" room (area) needs to have an identical level of radiological cleanliness as a "K" room (area), but the waste produced in it cannot be sent to a conventional route (unless an exemption process is applied).

- "N1" means that it is not possible to demonstrate that there is no contamination in the room.

- "N2" applies to rooms for which it is not possible to establish a programme for monitoring and cleaning of contamination during the operation phase. In practice "N2" at design stage applies to rooms, which are not freely accessible due to irradiation aspects, and to contaminated sumps and pools.

{ CCI removed }[a]

2.1.3 Allowances made for any reasonably foreseeable abnormal operations

The EPR cleanliness / waste zoning is related to normal operating conditions. However, in order to account for incidents that may occur during the operational phase, a conservative approach was applied when establishing the zoning. The assumption is made that all the valves, pumps, exchangers, which contain active fluid under pressure and high temperature are likely to leak. The EPR cleanliness / waste zoning also accounts for airborn contamination that a leakage into an adjacent room can induce through walls openings. These assumptions are deemed to encompass reasonably foreseeable abnormal operations.

These assumptions lead to a predicted level of contamination of the rooms, at the time of decommissioning, higher than what should actually be expected, considering that the facility will be maintained and cleaned during the entire plant operation.

The operator is expected, during the EPR operation phase, to establish and maintain a cleanliness program. This programme will aim at preserving the initial cleanliness of the rooms by regular maintenance of equipment before significant leakage occurs that cannot be drained into the RPE [NVDS]; and to install adequate protection around an area wherever a contaminating worksite has to be installed. Once the work is completed, the room is to be cleaned-up back to its initial cleanliness level.

The conservative way that the cleanliness / waste zoning was performed at the design stage leads to the number of potentially contaminated rooms being greater than will effectively be the case during operation. It is therefore expected that the operator will be able to decrease the classification level of a number of rooms during the EPR lifetime, i.e. be able to declare a cleaner level than initially foreseen, due to good operating practices and maintenance of the facility.

In the absence of significant incidents, it is expected that the cleanliness / waste zoning of the EPR will remain at least as good as assigned at the design phase, or indeed will become even better.

2.2 STATUS REGARDING THE ACTIVATION OF COMPONENTS AND STRUCTURES

The activation of components is limited to the areas which are submitted to a neutron flux, i.e. in the vicinity of the reactor core.

Corrosion products activated in the core will be transported through the primary circuit. They may participate to the formation of hot spots that will potentially appear during the operation phase, and will have to be monitored and recorded by the operator since they cannot be anticipated at the design stage. However the EPR design has been made to minimise those products and their transport, as addressed in Section 4. Activated products will be removed at the beginning of decommissioning by decontamination of the primary circuit, as described in Chapter 2 of this document.

At the time of decommissioning, the components and structures can be classified as follows:

- ILW: only primary circuit activated components (part of the vessel and vessel internals), and about the 60 cm upper layer of the concrete of the reactor pit;

- LLW: Components in contact with the primary fluid and reactor coolant system non activated components are considered as LLW, and some concrete, such as about 90 cm of the reactor pit concrete beyond the ILW layer, and a layer of a few millimetres for concrete on floors, walls and ceilings depending on the category of the room (see Section 4);

- VLLW: Components not in contact with the primary fluid, the primary circuit insulation (except for the vessel insulation which is LLW) and cables, cable trays and supports located in Controlled Area are considered as VLLW; whereas cables, cable trays and support located in Non Controlled Area are considered as conventional wastes.

Regarding ILW, there are three families according to activity levels:

- The most activated are:
  - Heavy reflector and lower support plate
  - Specific activity associated with Co60 ~ 2.1E+9 Bq/g for raw waste 5 years after shutdown
- The intermediate activated components are:
  - Core barrel, upper core plate, flow distribution device and upper support columns (which are located under the upper support plate)
- The less activated components are:
  - Pressure vessel and cladding (in the active region of the fuel assemblies)
  - Specific activity with Co60 ~ 2.8E+5 Bq/g for raw waste 5 years after shutdown

All others internals structures classified as LLW at the time of production.

Further details regarding the BNI components and structure classification and quantities, and the calculations performed to establish the inventory of the activated waste are presented in Chapter 8 of reference [4]. Chapter 6 of the present report provide complementary information regarding the disposability of the waste.

3 IMPLICATIONS OF CHANGING THE ASSUMED DECOMMISSIONING START-TIME

Considering the zoning and the characterisation of activated components and structures presented in Section 2 above, it can be anticipated that changing the assumed decommissioning start time (shorter or longer operation duration, deferred decommissioning) will have limited impact on the plant status at the beginning of its decommissioning.

Activation of components and structures under neutron flux starts with the operation of the reactor. In all cases calculations will have to be performed during the preparatory phase of decommissioning to confirm the anticipated level of activation considering the real power and operating history (fuel cycles lengths, power fluctuations, outages durations).

Moreover, activation of components and structures is not proportionate to the exposure duration; indeed, for each radionuclide, after some radioactive period, depending of natural element concentration and neutron flux level, activity reaches an asymptote called activity at saturation. This is in particular the case for 60Co having a radioactive period of about 5 years.

In case of early plant shutdown, activity of the most activated components and concrete can be expected to be similar or lower than the one after 60 years of operation and the facility could actually be cleaner than was anticipated.

In case of life extension, the status described in Section 2 above should be applicable, since the operator cleanliness program will still be applied and the activation of components and structures will be similar to the one after 60 years. Therefore no change in the status can be identified at the current design stage.

Deferment of decommissioning would allow an increased period for decay of radioactivity as explained in Chapter 3 of the report.

It is concluded that changing the time of the start of decommissioning will have limited impact on the volume and characteristics of waste that is required to be disposed.

4 MINIMISATION OF ACTIVATION AND CORROSION PRODUCTS, AND MINIMISING TRANSPORT OF THOSE PRODUCTS THROUGH THE PLANT

The design of the EPR components includes selection and treatment of materials of the primary circuit with regard to minimising the consequent radiological impact. Materials in contact with the primary coolant must have a low release of activatable species, leading to limit the Cobalt content of materials and the use of cobalt-based hardfacing (Stellite™), and as a general rule to forbid Antimony and Silver as a material constituent. { CCI removed }[b]

In addition to the reduction of materials that can cause the production of radioactivity, the primary circuit chemistry is carefully specified and controlled, during the reactor operation, so as to limit as far as possible transport and activation of corrosion products { CCI removed }[b]

In particular, as corrosion products transport could occur during transients, chemistry program recommendations have been defined for the following transients:

- Start up
- Hot shutdown
- Shutdown for maintenance or refuelling

The monitoring and dosing systems are specified so as to permit the implementation of optimised conditioning (pH and Hydrogen concentrations), thus ensuring that radioactivity levels are reduced as far as is reasonably practicable.

A key element in the EPR™ design is the control of corrosion product concentrations in the primary coolant. Two aspects are considered (production of corrosion products which can become active and the optimisation of corrosion product transport) because they contribute to deposit inventory. Also, the primary circuit chemistry parameters and the conditioning requirements during hot functional testing are critical in maintaining optimum control and reduction of corrosion products in the primary circuit. { CCI removed }[b]

Chemistry requirements necessary for proper control and minimisation of deposits, along with the primary circuit chemistry parameter values and hot functional test procedure requirements necessary in achieving an optimum reduction in corrosion product concentration are defined. { CCI removed }[b] The implementation of these chemistry requirements will effectively reduce and ensure radioactivity in the primary circuit of the UK EPR™ so far as is reasonably practicable (SFAIRP).

5 METHODS FOR CONFIRMING PLANT CONDITIONS IN THE FUTURE

5.1 DURING OPERATION OF THE REACTOR

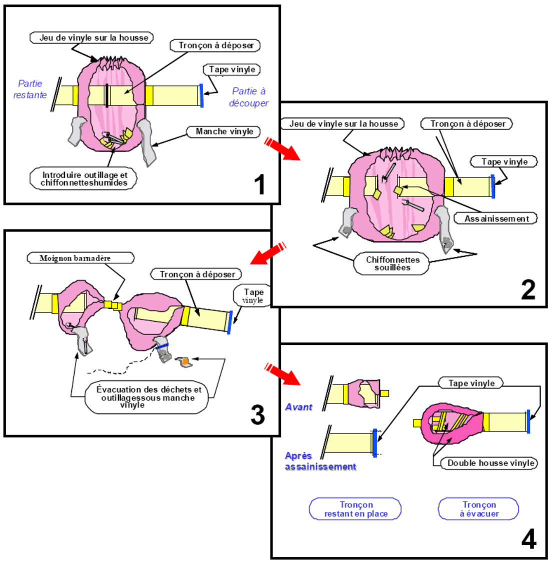
Primary coolant samplings will be performed regularly and allow the monitoring of activation and fission products. This allows updating of the transport and deposition modelling. During outages external gamma spectrometry will be performed on primary components such as hot and cold legs and steam generators.

An extensive programme of sampling and measurements is carried out during the operation of the reactor in order to control the chemistry of the primary coolant such that it is optimised to reduce the risk of corrosion and deposits in pipes and structures.

5.2 BEFORE DECOMMISSIONING

Primary coolant system coring and pressuriser scraping will be performed to provide samples suitable for further analyses. Similarly, reactor auxiliary system piping will be sampled through scraping, and samples will be cut-out in shielded work areas for analysis in the hot laboratory facilities (gamma spectrometry, alpha emitters and nuclides difficult to measure). For radionuclides difficult to measure in-situ, a water contamination spectrum and scaling factors will be defined. This will allow the determination of the subsequent radiological classification of circuits, waste classification and determination of the conditions of the site. Activation calculations will also be carried out where appropriate to support these findings.

Chapter 5 - Figure 1: Typical workshop to cut-out sample of auxiliary piping



Activation of components and structures are calculated using a code such as DARWIN-PEPIN. The input data required are the material, the flux and power history.

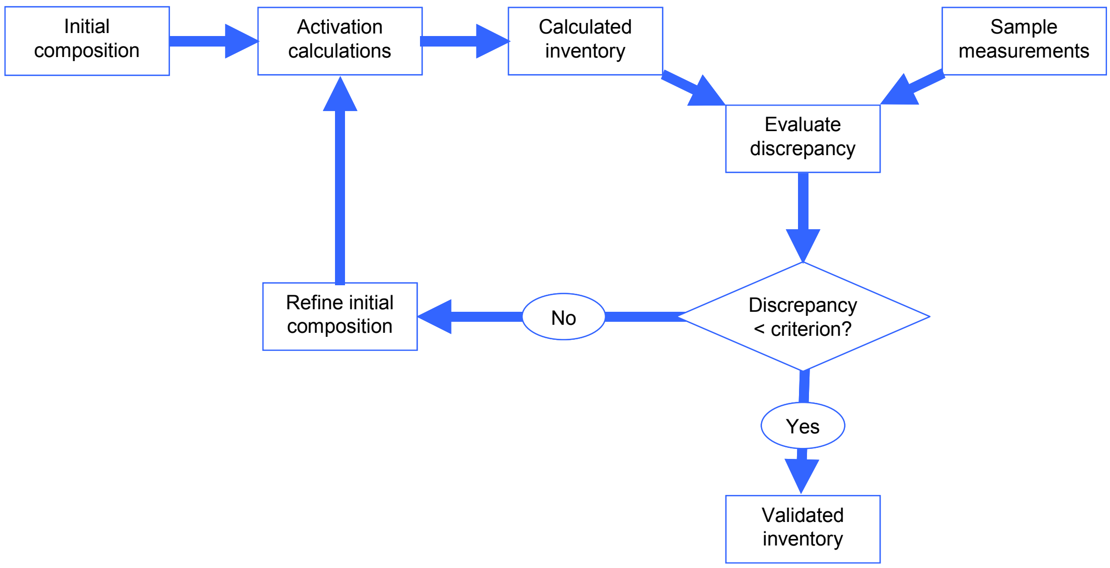
The results are the activity in Bq/g for each radionuclide, and the global activity of each waste stream. The initial conservative values will be consolidated with detailed calculation, using in-situ measurements.

5.3 ANALYSES AND CALCULATIONS USED TO CONFIRM THE STATUS

Chemical analyses (including ionic chromatography, mass spectrography, X-ray fluorescence) are used to determine the quantities of the main constituents and impurities concentration in steel and in concrete:

- Steel
  - Main components are typically: Fe, Ni, Cr, Zr
  - Impurities are typically: Co, Mo, Nb, Sn, B
- Concrete
  - Main components are typically: Ca, Si, Al
  - Impurities, such as: Ni, Co, Eu

Radiological analyses (including alpha spectrometry, gamma spectrometry, liquid scintillation), are performed to determine the radionuclides present in the samples. For difficult to measure nuclides (such as Nb94, Ag108m, Sn121, H3, Be10, C14, Cl36, Fe55, Ni59, Ni63, Sr90, Mo93, Zr93, Nb93m, Tc99) calculation of activation are performed using a calculation scheme similar to that shown below, in order to determine the inventory



5.4 CATEGORISATION OF SURFACES AND STRUCTURES

Once all the circuits have been removed, the rooms will be categorised in terms of contamination to decide which method and technique is most suitable with regards to demolition of the structures of the rooms. The method will be either to decontaminate by surface cleaning, or by scrapping the concrete to a certain level to recover a non contaminated surface; If this is not possible then it would be necessary to demolish the whole structure without cleaning and classify the structure as radioactive waste.

The objective is to eliminate the contaminated part of the concrete structure which will then be disposed of as radioactive waste, while the remaining part of the structure can be classified as conventional waste.

The work of categorisation will be based on the operation history records (mainly the up to date plant mapping with respect to cleanliness including circuit decontamination and dismantling feedback). Two types of surfaces can be identified with two categories for each, as described below;

- Surfaces with no migration / spreading (diffusion) of contamination inside the structure
  - Category 0: surfaces which cannot be contaminated (some ceilings and upper part of walls which cannot have been in contact with any contamination through either process or the operators activities);
  - Category 1: surfaces, which can have been contaminated only by aerosols or radioactive dust, and not by liquids. Nevertheless some surfaces coated with a leak-tight decontaminable paint ensuring that liquids have not penetrated inside the structures, will also enter in category 1. It must be justified that the surface has no cracks and that the paint has not been placed to cover any previous contamination incident. Ceilings are expected to fall in category 1.

- Surfaces with migration / spreading (diffusion) of contamination inside the structure
    - Category 2: surfaces, which are deemed to have been, and those, which have actually been, in contact with contaminated liquids since they show a surface contamination. Further analysis of the civil structure and the record of the contamination history should demonstrate that the there is no contamination deeper than the surface. The civil structure is examined on a case-by-case basis, taking into account information such as the status of the surface (whether there are cracks), historical data (frequency and volumes of radioactive liquid spillages on that surface), and the measured level of activity. Ceilings and walls with surface contamination will more likely fall in category 2 than floors with surface contamination.
    - Category 3: surfaces, which have unquestionably been in contact with contaminated liquids and have cracks, or damaged surfaces with stagnating liquids. Mainly floors are expected to fall in category 3.

The clean up process, therefore the volume of concrete to be scrapped from these surfaces will be adapted to the category.

A similar approach is followed for metallic structures; however, the nature of contamination (aerosols or liquid) has not the same impacts on metallic surfaces than on concrete surfaces. Potential contamination on metallic surfaces remains mainly superficial. The categorisation for metallic surfaces is analogous to the concrete categorisation as follows:

- Metallic surfaces with no suspicion of contamination fall into category "0";
- Metallic surfaces with no verifiable contamination but which may have been exposed to any type of contamination (aerosol or liquid) fall into category "1";
- Metallic surfaces with actual contamination fall into category "3" (there is no category "2" for metallic structures alone).

The categorisation of metallic parts is performed in parallel with the categorisation of the concrete surfaces. Two situations are possible:

- Case 1: The metallic structures are situated on a concrete surface

  The category of a concrete surface, which contains metallic parts, is defined as a whole. In that case the surface category is also applied to the metallic structures. A room will therefore be defined by a set of elements of structures and their associated category. Declassification of a room implies the declassification of all its civil structures. It is worth noting that the treatment of the metallic parts will be the same in case the surface category is "1" or "2". The classification of reinforcement bars is associated with the reinforced concrete.

- Case 2: For metallic structures not associated to a concrete surface, such as frames and metallic walls. The expertise to allow the categorisation (“0”, “1” or “3”) is based on the operation history and radiological measurements.

5.5 CONCLUSION

The sampling, analysis, calculation, categorisation of circuits, room and structures described in Section 5 will be used to select and optimise the decommissioning techniques and workshops and limit the volumes of radioactive waste at the time of decommissioning.

6 PREVENTION OF LAND CONTAMINATION

The EPR is designed in order to ensure the containment inside the buildings or the galleries of any radioactive or dangerous liquid substance, resulting from leaks and from internal flooding.

Circuits and equipment containing radioactive liquids consist of the primary and auxiliary circuits, which are in the buildings of the nuclear island (namely reactor building, safety auxiliary building, nuclear auxiliary building, fuel building), the equipment situated in the effluent treatment building and the pipes transferring the liquid effluent to the site storage tanks and eventually on to the discharge pond.

Note: Circuits and tanks containing hazardous non-radioactive substance (such as the diesel fuel tanks located in the diesel generators building, and tanks with substances such as hydrazine hydrate, located in the turbine hall) are similarly designed to prevent ground pollution.

Several levels of preventive measures are implemented in the design, in order to achieve the containment of radioactive and dangerous substances:

- Design and construction
  - Specification and subsequent quality control of the manufacturing and erection of metallic components so as to ensure that they remain leak-tight over the lifetime of the facility;
  - The implementation of a metallic liner on the walls and bottom of the concrete pools, tanks, sumps;
  - The buildings are erected on a concrete raft, with coating of the rooms' floor which are identified as being potentially flooded and part of their walls;
  - Pipes, which run outside the buildings, are installed in concrete galleries, which can be inspected;
  - Isolation valves are implemented along the circuits to allow the isolation of sections;
  - Internal flooding analyses are performed to show that the consequences of flooding events are acceptable.
- Collection and detection of potential leak:
  - Collection of any leakage through the RPE [NVDS] piping and sumps system in the nuclear island and through SEK [CILWDS] in the turbine hall;
  - Leak detection systems are designed and installed in the sumps to inform the operator of any leakages;

- Inspections of the equipment during maintenance.

More details on these measures, which are judged to be the best available techniques to prevent the contamination of the underlying ground and groundwater, are presented below.

6.1 DESIGN MEASURES

6.1.1 Main mechanical equipment

The EPR systems and their main mechanical equipment (such as tanks, pipes, heat exchangers), which contain radioactive liquids with potential for leaks, are PTR [FPCS], RCP [RCS], RCV [CVCS], REA [RBWMS], REN [NSS], RIS [SIS], RPE [NVDS], SEK [LWDS], TEP [CSTS], TEU [LWPS].

The mechanical classification of these equipment and the associated design and construction codes and requirements applicable to their design and manufacturing enable a high standard of manufacturing quality to be achieved. This in turn provides assurance that the systems will have high integrity. Detail regarding mechanical classification and the associated codes can be found in PCSR Sub-chapter 3.2 section 1.

6.1.2 Pools and concrete tanks

In order to prevent any contamination from the pools (IRWST, spent fuel pool, reactor pool) and the concrete tanks (ASG [EFWS], RBS [EBS] and RRI [CCWS]) a system is designed and implemented for detecting, locating and draining leaks. This system is installed next to the welds, on the inside wall of the leak-tight metallic liner; It consists of a mesh of channels installed along the anchoring point mesh of the liner, on the vertical wall and on the bottom of the pool.

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Moreover, in order to reduce the risk of overflow during operation, the concrete tanks (ASG [EFWS], RBS [EBS] and RRI [CCWS]) are built bigger than functionally required.

6.1.3 Piping between buildings - Effluent treatment storage tanks

Pipes transferring radioactive liquids between buildings and / or effluent storage tanks and / or to the discharge ponds are installed inside leak-tight concrete galleries, which allow the collection of any leak. The galleries are designed so that they can be inspected periodically. The galleries are site-specific installations to be designed depending on the site plot plan.

The installation of radioactive liquid storage tanks KER [LRMDS], SEK [LWDS], TER [Ex LWDS] is also site specific. While designing these tanks at the site specific stage, UK regulatory requirements related to protection of ground with respect to contamination will be taken into account.

6.1.4 Collection or leaks in the nuclear island buildings

Leak are collected and detected through the RPE [NVDS] system. This system consists broadly of two types of structures:

- RPE [NVDS] tanks containing primary effluents, process drains or chemical drains (RPE1/3, RPE4, RPE5 respectively),
- RPE [NVDS] sumps containing floor drains 1, 2 or 3 (RPE6, RPE7, RPE8 respectively).

In case of the a failure to contain fluids (e.g.. pipe failure), leaks are collected in gullies located in the different rooms. The gullies are connected to RPE [NVDS] sumps, according to their origin. There are three categories of RPE [NVDS] floor drains:

- Floor drains 1 (FD1): These are potentially contaminated and come from exceptional leaks from equipment carrying primary coolant and from floor washing. The sumps are installed in areas containing equipment transporting primary coolant.

- Floor drains 2 (FD2): These are slightly contaminated or uncontaminated and come from leaks, floor washings and from the bleeding of equipment (such as feedwater system or RRI [CCWS]). The sumps are installed in controlled areas that do not contain equipment transporting primary coolant.
- Floor drains 3 (FD3): These are produced solely in uncontrolled areas. They are usually uncontaminated and come from bleeding of equipment (such as feedwater system and RRI [CCWS]), from leaks and floor washing.

More information on the RPE functions and design is available in PCSR Sub-chapter 11.4 section 2.1.

Part of the effluent recovery system is embedded in the raft concrete: this is designed to prevent any leak through the concrete. The design consists successively of a floor drain, a double wall drain, and a sump

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6.1.5 Alarms about how leak detection systems

The operator in the control room is warned, of abnormal (excessive or continuous) liquid inlet in any RPE [NVDS] sump, by the means of the alarms associated to the RPE [NVDS] sumps level measurements sensors.

In case of alarm the operator stops the ongoing draining operation, then follows the procedure in order to: identify the cause of the alarm (such as pump defect, exceptional draining operation, and leak); he will then take appropriate compensatory action (such as isolation of the leaking circuit / equipment); he will then initiate the appropriate corrective action.

6.1.6 Internal flooding

The design of EPR takes into account internal flooding due to the emptying of circuits or equipment. The assumptions regarding internal flooding (initiators, duration, installation), are described in PCSR Sub-chapter 13.2 section 8. The requirements regarding the layout implementation with regard to flooding are applied all along the design; moreover a deterministic design verification is performed at the end of the layout design for each building, to confirm that (i) the equipment required for nuclear safety functions remain available (ii) the rooms, which are used as retention capacity have all been identified and their concrete protected with a leak-tight coating.

6.2 BASIS FOR INSPECTION OF THE INSTALLATION INCLUDING GROUND MONITORING

6.2.1 Visual inspection

The UK EPR operating procedures will contain in service inspection of the circuits and equipment, during plant walk down reviews, such as visual inspection. These allow checking of the external condition of the pipework. Visual inspection can be carried on to check:

- Mechanical damage in general (e.g. bending, breaks, pipe movement);
- Operation of support devices (e.g. free movement of rollers, mounting positions of standard support devices, operability of spring hangers etc.);
- Indication of leaks;

- Defects in threaded connections, measuring devices and impulse lines;
- Vibrations, noise (e.g. cavitation).

6.2.2 Ground / groundwater monitoring programme for the site specific phase

A site specific environmental protection and monitoring programme will be established by the UK EPR operator, to monitor the environment around the site.

Typically, a periodic sampling of underlying underground water is carried out within the boundaries of the plant to measure for indications of increased levels of radioactivity.

Monitoring of water tables localised right under the site (or in the vicinity) are also carried out to detect the occurrence of any other indications of leakage into the environment. Typically the analysis covers parameters such as:

- PH and conductivity
- Hydrocarbon
- Nitrogenous compounds
- Metals (total)
- Phosphates

In accordance with the requirements of the operator organisation, the results of the measurements are recorded, and periodically communicated to the relevant Authorities.

6.3 PREVENTION OF CONTAMINATION OF LAND AT DECOMMISSIONING STAGE

The combination of all the techniques described in Sub-sections 6.1 and 6.2 above contribute to the prevention of contamination of the ground / ground water during operation. These measures will also be available at the time of decommissioning.

During decommissioning the risk of leakage will be progressively reduced as the circuits stop being operated and are drained. The latest circuits of the EPR nuclear island to be drained will be:

- The IRWST circuit, which will be used for cutting under water the RPV;
- The circuits related to the spent fuel pool in the Fuel Building and the associated purification system of the cooling water.

6.4 CONCLUSION

In the EPR and interim storage facilities manufacturing of the equipment and their installation in buildings with protected floors and walls, the monitoring of potential leaks from the pools, tanks and sumps, periodic inspections and maintenance will prevent the land and groundwater becoming contamination should any leak occur.

Under consideration of the above preventive measures, the potential of the EPR to contaminate land is considered to be very low. Monitoring of land and groundwater around the site will enable detection of any contamination that could occur, due to failure of the design and operational measures.

7 REFERENCES

[1] { CCI removed }[b]

[2] { CCI removed }[b]

[3] { CCI removed }[b]

[4] "Solid Radioactive Waste Strategy Report (SRWSR)", NESH-G/2008/en/0123 rev A

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[6] { CCI removed }[b]

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CHAPTER 6 - TABLE OF CONTENT

1. INTRODUCTION

Decommissioning of the EPR and interim storage facilities generates radioactive waste, which needs to be disposed of. The aim of this chapter is show that the disposability assessment presented in the GDA submission aligns with the baseline decommissioning plans. It covers the radioactive waste generated during the decommissioning of the nuclear facilities of an EPR site (one single EPR^{TM} plant and associated Interim Storage Facilities (ISF for ILW and SF)) with respect to the current UK regulatory requirements.

Section 2 recapitulates the baseline assumptions related to (i) the EPR decommissioning as presented in the GDA submission, and (ii) the interim storage facilities proposed by EDF/AREVA for spent fuel and ILW.

Inventory of the wastes, including those relating to the decommissioning of the interim storage facilities is presented in Section 3.

Secondary wastes are discussed in particular in Sub-section 3.4 and Section 4 together with the sensitivity of the waste streams to the decommissioning processes.

Waste management and waste routes from the buildings to interim storage are described in Sections 5 and 6 respectively.

Disposability assessment and compliance with waste hierarchy and demonstration of BAT are discussed in Sections 7 and 8 respectively.

2. KEY ASSUMPTIONS OF THE DISPOSABILITY ASSESSMENT

2.1. INTRODUCTION

The facilities covered by the present disposability assessment are the Nuclear Island of the EPR^{TM}, the Spent Fuel Interim Storage Facility and Intermediate Level Waste Interim Storage Facility.

The assumed baseline is that the UK EPR^{TM} will commence decommissioning immediately after shutdown and de-fuelling, the timing of decommissioning being discussed in Chapter 3 of the present report.

Interim Storage Facilities will be operated for 100 years (from uploading of the first waste package). Decommissioning of each Interim Storage Facility will commence just after retrieval and transport of the corresponding last package.

The waste inventory considers that all nuclear buildings are demolished to one metre below ground level. Building structures below -1 m will be cleaned, identified and prepared (including making holes in the sills to put groundwater at equilibrium) before being left in place (final status of the site: brownfield).

The wastes considered comprise the wastes resulting from the decommissioning of the facilities, the secondary wastes generated during the decommissioning operations. They do not consider the operational wastes produced during the life of the EPR™, but consider operational wastes produced during the life of the Interim Storage Facilities.

2.1.1. Nuclear Island of the reactor

This chapter is related to the radioactive waste generated during the decommissioning of the nuclear island of a single EPR™ plant operated during 60 years (Reactor Building, Safeguard Auxiliary Buildings, Nuclear Auxiliary Building, and Effluent Treatment Building). It does not take into account the conventional waste or non radioactive hazardous waste generated from the dismantling of the conventional island plant (principally the turbine house and electrical switchgear) or the administrative buildings and plant infrastructure.

2.1.2. Spent Fuel Interim Storage Facility

The storage building will be located at, or adjacent to, the EPR™ site. The assumption is that all the assemblies from the EPR™ unit from 60 years' operation will be stored, representing around 3400 assemblies (for one EPR unit). The ISF lifetime is assumed to be 100 years from receipt of the first assembly for storage (although it would be capable of extension beyond that if necessary subject to any required refurbishment, replacement of equipment and safety re-justification).

The following four SF storage technologies have been considered in the PCSR:

1. A wet interim storage facility: fuel assemblies stored in a pool.
2. A dry interim storage facility: fuel assemblies stored in metallic casks.
3. A dry interim storage facility: fuel assemblies stored in vault type storage.
4. A dry interim storage facility: fuel assemblies stored in horizontal storage modules

These various storage options are described in References [1] and [2].

Before the interim storage facility can be decommissioned, retrieval of all fuel assemblies to the GDF (Geological Disposal Facility) must be complete. The precise nature of retrieval operations is dependent on the storage technology that will be used. As described in reference [6] retrieval is expected to finish by year Y0+110; Based on available information for similar facilities, the transport of the 3400 assemblies can take about 4.5 years for the various envisaged technologies. However, it is expected that SF packages will start to be transported to the GDF as soon as the GDF is available to receive spent fuel, i.e. to start before year Y0+105.

2.1.3. Intermediate Level Waste storage facility

The conceptual design (generic description and capacity) and the design rules have been provided for the ISF for ILW in the UK EPR™ Generic Design Assessment (GDA) submission, PCSR Sub-chapter 11.5 and supporting document (references [8] and [9]).

The main design assumptions are:

- The interim storage facility will be located on or immediately adjacent to the EPR™ reactor site.
- The facility's operational lifetime will be 100 years.

- Only ILW waste packages will be received.
- No defective packages will be accepted for storage, unless overpacked.
- Some waste will decay to levels permitting reclassification and disposal as Low-Level Waste (LLW) during the operational life of the plant.
- After receipt of the ILW produced during the 60 years of plant operation, the facility may require to be extended to accommodate reactor decommissioning wastes.

About 1800 packages of ILW will be generated during the 60 years of plant operation for one EPR.

A number of packages may however decay to LLW during the period of storage and these could be disposed of as LLW.

In addition to the above mentioned ILW packages, the decommissioning of the reactor will generate about 570 packages of ILW. Assuming a lifespan of 100 years of this ISF, considering the radioactive decay within the ISF, it is considered that less than 100 ILW packages will have to be finally transported to the ILW repository (reference [2]).

However, taking into consideration the assumption that the GDF will become available for disposal of ILW around 2040, it should not be necessary to wait until the end of the building lifespan to dispose of the packages (decision for the operating utility); the number of packages to transport will then lie between these 2 figures.

The minimum duration to empty the ISF for ILW of operational waste packages has been estimated at 200 days for the operational wastes packages, and about 60 more days for decommissioning waste packages, based on a processing rate of 9 to 10 packages per day (reference [6]).

Therefore it can be assumed that the ILW interim storage facility will empty around year Y0+100, even considering all waste to be exported at the end of the facility operation.

2.2. CHARACTERISATION

The assumption considered for the activation calculation of the near core equipment of the reactor, the contamination of the systems and classification of the wastes generated during the decommissioning of the reactor (see reference [2]) are the following:

- Waste classification assumptions for electromechanical equipment:
  - Plant assumed to operate normally,
  - Waste classified at time of immediate decommissioning,
  - Non activated primary components are LLW after decontamination,
  - Electromechanical equipment in contact with primary coolant are LLW,
  - Electromechanical equipment not in contact with radioactive fluids are Very Low-Level Waste (VLLW) or conventional waste,
  - Waste classification assumptions for civil structures:

- The concrete surfaces in rooms (ceilings, floors and walls) which may be potentially contaminated are LLW or VLLW,

- The remaining civil structures (concrete & steel) are conventional waste.

* Activation calculation for the components located near the core are completed with maximum values based on:

  - 38 operating fuel cycles at 100% nominal power (18-month cycles with optimum outage durations over 60 years),

  - Highest total neutron flux (DARWIN-PEPIN 2.1.1 activation analysis),

  - Material compositions with upper bound values.

  Consequently, the activation calculations have produced highly conservative estimates for radionuclide inventories compared to what should be found at the end of live evaluation.

For the ISF, 2 scenarios have to be considered:

* Dry storage technologies for ILW and spent fuel (except vault store) for which we do not expect open contamination, ILW and SF being conditioned in appropriated packages.

* Vault store and wet storage technologies for spent fuel for which surface contamination of the installation will have to be considered; concerning the vault store technology, we do not expect open contamination within the vault (SF being stored in canister) but in the hot cell operated for packaging SF prior transport to GDF and for the treatment of the used canisters.

Despite these assumptions, it is not possible at this stage to determine the exact split between the ILW, LLW and VLLW waste streams. A detailed characterisation of the wastes, will be determined at the time of the decommissioning work. Accuracy of these data will be improved through the life of the facilities (design, construction, operation).

2.3. INVENTORIES

The exact characteristics of the decommissioning waste cannot currently be determined and will be dependent on operational performance, decommissioning strategies, etc.

However, the information presented in the document ref. [7] represents the best estimates available at the current time for decommissioning waste quantities produced during the decommissioning of the Nuclear Island of one single EPR™ plant. They are given at production time (for an immediate decommissioning) and summarised in the following table:

	Mass (t)		
	ILW	LLW	VLLW
Reactor Coolant System	673	2735	1898
Nuclear Steam Supply System	0	2259	0
Balance of Nuclear Island	0	2824	2605
CONCRETE	0	75	455
TOTAL	673	7893	4958

These values take into account all the radioactive wastes produced by the decommissioning of the Nuclear Island of the reactor: dismantling of electromechanical equipment and clean-up of the building (prior to final demolition of the building as conventional concrete). They include primary wastes, but also secondary wastes, mainly the resins generated during the full decontamination of the primary circuit.

In addition, inventories of the waste produced by the decommissioning of the ISF are given on a very preliminary basis.. In order to determine the radioactive waste inventory generated by the decommissioning of the facility, the scenario associated with the design characteristics of each facility has to be considered for each of the possible technologies:

- Wet interim storage facility: fuel assemblies stored in a pool.

  After removal of the spent fuel assemblies, the main contaminated structures will be:

  - Storage racks,
  - Liner of the storage pool and transfer channels,
  - Circuits of water cooling and treatment systems,
  - Potentially the surface layer of concrete, if controls show that it is contaminated.

  The treatment of contaminated waste will be carried out within the facility, using existing resources.

  The wastes will be handled with the handling cranes in place.

  The effluents generated by the decontamination operations will be treated by the waste treatment systems provided within the facility.

  The wastes are expected to be LLW, VLLW or exempt waste after decontamination; they will be packaged in standard containers for transport to surface repository facilities. Most of the concrete will be conventional waste.

  Continuous monitoring of the facility (including continuous monitoring of the water activity) will contribute to the preparation of these operations.

- Dry interim storage facility: fuel assemblies stored in metallic casks.

For this technology, after the removal of the casks which contain the radioactive material, the facility itself can be classified as conventional after due radiological inspection and demolished conventionally; the active decommissioning of the facility is then essentially linked to the treatment of the metallic casks when emptied from spent fuel.

The primary objective when decommissioning metallic transport and storage casks is to reach the lowest waste category.

This objective can be achieved using the following scenario:

- Assessment of storage cask residual activity in order to determine the decontamination operations to be performed.

- Sorting the cask components according to the levels of decontamination to perform; generally speaking, the fuel basket is separated from the cask body and lids for that purpose.

- Decontamination of the components so as to reach the free release or exemption level and thus declassify this waste (if assessed to be BAT).

- If decontamination operations do not allow this declassification level to be reached for part of the equipment, it may be handed over to a licensed service provider for “hot” melting processes. Melting operations have been found to enable declassification or reuse of 90% of the melted products leaving only 10% as radioactive waste.

  These decontamination operations could be performed at the Central Conditioning Plant dedicated to the spent fuel encapsulation operations associated with the GDF, prior to their emplacement in the final repository.

  Indeed, co-locating the storage casks decontamination facility with the surface facility of the final repository site offers the advantage of resources sharing with the spent fuel unloading and encapsulation cells to be provided (effluent and waste treatment installations, in particular). Note that the SF ISF using the metallic cask technology is usually not equipped with such facilities.

  Future advanced spent fuel packaging concepts could involve packaging that does not require re-packaging, taking into account long term critically constraints, which enables direct geological disposal once available.

- Dry interim storage facility: fuel assemblies stored in vault type storage.

  The main stages of decommissioning procedure will be as follows:

  - Implementation of radiological and contamination levels measurements.

  - Components removal using operational equipment (high capacity handling cranes) and specific decommissioning handling devices (travelling gantry crane for example for wells removal).

  - Decontamination of removed component: this operation generates effluents for which a dedicated effluent treatment facility (potentially a mobile one) will be required on the ISF site.

- Volume reduction and conditioning for final packaging adaptation: for example size reduction, compaction, placing into standard containers for transport to surface repository facilities.

It is important to note that the continuous surveillance program foreseen at the ISF (for example the regular sampling of the storage wells internal atmosphere and the activity measurement at the exhaust stack) enables the decommissioning operating staff to anticipate the decommissioning procedure to be implemented.

Regarding the sequence of decommissioning operations and the time schedule, the storage vaults and equipment therein will be the first to be dismantled taking full advantage of the unloading cell containment to perform remote operations if needed with the objective to reach manual accessibility for the great majority of operations.

Considering past experience and feedback from earlier projects such as the management of the French UP1 and UP2-400 plants dismantling, time duration of 5 years for the decommissioning of a vault type ISF seems reasonable.

- ILW Interim Storage Facility.

The waste packages stored in the ISF for ILW will be removed from the building before the start of decommissioning.

The main stages of decommissioning procedure will be as follows:

- Radiological inspection of the facility (even though no contamination is expected due to the controlled conditions over the storage period). Indeed, during the storage phase, inspection and monitoring of the packages in the ISF is part of the operational procedures. Should corrosion of a metallic package be detected, measures are taken (e.g. overpacking), preventing potential spreading of contamination.
- Preparation of a radiological map of the facility and, if necessary, completion of required decontamination activities.
- Removal of equipment from the site (in parallel with the completion of the measurements required to allow release) from the site for recycling or for disposal at appropriately licensed facilities.
- Demolition of buildings and foundations using conventional methods.

The site occupied by the ISF for ILW will then be restored to an end state agreed with regulators and the appropriate authorities.

It is assumed, that approximately 1 to 3 years are required for decommissioning of the ILW interim storage facility to brown field condition.

3. PHYSICAL AND RADIOACTIVE INVENTORIES

Precision of the physical and radioactive inventories will be improved through the life of the facilities (erection, construction, operation) as more information is gathered.

3.1. NUCLEAR ISLAND OF THE REACTOR

The radioactive waste inventories produced during the decommissioning of the reactor have been provided in the SRWSR document and supporting document (ref. [2] and [10]).

LLW, VLLW and conventional wastes are transported as soon as they are produced.

As decommissioning ILW is stored on site in an ISF up to year 100 and the reactor is assumed to be operated for 60 years, radiological characteristics of this waste have been calculated 40 years after reactor shutdown in order to:

- Allow radioactive /heat decay (cobalt-60),
- Optimise shielding requirements for transport,
- Optimise the number of packages for disposal.

The results of decay storage for a period of 40 years in terms of ILW quantities are summarised in the following table.

	At production time				After interim storage			
ILW Waste	**Waste quantity**	**Type of package**	**No.**	**Packed volume (m^3)**	**Waste quantity**	**Type of package**	**No.**	**Packed volume (m^3)**
IER from decontamination	30/40 m^3	500l drum	370	220	0	-	-	0
Activated components	225 t	4 m box – 400 mm	28	600	180 t	4 m box – 100 mm	10	220
	221 t	3 m^3 box – 100 mm	167	450	210 t	3 m^3 box	75	200
Activated concrete	180 t	4 m box	6	130	0	-	-	0
TOTAL	**626 t + 30/40 m^3**	**-**	**571**	**1400**	**390 t**	**-**	**85**	**420**

3.2. ILW STORAGE FACILITY

It is not anticipated that the ISF itself will be contaminated. It is expected that its building and its foundations will be demolished using conventional methods and the resulting waste disposed of in accordance with relevant UK legislation.

If an unexpected local contamination event were to occur during the life span of the storage facility, the area affected would be decontaminated and the resulting waste sent to the waste building or off-site or treated on a mobile unit for conditioning as appropriate.

By transport of the waste packages (which are adequate for storage) to the GDF, the active inventory is removed from the ISF. Radioactive inventory resulting from the decommissioning of the ISF will then be limited to the wastes produced by the treatment of some potential local contamination. Indeed, the biggest waste volume that will be generated in the decommissioning phase is non-nuclear and will consist of the demolished concrete structures, creating conventional wastes.

Following removal of the radioactive inventory, the site occupied by the ISF would be restored to an end state agreed with regulators and the relevant authorities.

3.3. SF STORAGE FACILITY (WET / DRY)

3.3.1. Wet interim storage facility: fuel assemblies stored in a pool

The amount of potentially contaminated metallic waste is estimated to be:

- Racks: 500 tons
- Liners: 100 tons
- Circuits of water cooling and treatment systems: 150 tons

These metallic wastes are considered LLW to be disposed of at a surface repository.

Regarding the concrete, only the top layer of concrete may be cleaned if monitoring shows contamination. The quantity of contaminated concrete produced would be limited, and categorised as LLW. All the remaining concrete would be conventional waste.

3.3.2. Dry interim storage facility: fuel assemblies stored in metallic casks

It is expected that interim storage of an average of 3400 spent fuel assemblies into metallic casks will be equivalent to between 170 and 220 casks (in the case of casks containing about 20 assemblies). It is expected that after decontamination 90 to 95% of the total cask volume (once the casks have been emptied of the fuel assemblies about year Y0+110) can be disposed of as exempt waste thus leaving only less than 10% as radioactive waste.

Decommissioning time duration for these storage casks is greatly dependent on the staffing involved and cannot therefore be estimated at the present stage.

3.3.3. Dry interim storage facility: fuel assemblies stored in vault type storage

The radioactive waste will consist essentially of metallic wastes, concrete which is protected during operation by a metallic liner being classified as conventional waste.

These metallic wastes are the following:

- Approximately 600 steel storage canisters (containing the spent fuel assemblies).
- The main handling equipment (transport containers handling systems and trolleys, fuel assemblies unloading and conditioning equipment).
- Cell lining, drip trays, piping, etc…

A careful selection of material during the design stage will facilitate both dismantling operations and waste disposal according to the acceptability criteria for the decommissioning waste streams.

A high proportion of the vault type storage decommissioning wastes are anticipated to be classified as LLW and VLLW, although a very limited volume of ILW cannot be excluded.

3.4. SECONDARY WASTES

Secondary wastes correspond to the wastes generated during the decommissioning operations; they comprise two types of waste:

- Consumables used by the operators for decommissioning tasks (disposable suits, vinyl, scrap...); these wastes are generally either incinerated or compacted for volume reduction purposes.

- Wastes produced by the use of dedicated equipment, tools and installation for the decontamination and decommissioning works (filters, handling and cutting equipment, workshop structure...).

Only solid secondary wastes will be generated during these operations. Indeed, if liquid wastes are generated (e.g. when decontamination operations are performed using a decontamination solution (with generation of filters, resins and liquid effluents...)), then the liquid effluents generated will be treated as far as possible in the effluent treatment facility of the plan, which will be kept operational during almost the whole decommissioning of the reactor so that the wastes can be concentrated and cemented thereby greatly reducing their volume prior to final storage. A mobile unit can be necessary to treat the liquid effluents generated at the end of the decommissioning (and in particular during the decommissioning of the ISFs). Note that only small volumes of liquid wastes are generated and have to be treated.

It is important to note that all the resulting waste of a decontamination operation are no different in character from waste created during plant operation and can then be treated by the plant itself.

3.4.1. NI decommissioning

The ion exchange resins (IER) used for the decontamination process are the main secondary ILW produced during the post operational clean-out operations that will generate specific waste packages. Some additional secondary ILW (e.g. swarf) may also be produced, depending on the cutting technique used for dismantling the pressure vessel and associated internals but this is not expected to be a significant arising compared to the primary wastes. It will be added to the package of the primary wastes and therefore no extra packages need to be counted.

In addition, corrosion products, which constituted the contamination of the fluid primary systems, are deposited as an oxide layer on the internal surface of the equipment. Part of this oxide layer will be removed by decontamination operation and collected on the IER; the remnant layer thickness staying fixed on the equipment surface will be treated as appropriate by decontamination equipment.

Secondary wastes generated during the decommissioning of the reactor will be essentially LLW and VLLW. Quantities will depend on the technologies used and the detailed dismantling scenario. As a first estimate a quantity of about 15 to 20 thousand 200 litre drums for consumables (before compaction or incineration) and less than one hundred of HHISO containers for other secondary wastes can be anticipated for the decommissioning of the NI.

3.4.2. Wet interim storage facility: fuel assemblies stored in a pool

Secondary wastes will mainly be generated by cutting and decontamination operations.

The liquid effluents generated by the decontamination will be treated within the facility, using as far as possible the liquid waste treatment provided, or if needed at the end of the decommissioning, using a mobile treatment facility.

Secondary wastes generated are considered to have the same classification as the waste treated, i.e. LLW.

3.4.3. Dry interim storage facility: fuel assemblies stored in metallic casks

Considering the technology envisaged for this facility, no contamination is expected to be present in the ISF itself; thus no significant quantity of radioactive secondary wastes will be generated.

Secondary wastes are mainly generated by decontamination operations of the storage casks for which a treatment facility will be required (possibly located at the Central Conditioning Plant associated with the final repository, as suggested above). Parts of the decontamination liquids are likely to have activity levels requiring their classification as ILW.

Likewise, dismantling operations will also produce some secondary wastes such as wipes, gloves, vinyl clothing and/or paper to be incinerated.

3.4.4. Dry interim storage facility: fuel assemblies stored in vault type storage

Secondary wastes will be generated by decontamination and cutting operations completed within the storage vaults. Quantities will depend on the techniques used. Parts of the decontamination liquids are likely to have activity levels requiring their classification as ILW.

3.4.5. ILW Interim Storage Facility

Considering the technology envisaged for this facility, no contamination is expected to be present in this ISF; thus no significant quantity of radioactive secondary wastes will be generated.

4. WASTE STREAMS

4.1. BASELINE SCENARIO

LLW, VLLW and conventional wastes are transported off-site as soon as they are produced during the decommissioning of the various facilities for surface disposal, incineration or reuse according to their classification.

The assumption of the baseline scenario is that ILW produced during the decommissioning of the reactor are stored on site in an ISF so that most of these decay into LLW.. As described in Sub-sections 3.3 and 3.4, no ILW wastes are anticipated to be generated during the decommissioning of the Interim Storage Facilities. Should some ILW be produced they could be transported as soon as they are produced to the final repository which will be operational at that time.

The stream of radioactive wastes produced during the immediate decommissioning of the EPR, the ILW Storage Facility and the Interim Fuel Storage facility will be as follows:

- From year y0+62 (beginning of Nuclear Island decommissioning about two years after granting of the consent for decommissioning) to year Y0+77 or Y0+80 (end of Nuclear Island decommissioning, depending on the spent fuel cooling duration in the at-reactor fuel pool (see Figure 1 in Chapter 7 of the present report):
    - Transport of LLW and VLLW for disposal as soon as they are produced,
    - Transport of ILW to the ISF on site.
- During or about year Y0+100 (or before depending of GDF availability) transport of the ILW packages (produced during reactor operation and decommissioning) from the ISF on site to the GDF.

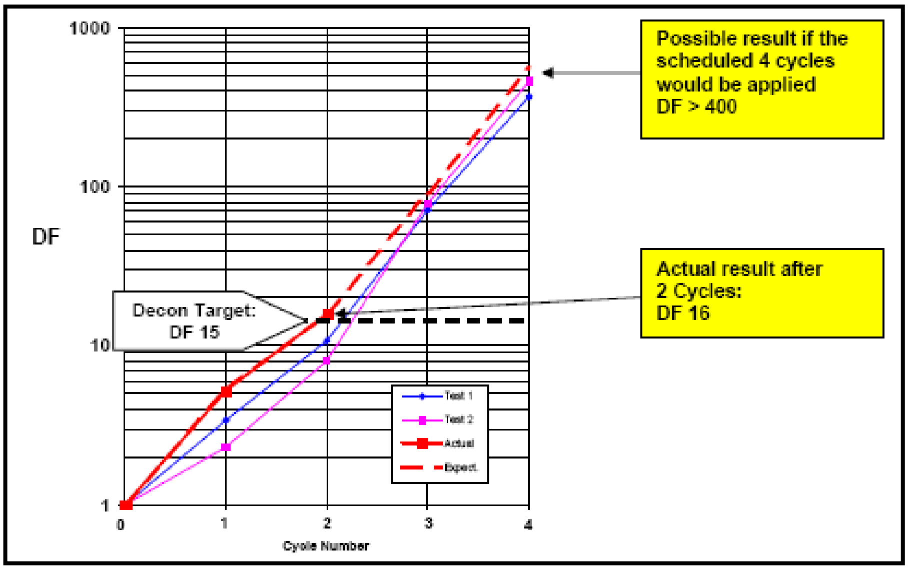
  The minimum duration to empty the ISF for ILW of operational waste packages has been estimated to be about 9 to 10 packages per day (reference [6]), i.e. 200 days for the operational wastes packages, and about 60 more days for decommissioning waste packages, i.e. less than one year is required in total.
- Therefore it can be assumed that the ILW interim storage facility will be ready for decommissioning around year Y0+100.
- Decommissioning of the ILW ISF will last less than a year and waste generated will be transported to appropriate disposal routes.
- From year Y0+105.5 (or before depending of GDF availability) to Y0+110: transport to the GDF of Spent Fuel packages produced during the reactor operation and stored in the ISF on site to the GDF.
- From year Y0+ 110 to year Y0+115: decommissioning of the ISF for SF with transport of the waste of all types produced to the dedicated repositories.

4.2. SENSITIVITY TO THE DECOMMISSIONING PROCESSES (DECONTAMINATION WASTE, SECONDARY WASTES)

The sensitivity of the data (packed volume, classification...) related to radioactive wastes generated during decommissioning operations to the processes used, can be illustrated by the following aspects:

- Management of activated components:
    - Direct disposal option at the time of decommissioning will increase the number of waste packages (consequences of higher radioactivity and heat output to be considered for the most activated components requiring the production of more packages to fulfil repository requirements limits).
    - Direct disposal option at the time of decommissioning will increase the ILW inventory, the dominance of short-lived radionuclides in some decommissioning ILW enabling it to be declassified to LLW within the on site interim storage period (see table in Sub-section 3.1).
- Dismantling techniques:
    - The choice of cutting technique can have a significant impact on the quantities of secondary wastes generated and will be taken into account in the assessment of BAT, at the time of decommissioning preparation, to ensure that secondary wastes are minimised.
    - In particular, based on experience feedback and without prejudging of the results of the BAT approach that will be completed later, preference is today for the most active components to employ as far as possible mechanical cutting techniques rather than thermal cutting, which generates contaminated air filters.
- Decontamination Wastes:
    - Initial full decontamination of the primary circuit
        - Decontamination of the primary circuit for immediate reactor dismantling simplifies intervention (reduction of dose levels linked to the Decontamination Factor (DF) achieved) and reduces quantities of ILW (declassification in LLW of part of primary circuit components) for disposal.
        - IER generated by application of a primary circuit decontamination process have been considered in the ILW inventory.

- The number of decontamination cycles will have an impact on secondary waste generated. The optimum will be defined on a case by case basis by the operator, taking into account of the dose saving target (linked to the Decontamination Factor completed – see figure hereafter where the target was in this specific case 15 – a BAT assessment will be completed prior to the decommissioning to determine what DF to aim for), minimisation of the secondary wastes generated and the initial contamination status of the circuit. Secondary wastes have been estimated within the GDA on a basis of a total of four HP/CORD UV cycles, which can be considered as conservative, the number of cycles varying usually between 1 and 4. Note that for the same individual DF, each successive cycle will generate more and more wastes as the oxide layer and base material to remove will increase.



- The completion of this initial full decontamination has been considered in the limitation of the ILW quantities (declassification to LLW); in order to be enveloped, the possible declassification of part of contaminated primary circuit components from LLW to VLLW has not be taken into account in the decommissioning waste inventory. However, this can be reasonably the case for some massive parts (with high thickness and simple geometry) as primary pipes, SG primary head for which declassification controls are conceivable. Of the 2735 t of LLW quantified in the CPP inventory, it can be roughly estimated that about 1000 t may be declassified to VLLW.

- Compared to the secondary wastes generated by this initial full decontamination (30/40 m^3 of resins), reduction of dose levels for some decommissioning operations and possibilities of declassification of waste is judged to be beneficial.

o Partial decontamination of a component

- Decontamination can be performed in-situ or in dedicated workshop in order to reduce dose level during the dismantling operations and/or to allow declassification of the radioactive waste.

- Definition of the optimum component decontamination technique on a case-by-case basis, in order to justify the decontamination tasks in terms of secondary wastes generated and collective doses expected.

5. WASTE MANAGEMENT

Intermediate level metallic and concrete wastes from the dismantling of the activated components near the reactor core are solid wastes on the basis of the guidance given in reference [5]. The waste packaging philosophy is to use shielded 4 metre boxes or 3 cubic metre boxes potentially incorporating additional shielding. In addition, it is anticipated that IER resulting from the decontamination will be packaged in 500 litre drums.

The solid LLW and VLLW produced during the dismantling of the reactor and the Interim Storage Facilities will be packaged as mentioned below:

- Conditioning of the LLW in HHISO-20' container,
- No special packaging for the VLLW for which only the global volume is considered.

Secondary wastes will be packaged with the same philosophy or in 200 litre drums for compactable wastes such as used Personnel Protective Equipment (PPE).

5.1. DURING DECOMMISSIONING OF THE REACTOR

Waste processing operations will be carried out in the Waste Treatment Building (ETB) and temporary facilities of the EPR. The ETB will be used for receipt, segregation, treatment and conditioning of solid radioactive wastes, as long as possible, in complement to the operations performed in-situ or in dedicated workshops (in particular the one installed in the Turbine hall). These facilities will have appropriate monitoring and inspection arrangements to ensure that only compliant waste packages are transferred to the ISF (ILW) or for transport (LLW, VLLW). After the ETB is decommissioned, if necessary, a mobile waste treatment unit will be used for treatment of any further liquid wastes.

LLW and VLLW will be transported to a suitable disposal facility (LLW) or to a local landfill (VLLW, subject to final assessment) as soon as they are produced without any conditioning (assumed to be completed at the disposal facility); buffer storage will be managed on site.

5.2. DURING OPERATION OF THE INTERIM STORAGE FACILITIES

The operational wastes are estimated on the basis of one reactor operated for 60 years, while ISF is operated for a period of 100 years from receipt of its first package.

5.2.1. Wet interim storage facility: fuel assemblies stored in a pool

The operational wastes arising from spent fuel storage are:

- Liquid effluents:

- Contaminated liquid effluents mainly generated during the loading and unloading of transfer/transport packaging.
- Service effluents, which are hardly or not at all contaminated, are generated by the emptying of non-active circuits which could become contaminated, purges and leaks from intermediate cooling water circuits, washbasins and showers in the hot changing rooms. Effluents of the circulation passages in controlled zones are included in service effluents.

- Solid wastes: the type of solid wastes generated by the plant during normal operation depends on the treatment systems that will be considered and may be different depending on the water treatment stage under consideration: mechanical filters, IER filters, ionic filter cartridges, evaporators. The use of such devices leads to the production of the following types of waste:
  - Filters,
  - Filter cartridges,
  - IER,
  - Sludge and insoluble material (from the oxide layer formed on the fuel),
  - Concentrates.

5.2.2. Dry interim storage facility: fuel assemblies stored in metallic casks

Operational wastes arising from spent fuel interim storage inside metallic cask can be considered as negligible: wastes are limited to the leakage monitoring systems implemented on each storage cask (pressure sensors in particular).

5.2.3. Dry interim storage facility: fuel assemblies stored in vault type storage

Operational wastes arising from a spent fuel interim storage in a vault type facility can be estimated on the basis of similar facilities under operation, in particular the Covra Habog multipurpose storage facility (in the Netherlands) and the Dry unloading facility TO located in La Hague, France. They are classified as LLW or VLLW.

- Liquid wastes: the volume of effluent generated by a vault type of facility is negligible: a few litres can be estimated as a conservative measure.
- Solid wastes: Solid wastes are mainly generated during maintenance operations. They include ventilation filters and wastes to be incinerated, mainly clothes, boots, and gloves. Solid wastes generated for one year of a vault type facility operation can be estimated to be:
  - About 2 compacted waste containers (200 litre drum),
  - About 11 drums destined to incineration (120 litre drum).

Both liquid and solid wastes are intended to be transferred to surface disposal facilities after conditioning.

5.2.4. ILW Interim Storage Facility

All types of packages (wastes with surrounding containers) stored in the facility will have received Letter of Compliance before being used. Once arriving at the ISF, waste packages are enclosed and stored in controlled conditions.

During storage phase, inspection and monitoring of the packages are part of the operational procedures. When corrosion of a waste package is detected, early measures are possible (e.g. overpacking), preventing potential spreading of contamination.

Thus release of contamination from a waste package is considered extremely unlikely and it can be expected, that only conventional wastes are generated during operation of the ISF.

If an unexpected local contamination event was to occur during the life span of the ISF, the area affected would be decontaminated and the resulting wastes sent to the ETB or off-site or treated on a mobile unit for conditioning as appropriate.

5.3. DURING DECOMMISSIONING OF THE INTERIM STORAGE FACILITIES

Depending of the technology envisaged, mainly LLW and VLLW will be produced during decommissioning of the Interim Storage Facilities (in addition to conventional wastes).

They will be packaged in-situ, and controlled prior to leaving the ISF building.

They will be transported to a suitable disposal facility as soon as they are generated.

6. WASTE ROUTES

6.1. SPENT FUEL

Wastes routes for the SF are technology dependent; after cooling in Fuel Building pool for some years, they are transferred to the ISF prior to transport to the GDF. The arrangements and procedures for final transport of the spent fuel from a vault dry storage facility and a wet storage facility are described in the UK EPR document “Spent Fuel Interim Storage Facility” (reference [3]). The procedures for options involving storage in dual-purpose casks including modular storage technology options are not described since they do not require re-handling of the fuel before final transport, the casks also being used for transport purposes.

For the other wastes, routes are related only with respect to the ILW produced during the decommissioning of the reactor, the other wastes being immediately transported when produced.

6.2. NI TO ILW INTERIM STORAGE FACILITY

The ILW produced during the decommissioning of the reactor will be placed in the appropriate packages in their production areas.

The packages will be transported alone (for shielded 4 metre boxes) or in a shielded transport container like the SWTC 285 (for 3 cubic metre boxes) or others (500 litre drums), these robust transport container being developed and approved for safe transport of ILW. These transport conditions will provide adequate shielding for transport and waste handling to the ISF and later at the repository site.

These ILW packages will then be stored in the ISF awaiting availability of the GDF for their final transport.

6.3. ILW INTERIM STORAGE FACILITY TO FINAL DISPOSAL

The final transfer of ILW packages to a final disposal facility takes place before decommissioning of the ISF.

Before a waste package is transported to the final disposal facility, the waste will be prepared if necessary (e.g. overpacked, re-conditioned etc), in the ISF to meet the requirements of the Letter of Compliance (LoC) for acceptance at the GDF.

7. DISPOSABILITY ASSESSMENT / ACCEPTABILITY

The purpose of the GDA Disposability Assessment was to undertake an assessment of the disposability of the higher activity wastes and spent fuel expected to be generated from operation of an EPR.

The GDA Disposability Assessment considered three types of wastes and materials:

- ILW arising from reactor operations (operational ILW);
- ILW arising from the decommissioning of the reactor and associated plant (decommissioning ILW) – it did not include ILW generated during decommissioning of the ISF. However the quantities are negligible and the types of waste produced are comparable to those produced by the decommissioning of the reactor;
- Spent fuel arising from reactor operation.

The GDA Disposability Assessment process comprises three main components:

- A review to confirm wastes and SF properties;
- An assessment of the compatibility of the proposed disposal packages with concepts for geological disposal;
- Identification of the main outstanding uncertainties, and associated research and development needs relating to the future disposal of the wastes and SF.

This assessment has been based on information on the nature of operational and decommissioning ILW, and SF, and proposals for the packaging of these wastes, supplied to RWMD by EDF/AREVA. This information has been used to assess the implications of the disposal of the proposed ILW packages and SF disposal packages against the waste package standards and specifications developed by RWMD and the supporting safety assessments for a GDF. The safety of transport operations, handling and emplacement at a GDF, and the longer-term performance of the system have been considered, together with the implications for the size and design of a GDF.

RWMD has concluded that sufficient information has been provided by EDF/AREVA to produce valid and justifiable conclusions under the GDA Disposability Assessment (see ref. [4]). RWMD has concluded that ILW and SF from operation and decommissioning of an EPR should be compatible with plans for transport and geological disposal of higher-activity wastes. It is expected that these conclusions eventually would be supported and substantiated by future refinements. This conclusion is supported by the similarity of the wastes to those expected to arise from the existing PWR at Sizewell B.

Wastes being dealt with through alternative routes, e.g. LLW and/or VLLW are not considered within the scope of this Disposability Assessment.

However, experience feedback on decommissioning and methods for the segregation of waste will be taken into account while preparing decommissioning activities. Wastes arising from decommissioning operations will be monitored and classified in the same manner as during the operational phase. As a consequence, it is reasonable to assume that such LLW arising from decommissioning activities would be acceptable to the LLWR (LLW Repository Ltd), as the waste will also have been demonstrated to be compliant with the LLWR acceptance criteria.

Decommissioning wastes that are expected to be LLW will be monitored in a similar manner as operational LLW to determine acceptability for disposal to the LLWR. Full characterisation of decommissioning LLW cannot be predicted at this time. However there is no evidence, on the basis of the extensive studies performed, that decommissioning wastes will be sufficiently different in their characteristics so as to prevent them meeting the disposability criteria for the LLWR.

In addition,

- secondary wastes produced during the decommissioning phase of the reactor,
- primary and secondary wastes produced during the decommissioning of the Interim Storage Facilities (SF and ILW),
- operational wastes arising from the operation of the Interim Storage Facilities,

will be similar to those produced during operation and decommissioning of the reactor and associated plant (with volumes expected to be low). They will therefore be treated similarly. It is reasonable to consider such ILW, LLW and VLLW to be compliant with the corresponding acceptance criteria for the relevant disposal routes. The operator will have the responsibility to deal with the wastes associated with operation and decommissioning of the ISF.

8. COMPLIANCE WITH THE WASTE HIERARCHY AND DEMONSTRATION OF BAT

The SRWSR document (reference [2]) outlines the waste treatment and conditioning options that can be feasibly deployed for the treatment of the different types of solid radioactive wastes arising from operation of the UK EPR. These installations will be used, as appropriate, later during the decommissioning of the reactor.

Within the constraints of the regulatory and licensing baseline for the UK EPR it is intended that there will be flexibility for future operators to select and optimise waste management strategies. This flexibility will permit changes to waste management techniques to reflect recent developments and national and international practices as new or improved options become available.

In accordance with good waste minimisation practice, wastes arising from the decommissioning of the UK EPR and the ISF will be segregated at source on the basis of its activity and its physical and chemical characteristics.

All radioactive material will be retained on-site until it has been appropriately conditioned and packaged or declared as exempt from regulatory control.

Decisions on key aspects are yet to be made and should be undertaken within the context of Best Available Techniques (BAT). These include the nature and detailed design of the ISF for SF, the detailed design of the ISF for ILW, the decommissioning plan/strategy, the specification of steel composition, the use of stellite, etc. These decisions are to be made by the prospective operators and BAT assessments will necessarily form part of the decision making processes.

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CHAPTER 7 - TABLE OF CONTENTS

1. INTRODUCTION

This chapter provides information on Decommissioning Plans for the UK EPR design, with the aim of showing underpinned decommissioning plans and programmes for the whole life-cycle, based upon the assumed decommissioning processes.

A number of specific expectations relating to decommissioning plans are listed below, together with a reference to the Sub-section(s) of the chapter in which the expectation is addressed:

Identify the decommissioning plan and programme based upon a baseline decommissioning methodology (Section 2 (Scope), Section 3 (plan and indicative programme))

- Be consistent with Government policy and the disposability assessment (Sub-sections 2.4, 2.6 and 3.5)
- Address the whole decommissioning lifecycle, including decommissioning of any interim waste store (Section 2 (Scope) and Section 3 (plan))
- Substantiate the stated timescales, related to the operational date of the reactor; the relevant safety and environmental submission schedule and technology choices. (Sub-sections 3.3 and 3.4, in particular Chapter 7 - Figure 1)
- Consider the timescales for any necessary fuel storage period in the at-reactor fuel pool and any interim dry waste storage on-site (Sub-sections 2.4, 2.6, 3.3 and 3.4)

It is noted that decommissioning is ultimately the responsibility of the reactor operator and that, as such, the decommissioning plan that is presented in this chapter can only be indicative at the current stage of development of the life-cycle of the UK EPR and is also generic rather than site specific. However, EDF and AREVA understand that the GDA process requires a sufficient level of confidence with respect to the development of a viable decommissioning scheme and the production of a decommissioning plan to a level of detail that demonstrates how at least one viable decommissioning scheme could be implemented.

It is also noted that there is a regulator expectation that it will be possible to provide a greater level of detail in decommissioning plans if an operator has been identified, because of the development of decommissioning plans to support an application for a Funded Decommissioning Plan. This report takes cognisance of the work that is being carried out by EDF to prepare costed decommissioning plans for PWRs in France and to prepare a site-specific Decommissioning and Waste Management Plan for Hinkley Point C, particularly in the development of an overall Work Breakdown Structure (WBS) and high level schedule for decommissioning of an EPR unit. However, it is important to note that as the decommissioning plans will be developed by the operator the information provided by EDF and AREVA for the GDA should not be regarded as being binding on future operators.

The remainder of the report contains the following information:

- Section 2: Overview of the main elements of the scope of the decommissioning plan for the UK EPR
- Section 3: An overview of the Decommissioning Plan and Programme for Nuclear Island Decommissioning including, as follows:
    - An overview of the development of the Decommissioning Plan;

- Assumptions underpinning the Decommissioning Plan;
- The baseline decommissioning plan for the Nuclear Island (reactor island);
- The estimated duration of UK EPR decommissioning;
- An indicative summary programme for decommissioning of the UK EPR.
- A review of UK EPR decommissioning in the context of government policy and the Disposability Assessment.

- Conclusions

2. SCOPE OF THE DECOMMISSIONING PLAN FOR THE UK EPR

2.1. ASSUMPTIONS UNDERPINNING THE BASELINE DECOMMISSIONING PLAN

A number of assumptions have been made in the development of the baseline decommissioning plan for the EPR presented in this report, as follows:

- The UK EPR will operate for a period of 60 years;
- Decommissioning starts immediately after permanent plant shutdown and there is no period of care and maintenance to allow radioactive decay. This strategy is referred to as early site clearance. The timing of decommissioning is discussed in Chapter 3 of the present report;
- Existing buildings and systems are re-used for decommissioning activities when possible.

{ CCI removed }[b]

- Interfaces between the buildings are taken into account where possible. For example dismantling of the Nuclear Auxiliary Building takes place only after reactor vessel dismantling;
- LLW, VLLW and exempt wastes arising from decommissioning are disposed of shortly after dismantling;
- ILW packages arising from decommissioning are stored on site and then disposed of to the GDF 40 years after plant shutdown. This will allow decay of a number of packages to LLW during the storage period, as discussed in Chapter 6 "Disposability Assessment" of the present report.

2.2. OVERVIEW OF THE SCOPE OF THE BASELINE DECOMMISSIONING PLAN

The overall period covered by the baseline decommissioning plan commences with a stage of Pre-Closure Preparatory Work which starts five years prior to the End-of-Generation (EoG) and ends when all station buildings and facilities have been removed (and for a specific site would end when the site has been returned to the agreed end state). The objective of dismantling and demolition of the plant and buildings on the station is the safe removal of all plant, equipment and wastes from the site utilising methods for dismantling, demolition and waste management which will ensure safety of all personnel, the public and the environment.

For the purpose of the planning of decommissioning the process is divided into a number of activities which form the basis of the Work Breakdown Structure (WBS). This defines the work packages and the activities, which need to be carried out to decommission the UK EPR and manage the associated decommissioning wastes. The elements of the WBS below can be regarded as generic to decommissioning of the UK EPR, noting that the detailed WBS will be site and operator specific. These are as follows:

- Pre-Closure Preparatory Work;
- Fuel Management;
- Site Operation and Plant Preparation;
- Management of Potentially Mobile Wastes;
- Plant and Reactor Decommissioning.

The scope of the plan covers decommissioning and the management and disposal of radioactive and hazardous wastes until all plant, facilities and buildings have been decommissioned and all wastes, including spent fuel, removed from the site. The scope therefore addresses the power plant and the interim storage facilities for spent fuel and ILW, noting that the choice of methods of interim storage of ILW and spent fuel is made by the operator.

During the operational life of the UK EPR it is anticipated that there will be systematic reviews of the decommissioning plan to take account of operational experience, not only of the UK EPR but also the decommissioning of other reactors. Many PWRs will have been decommissioned in the UK, France and internationally by the end of the operational period of the UK EPR. This will provide a strong knowledge base of decommissioning experience which can be used to improve the robustness of the decommissioning plan for the UK EPR throughout the operational phase and beyond.

Further information on the main elements of the scope of the baseline decommissioning plan is presented in the following sub-sections. These do not provide detailed information on the technical approaches to the work set out or the programme but are intended to provide information on the anticipated scope of decommissioning of the UK EPR. Information on decommissioning logistics is provided in Chapter 2 of the present report. The scope of the plan addresses the whole decommissioning lifecycle, except for final site remediation and de-licensing which is not part of the GDA.

2.3. PRE-CLOSURE PREPARATORY WORK

It is assumed that detailed preparatory work for the shutdown and decommissioning of the UK EPR will commence five years prior to End-of-Generation. The work to be undertaken is that required to obtain the necessary permissions/consents for decommissioning to proceed in a timely manner, to undertake preliminary studies to and to prepare for End-of-Generation of each unit.

The generic work to be undertaken includes the following:

- Development of Strategy;
- Development of Arrangements;
- Development of Project Controls;
- Preparation of planning and environmental documentation (e.g. anticipated to be equivalent to existing legislation for Environmental Impact Assessment, Planning Consent, Article 37 submission and Environmental Permit application);
- Decommissioning studies;
- Preparation and updating of safety and waste management documentation, the Decommissioning Safety Case and Letters of Compliance.

It may be noted that detailed information on safety and environmental submissions is not available at the current stage of development of the Decommissioning Plan for the UK EPR. The development of a detailed schedule of safety and environmental submissions will be the responsibility of the operator.

2.4. FUEL MANAGEMENT

The work related to nuclear fuel to be undertaken after the End of Generation (EoG) includes the following:

- the defuelling of the reactor and storage of spent fuel in the Fuel Building Storage Pool;
- the operation of the Fuel Building Storage Pool until complete emptying;
- the transfer of the spent fuel from the Fuel Building Storage Pool to the Spent Fuel Interim Storage Facility;
- the operation of the Spent Fuel Interim Storage Facility;
- the emptying of the Spent Fuel Interim Storage Facility and transport of the spent Fuel to the Repository.

The Fuel Building Storage Pool is provided as part of the UK EPR Nuclear Island. The capacity of this pool is limited to about ten years of operation; once sufficiently cooled, the fuel is removed to make way for spent fuel from ongoing refuelling outages.

A Spent Fuel Interim Storage Facility (SF ISF) will be built on the site to accommodate this fuel. This facility will be sized to accommodate the whole lifetime arisings of fuel from the operation of the unit, will be operational for at least 100 years and will be designed in order to be able (at least at some point during decommissioning of the EPR) to operate as a standalone facility depending on its own services.

Following End-of-Generation removal of the fuel from the reactor will commence as soon as practicable. The fuel will be removed from the reactor and transferred to the Fuel Building Storage Pool, where it will be stored for a period before transfer to the Interim Fuel Storage Facility. The duration of storage in the Fuel Building Storage Pool will depend on the mode of subsequent interim storage of spent fuel.

{ CCI removed }[b]

It has been estimated (see reference [1]) that the process of fuel retrieval, packaging and transport of the fuel for direct disposal at a suitable repository will start as soon as the GDF is available, before the end of the facility 100 years lifespan and last less than 5 years.

{ CCI removed }[b]

2.5. SITE OPERATION AND PLANT PREPARATION

This section describes the “operation” of the site during decommissioning and management of the fuel and wastes. The work to be undertaken also includes the preparation of the Nuclear Island for decommissioning and includes:

- Post Closure Plant Operation, including operational waste management;
- Making Safe Redundant Plant and Equipment;
- Primary Circuit Decontamination;
- Post Operational Clean-Out;
- Installation of a new Decommissioning Site Electrical Supply and Electrical Distribution System which enables the decommissioning of the existing high voltage electrical systems;
- Site maintenance and operations during decommissioning.

Various systems are required to remain operational to maintain the safe operation of the plant as defuelling, Fuel Building Storage Pool operation, associated operational waste management and other decommissioning work proceeds.

{ CCI removed }[b]

Primary circuit decontamination will be carried out to reduce the deposited contamination within the primary circuit components.

{ CCI removed }[b]

To facilitate decommissioning and the removal of some of the services, new alternative services will be installed as necessary.

{ CCI removed }[b]

2.6. MANAGEMENT OF RADIOACTIVE WASTES

This section describes the management of radioactive operational wastes during the decommissioning of the EPR. This includes:

- The retrieval, processing, transport and disposal of the final amounts of operational wastes present in the EPR at the time of End-of Generation;
- The processing, transport and disposal of secondary ILW arising during decommissioning;
- The transport and disposal of ILW which arose during the operational period and has remained in storage following the End-of Generation;
- The operation of the Effluent Treatment Building to treat liquid effluents until key decommissioning tasks have been completed (e.g. Fuel Building Pool removal and Reactor Vessel dismantling) followed by use of mobile plant once the Effluent Treatment Plant has been decommissioned.

A number of solid radioactive waste forms are generated throughout the operational period of the EPR:

- Ion exchange resins;
- Spent filters;
- Dry active waste and metals (generated through routine and maintenance operations throughout the Nuclear Island, small components may be ILW, but mainly arises as LLW);
- Sludges from tanks and sumps;
- Evaporator concentrates.

These wastes are generated and treated throughout the station operational period. Waste retrieval and processing facilities will be provided early in the station lifetime to facilitate this process. Further wastes will be generated subsequent to the End of Generation, primarily ion exchange resins and spent filters arising from the decontamination of the primary circuit, the treatment of water in spent fuel pools and the dismantling of the reactor pressure vessel and its internals. The facilities used during the operational period of the station are assumed to be available for the treatment of the final amounts of operational wastes present in the EPR at the time of shutdown.

Waste treatment facilities will be provided to process ILW and LLW into packages suitable for interim storage on site and disposal off site. Waste retrieval plant and equipment will be provided at the point of arising and processing plant and equipment will be available. These will be used throughout the operational period to package LLW into appropriate containers for disposal off site, and to package ILW into a form suitable for disposal in the Geological Disposal Facility for higher activity wastes.

It has been assumed that a disposal route for solid LLW will be available throughout the UK EPR operational and decommissioning periods, and that operational and decommissioning waste will be packaged and disposed of to this facility, consistent with current arrangements for the use of the Low Level Waste Repository (LLWR).

A disposal route for ILW is assumed to be available from 2040 for legacy wastes with legacy waste disposal currently anticipated to have been completed by 2130. An appropriately sized ILW ISF will be constructed on site early in the operational period to accept packages of ILW. The ILW ISF will be provided on site to store ILW from an early point in the operational period of the station, with a reference assumption of two years from start of generation.

{ CCI removed }[b]

It is assumed for purpose of the baseline decommissioning plan that decommissioning ILW will be stored in the ILW ISF until 40 years after reactor shutdown. Further information is provided in Chapter 6. Storage capacity will be provided for the lifetime arisings of operational ILW and for arisings of decommissioning ILW. The ILW ISF will consist of:

- Receipt and dispatch area;
- Interim storage space for ILW;
- Package inspection area;
- Storage area that permits removal of ILW that may become LLW following a period of decay storage.

It is assumed that operational wastes will continue to be stored on site throughout the operational period. The ILW ISF will be designed for at least 100 year lifetime and will be designed in order to be able (at least at some point during decommissioning of the EPR) to operate as a standalone facility depending on its own services.

The minimum duration to empty the ISF for ILW of operational waste packages has been estimated to be about 9 to 10 packages per day (reference [1]), i.e. 200 days for the operational wastes packages, and about 60 more days for decommissioning waste packages, i.e. would take less than one year to remove all waste packages from the facility. Once empty the ILW ISF can be decommissioned and demolished. This is anticipated to last from 1 to 3 years..

2.7. PLANT AND REACTOR DECOMMISSIONING

This section describes the work to be carried out to decommission the reactor and other plants and the management of decommissioning wastes, building on the work that has already been carried out under Site Operation and Plant Decommissioning. This will include:

- Decommissioning of the Nuclear Island, including:
  - Reactor Building;
  - Fuel Building;
  - Safeguard Electrical and Mechanical Buildings;
  - Nuclear Auxiliary Building;
  - Effluent Treatment Building (once key decommissioning tasks have been completed including dismantling of the reactor vessel and decommissioning of the Fuel Building Storage Pool);
  - Access building;
  - Other Nuclear Island facilities including:
    - Emergency Diesel Buildings;
    - Hot Laundry;
    - Hot Workshop, Warehouse and Decontamination Facilities;
    - Contaminated Tools Store;
    - Transit Area for LLW;
    - Tanks for the Liquid Radioactive Monitoring and Discharge System, the Additional Liquid Waste Discharge system and the Conventional Island Liquid Waste System (referred to as the TER, KER and SEK tanks respectively);
  - The Interim Storage Facilities for Spent Fuel and ILW (once these have been emptied of stored fuel and waste respectively);
- Conventional Plant Decommissioning, including:
  - Turbine Hall Decommissioning;

    { CCI removed }[b]

  - Turbine Hall demolition.
- Removal and demolition of all other plant, including the cooling water system, pumping station, off-shore structures, and various auxiliary buildings such as non-radioactive material and waste storage facilities.

Further information on decommissioning is provided in the following sub-sections.

2.7.1 Preliminary / Enabling Works

All plant and equipment will have been isolated, drained or vented and made safe prior to its decommissioning, as part of Site Operation and Plant Preparation. A number of activities will have already been carried out after End-of-Generation in preparation for plant and reactor decommissioning, including the making safe of redundant plant and systems, primary circuit decontamination and the provision of new electrical systems. There may however be residual radiological, chemical or other hazards which must be addressed during the decommissioning process.

However, other enabling works will also need to be carried out before Nuclear Island decommissioning can be started. This will include construction of the Decommissioning Waste Processing Facility (DWPF) for the size reduction and packaging of wastes arising from decommissioning of the Nuclear Island. The primary circuit components, other than the reactor, will be removed and transferred to the DWPF for subsequent dismantling and waste management.

Removal of the major Nuclear Steam Supply System (NSSS) components will not commence until this facility is completed and available to receive the components. Any other preliminary works required to export these major components from the Nuclear Island will be carried out as part of this preliminary and enabling work.

2.7.2 Nuclear Island Decommissioning

For the purpose of this report, the Nuclear Island (NI) is taken to include all plant, equipment and the buildings which present a radiological hazard during decommissioning, the facilities of which have been listed above.

This section presents a summary of the baseline decommissioning plan for the Nuclear Island.

The plant and equipment will be isolated electrically and mechanically, and connections to auxiliary systems severed and sealed. Thermal insulation and cladding on the primary circuit will be removed to permit further dismantling tasks.

2.7.2.1 Reactor Coolant System and Reactor Vessel

This will involve the following tasks:

- Dismantling of the reactor coolant system outside the reactor vessel {CCI removed}[b] This includes:
    - Dismantling of the steam generators;
    - Dismantling of the Pressuriser;
    - Dismantling of the Reactor Coolant Pumps;
    - Dismantling of the Primary Circuit pipework;

- Dismantling of the Reactor Vessel and internal equipment underwater using remotely operated cutting equipment

  {CCI removed}[b]

  Remotely operated dismantling of reactor vessel and internal equipment was successfully demonstrated by a European demonstration project in the late 1990s. The technique has also been used in the decommissioning of PWRs in the USA and Germany and is planned to be used in the decommissioning of both French and Spanish PWRs over the coming years. It is a viable technique which is supported by successful application to a number of PWR decommissioning projects.

2.7.2.2 Other Nuclear Island Plant

Following completion of removal of the primary circuit components, decommissioning will progress to the remainder of the plant and equipment within the Reactor Building. This includes dismantling of remaining auxiliary circuit reactor building components including components outside the reactor coolant system, the reactor cavity and the spent fuel pool cooling and treatment system.

Each item of plant will be cut into suitably sized segments, sentenced, treated and packaged appropriately, with wastes being transferred as appropriate to the DWPF for size reduction, processing and packaging prior to disposal. Where appropriate packages will be prepared in-situ, in installed dedicated working areas in the buildings.

{CCI removed}[b]

Other Nuclear Island Plant and Buildings include the following:

- Reactor Building;
- Fuel Building;
- Nuclear Auxiliary Building;
- Access Building;
- Safeguard Electrical Buildings;
- Safeguard Mechanical Buildings;
- Effluent Treatment Building;
- Hot Laundry;
- Hot Workshop, Warehouse and Decontamination Facilities;
- Emergency Diesel Buildings;
- Contaminated Tools Store;
- Transit Area for LLW

{ CCI removed }[b]

Other Nuclear Island plant comprises large quantities of tanks, pipework, ductwork, valves, heat exchangers, ventilation ductwork, fans, filters, pumps, motors, sensors, electrical panels, cable trays, cables etc. It also includes the polar crane mounted inside the Reactor Building. Some of these buildings and facilities house systems which are internally radioactively contaminated, for example the Effluent Treatment Building, the Nuclear Auxiliary Building and the various hot facilities. Each also contains a significant amount of plant, equipment and services which have no radiological hazard associated with them.

The scope of work includes:

- Radiological surveys;
- Removal and dismantling of equipment, with size reduction where necessary;
- Transfer of wastes to the Decommissioning Waste Processing Facility as appropriate for waste classification, size reduction, processing and packaging;
- Decontamination and clean-up of nuclear buildings once removal of electro-mechanical equipment has been completed, primarily by means of removal of surface contamination using standard techniques;
- Disposal of wastes off-site with recycling of suitable materials where possible.

2.7.2.3 Nuclear Island Building Demolition

Following removal of the Reactor Coolant System, Reactor Vessel and the other Nuclear Island equipment, the Nuclear Island buildings will be decontaminated and demolished.

The Reactor Building consists of a primary containment and a secondary containment. The Reactor Building primary containment is a pre-stressed domed cylindrical concrete structure with an integral steel liner, the tension of which is provided by a lattice of steel tendons. The entire inner surface of the building is lined with steel liner plates welded to form a continuous surface secured to the reinforced cladding. The secondary containment is a domed structure covering the top of the primary containment which is partially clad externally. The external cladding will be dismantled and the secondary containment will then be demolished.

The reactor compartment (pit) comprises a very heavily reinforced concrete cylinder carrying the support ring on which the Reactor Vessel is supported. The structures will be dismantled and cut into suitably sized blocks which will be transferred to the DWPF where they will be sentenced, processed and packaged appropriately for disposal.

The other buildings which comprise the Nuclear Island are primarily concrete structures. The scope of work, following the completion of removal of all plant equipment and services will include:

- Radiological surveys;
- Decontamination and clearance monitoring;

- Demolition of all structures, etc. to a depth of 1 metre below ground;
- Radiological and chemical monitoring of any excess building rubble generated from the demolition of these buildings, with crushing and grading of uncontaminated, inert material as infill for basements and voids on the site.
- Disposal of wastes off-site.

2.7.2.4 ILW Interim Storage Facility

On completion of the task to remove all waste packages, the facility will be closed. All operational systems will be made safe and a commensurate radiological survey undertaken. It is assumed that the facility will be uncontaminated, thus requiring only the safe employment of conventional deplanting and demolition methods.

The scope of work will include:

- Making safe operational systems;
- Radiological survey;
- Removal of hazardous materials;
- Removal of plant and equipment;
- Building demolition;
- Recycling of materials for re-use where applicable;
- Disposal of wastes off-site.

2.7.2.5 Spent Fuel Interim Storage Facility

It is assumed that spent fuel will be stored for up to approximately 100 years after the first spent fuel assembly is transferred from the fuel building into the SF ISF. Once the transfer of the spent fuel from site for disposal has been completed, then the Spent Fuel Interim Storage Facility will be decommissioned. The scope of work will depend on whether the facility is based on wet or dry storage of spent fuel and will include:

- For a wet storage facility:
  - Drainage and decontamination of the fuel storage pond for a wet storage facility;
  - Decontamination, drainage and dismantling of the associated water treatment plant for a wet storage facility;
  - Dismantling of the fuel storage racks, etc. for a wet storage facility;
- For a dry storage facility:
  - Dismantling of dry cask storage facilities for a dry storage facility;

- Dismantling of the fuel handling facilities;

- For both wet and dry storage facilities:
  - Dismantling of cask handling facilities;
  - Dismantling of the ventilation systems;
  - Decontamination and clearance monitoring of the SF ISF;
  - Demolition of the SF ISF;
  - Packaging and disposal of radioactive wastes.
  - Recycling of inert, uncontaminated material for backfilling of basement areas and voids where possible.

2.7.3 Conventional Plant Decommissioning

For the purpose of this report, Conventional Plant is taken to include all plant, equipment and the buildings which are associated with power generation or the operation of the site which do not present a radiological hazard. This therefore includes the systems, plant, equipment, facilities and buildings listed below:

- Turbine Hall;
- Generator Switchgear and Main Transformers;
- CW Pumphouse/Forebay;
- CW Intake Structures;
- CW Outlet Structures, Tunnels and Outfall;
- Substation and On-site Transmission Towers.

Decommissioning will utilise current proven techniques for dismantling and waste management, in accordance with prevailing regulations, international guidance and best practice.

2.7.4 Balance of Plant

The Balance of Plant includes the ancillary buildings, plant, equipment and facilities supporting the operation of each unit, and the common facilities such as workshops, offices, welfare and other miscellaneous buildings and facilities on the site.

The above will have been made safe as part of Site Operation and Plant Preparation. The scope of work for decommissioning is:

- Removal of fixtures, fittings, services and temporary structures (known as “soft-strip”);
- Demolition of buildings and removal of structures;
- Backfilling of demolition voids with inert, uncontaminated material;

- Removal of roads, hard standings, pipe and cable trenches;
- Grouting of on-shore pipes, culverts, tunnels, manholes and chambers.

2.8. REVIEW OF THE SCOPE OF THE OVERALL DECOMMISSIONING PLAN FOR THE UK EPR

The information in Sub-sections 2.1 to 2.7 indicates that the decommissioning plan being developed for the UK EPR addresses the whole of the decommissioning lifecycle in that it includes the decommissioning of the Spent Fuel and ILW Interim Storage Facilities in addition to the Nuclear and Conventional Islands and the Balance of Plant.

3. OVERVIEW OF THE DECOMMISSIONING PLAN AND PROGRAMME

3.1. OVERVIEW OF THE DEVELOPMENT OF THE DECOMMISSIONING PLAN

The development of the decommissioning plan for the UK EPR by EDF and AREVA has taken account of the reactor dismantling operations performed in a number of countries on first generation nuclear power plants, with a view to selecting dismantling techniques and assessment of durations for the decommissioning of reactor units. The typical duration for decommissioning of PWR units in the USA has been identified as approximately 12 years.

{ CCI removed }[b]

3.2. BASELINE DECOMMISSIONING PLAN FOR THE NUCLEAR ISLAND

The baseline decommissioning methodology for the Nuclear Island is addressed in the Chapter 2 of the present report on Decommissioning Logistics.

{ CCI removed }[b]

3.3. DURATION OF UK EPR DECOMMISSIONING

In developing the decommissioning plan for the EPR two scenarios have been considered with respect to the duration of spent fuel storage in the reactor's Fuel Building Storage Pool prior to transfer for long term interim storage on-site.
{ CCI removed }[b]
It is noted that the decision on the mode of interim spent fuel storage and thus of the period of storage in the Fuel Building Storage Pool is a matter for the operator.

These durations have been taken into account in the preliminary assessment of the duration of decommissioning of the UK EPR, including the Conventional Island and Balance of Plant but excluding the decommissioning of interim storage facilities for ILW and spent fuel and the site remediation phase.

{ CCI removed }[b]

It may be noted that these durations do not take account of any regulatory hold points other than permission for shutdown. At the current stage of development of the UK EPR this is considered to be appropriate and it is anticipated that the programme of safety and environmental submissions will be further developed by the operator during the lifecycle of the reactor, taking account of the interdependencies between systems that maintain safety during decommissioning. This work will be expected to draw on the experience of decommissioning of other PWRs.

{ CCI removed }[b]

{ CCI removed }[b]

3.4. INDICATIVE SUMMARY PROGRAMME FOR DECOMMISSIONING OF THE UK EPR

The production of a fully detailed schedule for decommissioning is not considered to be necessary at the current stage of development of the lifecycle of the UK EPR for the GDA. The production of such a plan will be the responsibility of the operator, noting that an operator will be required to produce a Funded Decommissioning Plan prior to construction of a new reactor.

The information presented in Sub-sections 3.2 and 3.3 has been used to compile Chapter 7 - Figure 1, which presents an indicative summary programme for the main elements, namely:

- The UK EPR unit;
- The ILW Interim Storage Facility (ILW ISF);
- The Spent Fuel Interim Storage Facility (SF ISF).

The timescale in Chapter 7 - Figure 1 is defined relative to the commencement of operation of a UK EPR unit (referred to as Y0). The letter of compliance process for the different wastes is provided in accordance with what is presented in reference [2].

The information in Chapter 7 - Figure 1 covers a number of key milestones for decommissioning and waste management. It addresses the whole decommissioning lifecycle up to and including the completion of decommissioning of the SF ISF, which will be decommissioned much later than the rest of the UK EPR because of the current assumptions regarding the availability of a GDF and the need to cool spent fuel prior to transfer to the spent fuel GDF. The milestones cover the two technology choices of wet and dry interim storage of spent fuel in accordance with what is presented in reference [1].

The period of storage of decommissioning ILW will depend on the decommissioning strategy and waste strategy selected by the operator. No timescale is thus provided for the commencement of the transport of ILW as this will be determined by the operator and the overall schedule of transport of wastes from UK producers of higher activity wastes to the GDF. Earlier closure of the ILW ISF may be possible than the timescale presented in Chapter 7 - Figure 1.

It is estimated that it would take less than one year to remove all packages from the ILW interim storage facility (see Sub-section 2.6). Therefore it can be assumed that the ILW interim storage facility will be ready for decommissioning around year Y0+100, even considering all waste to be exported at the end of the facility operation.

It may be noted that the milestone for closure of the ILW ISF is based on the latest anticipated closure date of 40 years after reactor cessation of operation, at which time some operational (and decommissioning ILW) will have decayed to LLW.

Safety and Environmental applications are part of the plant lifecycle; i.e. at each of the steps (design, construction, commissioning, operation then decommissioning) submissions are prepared with the most up to date information, to obtain from the regulators the consent to start the new phase. During operation of the EPR and the storage facilities, the Licensee will have to comply with SLC15 and prepare reassessment of the safety of the facilities; periodic environmental reassessments are also performed to confirm the discharges limits of the site. These are illustrated on Chapter 7 - Figure 1, however precise schedules will have to be defined at the site specific phase.

3.5. REVIEW OF UK EPR DECOMMISSIONING IN THE CONTEXT OF GOVERNMENT POLICY AND THE DISPOSABILITY ASSESSMENT

This Sub-section presents a review of the durations and assumptions made in the development of the baseline decommissioning plan for the UK EPR against relevant elements of government policy for radioactive wastes and relevant elements of the Disposability Assessment for Wastes and Spent Fuel arising from operation of the UK EPR. The relevant elements, which relate to disposal of higher activity wastes, radioactive wastes from new nuclear power stations, spent fuel and decommissioning wastes, are presented in Table 2 of Chapter 7.

The baseline decommissioning plan and the indicative summary programme for the UK EPR presented in Figure 1 of Chapter 7, have been reviewed against the key elements of government policy and the disposability assessment as set out in Table 2 of Chapter 7. The outcome of this review is presented in Table 3 of Chapter 7.

The durations in the baseline decommissioning plan and indicative summary programme presented in Figure 1 of Chapter 7 and the information in Table 3 of Chapter 7 demonstrate consistency with the key elements of government policy and the Disposability Assessment in terms of the provision of safe, secure storage of spent fuel and ILW. The only area where there is not complete assurance is that the life period of about 100 years for the spent fuel storage facility will allow all assemblies to be sufficiently cooled prior to disposal to the GDF. This will be addressed at the site specific phase together with the definition of the GDF characteristics. Should more years be needed for cooling a number of assemblies further storage would be considered; if necessary the spent fuel storage facility would either be substantiated for a further period of operation, be refurbished to meet the required standards to allow a further period of operation or a new store built.

4. CONCLUSIONS

The scope of the decommissioning plan for UK EPR takes account of decommissioning requirements for the whole lifecycle of the UK EPR, including interim storage facilities for spent fuel and ILW.

The decommissioning plan for the UK EPR is based on the application of viable techniques that have been successfully demonstrated for PWRs { CCI removed }[b]

The overall durations for reactor dismantling are broadly consistent with those planned for other PWRs and with international experience of reactor dismantling carried out to date, taking account of differences in the design of the reactor and the impact of different approaches to spent fuel storage.

The plan is largely consistent with government policy and the Disposability Assessment, with the exception of the assumptions relating to the period of storage of spent fuel which is sufficient to allow disposal to the GDF. Further work will be carried out at the site specific stage, once GDF characteristics are available to confirm the spent fuel assemblies necessary cooling period before disposal.

5. REFERENCES

[1] Plan for the development of waste management facilities over the EPR lifetime, ELIDC0902019 revision B

[2] The case for disposability of spent fuel and ILW, R10-017 revision A

[3] Managing Radioactive Waste Safely – A Framework for Implementing Geological Disposal, Cmnd 7386, June 2008

[4] Department for Business, Enterprise and Regulatory Reform, "*Meeting the Energy Challenge: A White Paper on Nuclear Power*", January 2008. www.berr.gov.uk/ energy/nuclear-whitepaper/page42765.html

[5] Consultation on Funded Decommissioning Programme Guidance for New Nuclear Power Stations, Department for Business, Enterprise and Regulatory Reform, February 2008

[6] Generic Design Assessment: Summary of Disposability Assessment for Wastes and Spent fuel arising from Operation of the UK EPR, NDA Technical Note 11261814, NDA, October 2009

CHAPTER 7 - TABLE 1

INDICATIVE TASK DURATIONS FOR DECOMMISSIONING OF THE UK EPR NUCLEAR ISLAND AND INTERIM STORAGE FACILITIES

KEY ELEMENTS OF DECOMMISSIONING METHODOLOGY	{ CCI removed }[b]
Pre-closure preparatory work	{ CCI removed }[b]
Preparatory work for dismantling activities	{ CCI removed }[b]
Primary circuit decontamination	{ CCI removed }[b]
Dismantling of the reactor coolant system outside the reactor vessel	{ CCI removed }[b]
Dismantling of the Reactor Vessel and internal equipment	{ CCI removed }[b]
Dismantling of remaining non-primary circuit reactor building components	{ CCI removed }[b]
Dismantling of electromechanical equipment in other Nuclear Island buildings: Fuel Building Safeguard Buildings (Electrical and Mechanical) Nuclear Auxiliary Building	{ CCI removed }[b]
Decontamination and clean-up of nuclear buildings Reactor Building Fuel Building Safeguards Buildings Nuclear Auxiliary Building	{ CCI removed }[b]
Demolition of buildings Reactor Building Fuel Building Safeguards Buildings Nuclear Auxiliary Building	{ CCI removed }[b]
Decommissioning of ILW ISF	{ CCI removed }[b]
Decommissioning of Spent Fuel ISF	{ CCI removed }[b]

CHAPTER 7 - TABLE 2

SUMMARY OF KEY ELEMENTS OF GOVERNMENT POLICY AND THE DISPOSABILITY ASSESSMENT

N°	Key element of Government policy	Reference
1	Geological disposal is the way higher activity radioactive waste will be managed in the long term. This will be preceded by safe and secure interim storage until a geological disposal facility can receive waste. This period will include contingency planning to cover any uncertainties associated with implementation. Storage is a proven, safe and secure technology for the interim management of higher activity radioactive waste.	Page 10, Managing Radioactive Waste Safely – A Framework for Implementing Geological Disposal, Cmnd 7386, June 2008.
2	"Having reviewed the arguments and evidence put forward, the Government believes that it is technically possible to dispose of new higher-activity radioactive waste in a geological disposal facility and that this would be a viable solution and the right approach for managing waste from any new nuclear power stations. The Government considers that it would be technically possible and desirable to dispose of both new and legacy waste in the same geological disposal facilities and that this should be explored through the Managing Radioactive Waste Safely programme. The Government considers that waste can and should be stored in safe and secure interim storage facilities until a geological facility becomes available".	Department for Business, Enterprise and Regulatory Reform, "*Meeting the Energy Challenge: A White Paper on Nuclear Power*", January 2008. www.berr.gov.uk/ energy/nuclear-whitepaper/page42765.html
3	Operators will be obliged to provide safe and secure interim storage facilities that are technically capable of being maintained or replaced to last for at least 100 years from the time waste is first emplaced in them.	Page 69, Consultation on Funded Decommissioning Programme Guidance for New Nuclear Power Stations, Department for Business, Enterprise and Regulatory Reform, February 2008.
4	Spent fuel is assumed to be managed by direct disposal after a period of interim storage.	Section 2, Page 2, Generic Design Assessment: Summary of Disposability Assessment for Wastes and Spent fuel arising from Operation of the UK EPR, NDA Technical Note 11261814, NDA, October 2009.

N°	Key element of Government policy	Reference
5	Current RWMD generic disposal studies for spent fuel define a temperature criterion for the acceptable heat output from a disposal canister. In order to ensure that the performance of the bentonite buffer material to be placed around the canister in the disposal environment is not damaged by excessive temperatures, a temperature limit of 100°C is applied to the inner bentonite buffer surface. Based on a canister containing four EPR fuel assemblies, each with the maximum burn-up of 65 GWd/tU and adopting the canister spacing used in existing concept designs, it would require of order of 100 years for the activity, and hence heat output, of the EPR fuel to decay sufficiently to meet this temperature criterion.	Section 6, Page 6, Generic Design Assessment: Summary of Disposability Assessment for Wastes and Spent fuel arising from Operation of the UK EPR, NDA Technical Note 11261814, NDA, October 2009.
6	The reference decommissioning assumption advised by EDF/AREVA is that transport of decommissioning waste occurs 40 years after reactor shutdown. Inventory calculations have been undertaken in line with this assumption. With such a delay, EDF/AREVA has assumed that even the highest specific activity bioshield concrete will have decayed to LLW, that any resins from a final decontamination of the primary circuit will also be LLW, and that these materials will be suitable for disposal to a LLW repository.	Appendix B3.2, Page 18, Generic Design Assessment: Summary of Disposability Assessment for Wastes and Spent fuel arising from Operation of the UK EPR, NDA Technical Note 11261814, NDA, October 2009.

CHAPTER 7 - TABLE 3

REVIEW OF THE BASELINE DECOMMISSIONING PLAN AND PROGRAMME AGAINST KEY ELEMENTS OF GOVERNMENT POLICY AND THE DISPOSABILITY ASSESSMENT

Key Element	Review
1.	The baseline decommissioning plan includes provision for the safe and secure interim storage of both ILW and spent fuel and thus is consistent with this element of government policy.
2.	The baseline decommissioning plan is consistent with this element of government policy.
3.	The baseline decommissioning plan is consistent with this element of government policy.
4.	The baseline decommissioning plan is consistent with this element of the disposability assessment.
5.	The baseline decommissioning plan currently assumes that spent fuel will be stored for a period of 100 years from the start of reactor operation, and that after this time period the spent fuel will be disposed of to the GDF. The design life of the spent fuel storage facility is 100 years. The disposability assessment indicates that it would take a period of 100 years for canisters containing fuel with maximum burn-up fuel to decay sufficiently to meet the temperature criterion for acceptance at the GDF. If this was found to be the case then a storage period of 100 years may not be sufficient to allow cooling of all spent fuel to meet the temperature criterion, particularly the fuel arising in the later stages of reactor operation. However, the initial disposability assessment undertaken was considered to be conservative with respect to the assumptions made on the burn-up of fuel and the heat output of canisters and further information was presented in the Disposability Assessment on the potential variation of storage period with fuel burn-up levels and the number of spent fuel assemblies per canister. Further work will be carried out to assess the heat output of spent fuel canisters with a view to optimising storage arrangements and the storage period while complying with the requirements specified for disposal of spent fuel to the GDF once the GDF characteristics are known. In the event that it is necessary to store fuel for a longer period than 100 years then appropriate contingency arrangements will be provided should they be required. Potential options include substantiating the existing storage facility for an additional storage period and the provision of new or refurbished storage facilities. None of these options are considered to present significant technical challenges, particularly in the light of the additional space available once the EPR has been decommissioned. It will be the responsibility of the operator to provide safe and secure interim storage for spent fuel for as long as required.

Key Element	Review
6.	The baseline decommissioning plan is consistent with this element of the disposability assessment. The assumption that decommissioning ILW will be stored until 40 years after reactor shutdown will enable decay storage of some ILW to LLW, thereby reducing the volume of waste to be disposed of to the GDF. It is recognised that there are alternative options to the baseline decommissioning plan of immediate decommissioning followed by storage of decommissioning wastes until 40 years after reactor shutdown. One option would be to dispose of ILW as soon as it arises instead of waiting for decay storage, although this would be subject to the availability of the GDF. An alternative option would be to modify the overall decommissioning strategy from immediate to deferred decommissioning to take the benefit of decay of decommissioning wastes *in situ*. Decisions on waste storage, the timing of waste disposal and the future decommissioning strategy will be the responsibility of the operator and will be taken at an appropriate stage in the lifecycle of the UK EPR, in compliance with the relevant site licence conditions and taking cognisance of regulatory guidance and the availability of disposal routes.

CHAPTER 7 - FIGURE 1

INDICATIVE SUMMARY PROGRAMME FOR DECOMMISSIONING OF THE UK EPR

{ CCI removed }[b]	**UK EPR unit**	**ILW Interim Storage Facility (ILW ISF)**	**Spent Fuel Interim Storage Facility (SF ISF)**
{ CCI removed }[b]	*Site licence granted*		
{ CCI removed }[b]	**Conceptual Letter of Compliance (LoC) for decommissioning ILW (subject to periodic review)**	**Conceptual LoC for ILW (pending on GDF characteristics)**	
{ CCI removed }[b]	*Loading Authorisation*	*License for the facility granted* **Interim LoC for ILW**	
{ CCI removed }[b]	**Start of operation**	**Final LoC for ILW**	**Conceptual LoC Spent Fuel (pending on GDF characteristics nd subject to periodic review)**
{ CCI removed }[b]		Placement of first ILW packages in ILW ISF	
{ CCI removed }[b]			Latest date for ISF choice Submission of SF ISF safety case
{ CCI removed }[b]			*Authorisation of operation of Spent Fuel Interim Storage Facility ** *(* Then periodic safety reassessment according SL15)* First Fuel Assembly received in ISF
{ CCI removed }[b]	**Interim LoC for decommissioning ILW (subject to periodic review)**	*ILW GDF assumed to commence operations for legacy wastes*	**Interim LoC Spent Fuel (subject to periodic review)**
{ CCI removed }[b]	Commencement of Pre-Closure Preparatory Phase **Final LoC Decommissioning ILW**		**Final LoC for Spent Fuel**
{ CCI removed }[b]			*SF GDF assumed to commence operations*
{ CCI removed }[b]	End of Generation Defuelling of reactor and transfer of fuel to Fuel Building Storage Pool Primary Circuit Decontamination Commencement of Preparatory Works for Dismantling Activities, including decommissioning of the Turbine Hall and construction of the Decommissioning Waste Processing Facility	First decommissioning ILW transferred to ILW ISF	
{ CCI removed }[b]	Commencement of dismantling of the reactor coolant system outside the reactor vessel		
{ CCI removed }[b]	End of period of Fuel Building spent fuel storage for "Short term pool storage scenario"		Last Fuel Assemblies received into SF ISF in case of "Short term pool storage scenario"
{ CCI removed }[b]	Commencement of dismantling of the Reactor Vessel and internal equipment		
{ CCI removed }[b]	Commencement of dismantling of Reactor Building non-primary circuit dismantling		
{ CCI removed }[b]	Completion of dismantling of the Reactor Vessel and internal equipment		
{ CCI removed }[b]	End of period of Fuel Building spent fuel storage for "Long Term pool storage scenario"	Last operational ILW generated from Fuel Building Storage Pool operations	Last Fuel Assemblies received into SF ISF for "Long Term pool storage scenario"
{ CCI removed }[b]	Completion of UK EPR reactor dismantling for "Short term pool storage scenario"		SF ISF is a stand-alone facility for "Short term pool storage scenario"
{ CCI removed }[b]	Completion of UK EPR reactor dismantling for "Long Term pool storage scenario"		SF ISF is a stand-alone facility for "Long Term pool storage scenario"
{ CCI removed }[b]		30 years since last operational ILW which can decay into LLW has been stored and 40 years since reactor shutdown.	
{ CCI removed }[b]		Completion of export of ILW to GDF (including ILW from decommissioning) Commencement of decommissioning of ILW ISF.	
{ CCI removed }[b]		Completion of decommissioning of ILW ISF.	
{ CCI removed }[b]			Latest date for commencement of export of spent fuel to SF GDF
{ CCI removed }[b]			Completion of export of spent fuel to SF GDF

{ CCI removed }[b]	**UK EPR unit**	**ILW Interim Storage Facility (ILW ISF)**	**Spent Fuel Interim Storage Facility (SF ISF)**
{ CCI removed }[b]			Completion of decommissioning of SF ISF
{ CCI removed }[b]	RETURN TO BROWN FIELD		

CHAPTER 8 - TABLE OF CONTENT

1. INTRODUCTION

Timely, safe and cost-effective decommissioning of nuclear facilities can only be achieved if it is planned on the basis of complete and accurate information. The necessary information must be accumulated from the earliest stages of design development and throughout the facility life-cycle, being generated, preserved and owned in an appropriate manner such that it remains valid and accessible even after periods of many decades.

The information to be retained and transferred between those responsible for each life-cycle stage will range from physical records to knowledge gained through experience by successive generations of operators. Thus the process of knowledge retention and transfer will need to encompass both physical and human aspects of knowledge management. In addition to the facilitation of decommissioning planning, records will also need to be kept for legal reasons and to facilitate the de-licensing process.

Because decommissioning is the final phase of the facility life-cycle and will take place many decades after the earliest design phases, and in particular because of the potential for significant delays between permanent shutdown and the completion of dismantling, compliance with the principles of good practice in relation to knowledge management will be of particular importance for decommissioning. Given that it is anticipated that interim stores for spent fuel and intermediate level waste will remain in service for a considerable period after the completion of decommissioning of the reactor itself, records required for decommissioning of those facilities will need to be generated and retained over a particularly long period.

For the physical aspects, the strategies include the means to ensure records preservation over time, such as adequate planning and budgeting, use of proven electronic records management tools, provision of safe secure storage facilities, and duplication of stored copies of records.

To address the human aspects, strategies will be in place to ensure that the knowledge records, skills, techniques, languages, tools and experience needed by future generations to use the information are available.

The legal responsibility for record retention lies with the licensee and they must ensure that those who generate relevant records transfer them to the licensee. Since it is the licensee who will be responsible for decommissioning safely, it must be they who determine what records are relevant and must be retained. However, the early stages of the design process, including the generic design stage will pre-date the establishment of the licensee’s arrangements for knowledge management for the facilities. Thus those agencies involved in the design of the EPR facilities must anticipate the licensees’ needs in regard to retention of knowledge and information for decommissioning and ensure that their own knowledge management systems are suitable and sufficient to ensure the effective transfer of knowledge and information to the licensee.

Granting of a site licence by HSE will be conditional on the licence applicant having developed adequate strategies, plans and programmes for the decommissioning of nuclear plant and for the management of radioactive wastes. A robust system for the maintenance of records relevant to decommissioning will be a key element in these arrangements.

In the UK, there is a specific legal requirement under Nuclear Site Licence Condition 6 (SLC6) to maintain records demonstrating compliance with the requirements of any of the other site licence conditions including those dealing specifically with decommissioning and the disposal of radioactive waste (SLC33 and SLC 35). Records will also require to be maintained in relation to the licensee's duties under, for example, the Nuclear Reactors (Environmental Impact Assessment for Decommissioning) Regulations 1999, the Ionising Radiations Regulations 1999 and the Environmental Permitting Regulations 2010.

This report describes the characteristics of knowledge and information management systems that will be required to ensure secure retention of relevant knowledge and to facilitate its transfer between all stages of the life cycle, including systems to identify and retain the knowledge most pertinent to decommissioning from the design, construction and operational phases.

In this context, knowledge transfer consists of the:

- Handover of practices and knowledge, well proven through use in operation, in a non-documented form. This is based on the communication of experience through training.

- Handover of recorded information that is documented and retained in a variety of purpose-designed systems.

- Training of operators in relation to the types of information available and the operation of the record management system

- Training to develop the necessary technical and management skills to ensure the retention of an appropriate competency baseline through all life-cycles of the facilities.

  The transfer of knowledge will be between successive generations of operator and facility operators but also, in some cases between organisations tasked with implementing different phases of the life-cycle. These organisations may be part of the licensee's organisation but may also include external contractors. In all cases, however, the responsibility for setting up and maintaining systems for knowledge transfer will remain with the nuclear site licensee.

2. RETENTION AND TRANSFER OF KNOWLEDGE AND COMPETENCE

2.1. INTRODUCTION

In addition to large quantities of documentary records, it must be recognised that vast knowledge and experience of the plants to be decommissioned and their history will be held by the personnel who commissioned and operated the plant or participated in earlier phases of decommissioning. This is sometimes known as 'site memory'. This knowledge is, by definition, unrecorded. It is therefore very important to ensure that as much of this knowledge and experience as possible is recorded prior to the release of staff before or during the early stages of decommissioning. The loss of such information has long been recognised as a significant threat to the effectiveness and safety of operations in the later phases of the nuclear facility life-cycle and, in particular to that of decommissioning operations. A related issue is the problem of retaining within the workforce, sufficient and appropriate competencies over the very long term, particularly as those required will inevitably vary between phases of the life-cycle.

2.2. KNOWLEDGE RETENTION AND TRANSFER

As well as detailed working knowledge of plant, systems and buildings, staff will be expected to have knowledge of:

- What engineering modifications have been implemented;
- Abnormal events which might have generated legacy hazards which may not be fully documented elsewhere;
- Other historical events affecting decommissioning e.g. contamination sealed onto surfaces to an extent sufficient to remove an operational hazard but which may be resuspended during dismantling operations.

To facilitate the transfer of this experiential knowledge, a number of complementary approaches will be considered. Firstly, key staff may be retained following plant shutdown and into the early stages of decommissioning to act as 'knowledge engineers'. The knowledge engineers should have been senior personnel with a good knowledge of the facilities and their history. Ideally, engineers with different backgrounds (including people such as shift engineers, maintenance engineers, senior authorised persons or other suitably qualified and experienced persons) should be retained. Their key role would be to support specialist decommissioning contractors and the decommissioning engineering team in the preparation of decommissioning plans and method statements etc. They could also act as guides and ensure that decommissioning teams understand the particular working requirements within specific facilities and maintain the teams' safety in hazardous areas where they have a good understanding of the hazards present. They will also have a good understanding of the site record keeping systems (including weaknesses therein) and would assist in the gathering of reports, drawings and other information as is required. They may be employed to review decommissioning documentation such as method statements, ensuring that it reflects the as-built, or as-modified, status of the plant.

In addition to the retention and deployment of knowledge engineers, all personnel employed in technical roles during relevant phases of the facilities' life-cycle (commissioning through to early decommissioning) would undergo an exit interview on leaving the facilities' operating staff with a view to collating any relevant historical plant information that may assist future decommissioning activities. It is considered to be important that these interviews are confidential and that a 'no blame' approach is taken, whereby staff are encouraged to divulge information that may not have been formally recorded during the facilities' operational phase. Having recorded this information within the record management system, its transfer to those undertaking decommissioning will be facilitated in the same way as other documented information through training of key staff both in relation to the material itself and the use of the record management system.

2.3. RETENTION OF COMPETENCIES

2.3.1. Introduction

As is the case for retention of records, the duty to maintain suitable and sufficient arrangements to ensure adequate human resources on the licensed site in relation to competencies and skills required for safe operation will lie with the site licensee. However, these future requirements must be borne in mind throughout the site's life-time to facilitate their being met over the long term and particularly in relation to decommissioning. The nature of the competencies and skills that will be required and the type of arrangements and systems which will be required to ensure their retention over the long term are described in the following sections.

The maintenance of competence is a site-wide issue and the licensee's arrangements will require to cover all nuclear plants on the site i.e. as a minimum, the EPR (including storage pool), the Effluent Treatment Building, the ILW ISF and the Spent Fuel ISF through all stages of their life-cycle including decommissioning.

Suitable and sufficient competent resource will need to be maintained for the safe operation of each facility in accordance with the requirements of their individual safety cases. However, the development of a 'nuclear baseline' will require consideration of the site holistically. That is, the possibility of simultaneous demand from more than one plant for a particular type of resource will require to be factored in. On the other hand, the possibility of deployment of the same specialist resource (e.g. maintenance teams) to a number of different plants at different times will also have to be considered.

2.3.2. Required Competencies

Competencies in the following areas are likely to be required for decommissioning. Some may be provided from a centralised site resource pool and deployed as required or on a scheduled basis:

- Plant and Process Operation:
    - active handling.
    - crane and hoist operation.
    - ventilation plant operation.

- Engineering Support:
  - Design.
  - Procurement.
  - Manufacture.
  - Commissioning.
  - Maintenance.
  - Radiological protection.
  - Decontamination
  - Dismantling
- Safety Case Specialists.
- Health and Safety Support
- Local Incident Response.
- Site Emergency Response.

The licensee's organisation will require adequate human resources in relation to the necessary competencies and knowledge and numbers to manage safety reliably at all times including the decommissioning phase. In particular, there will have to be adequate numbers of suitably qualified and experienced persons available to ensure that only such persons undertake and control or supervise duties which have been identified as having a potential affect on safety. Clearly there will be a requirement to maintain suitable managerial as well as 'technical' competencies.

The requirement to provide continuous monitoring of safety related parameters both during operational and any care and maintenance phases of decommissioning will require that control and instrumentation expertise be retained for maintenance and calibration. Health physics services will still be required to perform monitoring for planning of decommissioning operations and in support of decontamination operations, operational cover and dosimetric functions. The requirement for competencies required for response to abnormal events and incidents will remain and safety case specialists will be required to perform LC15 periodic safety reviews and production and maintenance of safety cases for individual decommissioning tasks.

What is clear is that the amount of resource in each of these areas is likely to be different to that required for the operational phase both in regard to the nature of skills and the amount of resource required.

Some of the specialist services would probably be provided in the early years of the decommissioning phase by site-wide service providers within the licensee's organisation. However, the greatly reduced level of demand after shutdown of the reactor and other major facilities may well make the retention in-house of such services impracticable and external contractor service organisations may be employed. It is noted that such a process of "contractorisation" has commonly occurred on UK licensed sites when reactors and other major facilities on a site have ceased operation and gone into care and maintenance. Under such circumstances, the competency set required would include those required for intelligent customer capability.

It is quite possible that the licensee's capability for process and equipment design will diminish during the period following reactor shutdown. However, prior to the commencement of the decommissioning phase, either a suitable workforce will be produced by recruitment and appropriate, systematic training or the necessary expertise will be bought in through contract agreements – the intelligent customer capability having been retained.

Further, should the proposed EPR be one of a fleet of new reactors, there will exist within the fleet a pool of common knowledge, skills and competencies that will be transferable between individual reactor sites. Since the life cycles (including their decommissioning phases) of these installations and their associated waste facilities are likely to be staggered, transfer of resource between sites may be a solution to the problems created by fluctuating competency requirements on individual sites.

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2.3.3. Arrangements for Maintenance of Competence

It is firstly emphasised that the system of arrangements to ensure an adequate nuclear baseline will require a holistic perspective to be maintained, and not be too narrowly focused on individual roles. It is the organisation which is required to have the capability to maintain the safety of its undertakings. The arrangements for the maintenance of the nuclear baseline and other safety management arrangements throughout the licensed period will be fully integrated into the business management organisational structure to ensure adequate consideration is given to safety and environmental protection related matters in the business decision making process and clear lines of accountability and responsibility for safety and environmental protection.

Before granting a nuclear site licence for a new power reactor site, HSE require to be satisfied that the applicant will have an adequate management structure, capability and resources to discharge the duties incumbent on a site licence holder with the nature of the organisation and resources being commensurate with the nuclear risk posed by the site's facilities. Thus the arrangements for defining and maintaining an adequate nuclear baseline and competency management organisation will be developed and implemented well before operation of the site's facilities commences. These arrangements will then require to be maintained throughout the licensed period through to and beyond decommissioning.

Clearly the spectrum of competencies and manning levels required will vary across the stages of the facilities life cycle. However, the necessary variations in the baseline may be anticipated with some confidence such that the requirements for decommissioning may be preliminarily defined even at the design stage and pre-licensing and certainly will be capable of definition years in advance of any anticipated step change in baseline requirements such as those that will occur on shutdown of the major facilities and commencement of decommissioning.

The process for defining the baseline for decommissioning and the preparation for its implementation will be commenced well in advance of the transition between phases. This will include:

- Identification of gaps between the ‘current’ and altered baselines.
- Identification of measures to address shortcomings e.g.
  - Succession planning.
  - Redeployment.
  - Recruitment.
  - Training.
  - Employment of contractors.
- Safety justification and due process for changes to the baseline.

2.4. EFFECT OF DECOMMISSIONING STRATEGY

Although the preferred option is immediate decommissioning of the reactor and associated facilities at the end of operation, this process will take decades to complete and it is likely that most senior engineering personnel with operational knowledge of the plant will be lost over the period. A significant amount of otherwise unrecorded knowledge could potentially be lost if there is no systematic and rigorous system in place to identify and retain it. Similarly, without a robust system for the maintenance of competence, the loss of key skills could have significant detrimental effect on the efficiency and safety of decommissioning operations.

Should premature shutdown and decommissioning be required, for whatever reason, the risk of loss of knowledge and competencies remains although it may be less pronounced than for immediate decommissioning.

Finally, any significant deferment of decommissioning (e.g. a period of care and maintenance) could only exacerbate the potential problems associated with knowledge and competency retention since it is even more unlikely that key staff with operational experience of the decommissioning facilities and the necessary competencies will remain available.

3. MANAGEMENT OF RECORDS FOR DECOMMISSIONING

3.1. INTRODUCTION

The primary purposes for the retention of records may be broadly defined as follows:

- To meet statutory and regulatory requirements;

- To enable an effective defence to be developed in the case of possible future litigation;
- To support the development of plans, strategies and techniques for decommissioning operations;
- To permit the development of a safe and environmentally sound approach to decommissioning.

Clearly, there will be significant overlap between these individual objectives and some records will contribute to the achievement of more than one objective.

The records that need to be retained to demonstrate current and historical regulatory compliance will be well known to the licensee since they will essentially comprise the documentation generated and kept for that purpose during the operational phase.

In relation to developing plans and strategies which will ensure safe, environmentally sound and efficient approaches are taken to decommissioning, records may be employed to determine, for example:

- Methodologies and techniques employed e.g.
  - Decontamination techniques;
  - Dismantling strategies;
  - Size reduction methods;
  - Lifting methods;
  - Remote or manual methods;
- Sequencing and timing of operations e.g.
  - When active ventilation is removed;
  - When shielding is removed;
  - When containment structures are dismantled;
- Access routes e.g.
  - Materials flow;
  - Introduction or removal of large equipment items;
- Waste Management e.g.
  - Classification of decommissioning wastes;
  - Quantities for disposal;
  - Disposal routes for:

    - Radioactive wastes;
    - Hazardous wastes;
    - Conventional wastes;
  - Conditioning options;
  - Packaging options.

3.2. SYSTEMS FOR RETENTION AND TRANSFER OF RECORDED INFORMATION

3.2.1. Introduction

The systems that will be put in place to manage recorded information relevant to decommissioning will be designed to ensure that the recorded information retained remains fully transferable between generations of operators charged with the decommissioning of the EPR and its associated facilities and to other interested stakeholders such as the nuclear and environmental regulatory agencies. That is, they will ensure the 'transferability' both of the information contained in the retained records and of the systems in place for their management. Key aspects of transferability include relevance, accessibility, retrievability and usability and possibly of greatest importance, 'preservability' since the former aspects become irrelevant if records do not survive. Threats which could undermine transferability of recorded information will require to be identified via a formal hazard identification procedure and identified safeguards incorporated into the design of the record management system. However, certain generic threats can be identified at this time, including:

- Physical deterioration of records;
- Obsolescence of hardware and software systems;
- Natural external hazards such as seismicity and flooding;
- Internal hazards such as fire, flooding and failure of environmental control systems;
- Malware infiltration of computerised record storage and management systems and the corruption or loss of stored data;
- Unauthorised physical access to and sabotage or theft of records;
- Loss of required knowledge and competencies for the management and/or interpretation of records.

Records of relevant information will be created in all phases of the life-cycle of a nuclear facility. Thus, the amount of information is likely to be very large. To facilitate the effective use, storage and transfer of this information, a record management system will be created and operated over the prolonged period covered by the pre-operational, operational, closure and decommissioning phases of the facilities. The record management system will be fully integrated into the safety management, quality and business systems to promote active management, to develop a process of understanding of the relevance of the records to the management of nuclear safety and to ensure fully informed management decision-making.

The record management system is likely to be employed for records for many purposes other than the facilitation of decommissioning. A minimum requirement will be some form of 'flagging' system to identify those records that may be of particular relevance to decommissioning. The quality of the record management system is of critical importance since it will be the medium through which information is transferred between generations and, in fact transfer of information between the operational and decommissioning phases is likely to be accomplished by the transfer of the record management system itself.

The record management system will be designed to meet the following objectives:

- Provide comprehensive accurate and up to date information about the condition of the facility and its equipment;
- Provide historical information about operational management of the facility and maintenance history data;
- Provide the means for the secure storage of this information;
- Provide the means for timely and accurate retrieval of the information when required;
- Provide adequate tools for data analysis;
- Provide for the automatic identification and highlighting of discrepancies and anomalies.

3.2.2. Preservation of Records

To remain available to future generations both of operators and other stakeholders such as regulatory agencies, records will require to be in a form that physically endures over a very extended time period (from the early design phases through to decommissioning) without loss or corruption of data. In order to ensure this is the case, a careful and ongoing evaluation of the long term preservation characteristics of file formats and storage media and the necessary environmental conditions for storage will need to be made taking account of experience gained in other areas where long term retention of information is of importance and keeping abreast of developments in the field.

Additionally, the record management system will be subject to frequent periodic audits and inspections of systems, applications, codes, media and processes to prevent data loss. Where individual records or sets of records are found to be vulnerable to deterioration they will be transferred to more durable media or their storage conditions re-evaluated. To ensure that administrative failures do not result in data loss, the collection, secure storage, retention, migration and maintenance of decommissioning records and associated audits will require to be a fully integrated, proceduralised element of the facilities' quality assurance programme.

3.2.3. Obsolescence

It is inevitable that, over the extended operational period that the information will be of use, significant developments will take place in information storage and management technologies just as have been witnessed over the past decades.

Clearly, there is little point in preserving files on storage media that may not be able to be accessed due to the obsolescence of the media themselves or of the hardware required for access. Thus, in developing the long term information management plan, a careful evaluation of the long term technological considerations associated with formats, media, migration and indexing of records will need to be undertaken. These are not only requirements for the initial development of a record management system but such considerations will need to be kept under continuous review since once accessibility and retrievability have been lost it may not be possible to re-establish them and further transfer of recorded knowledge and information will be prevented.

In addition to the obsolescence of systems employed for data management and retention, the obsolescence of software employed for performing analyses whose results are the subject of records must be considered. This may require repetition of calculations employing current software codes or preservation of copies of the software originally employed or at least details of its functionality to permit future generations to evaluate the validity of the conclusions of the original analyses.

Employing diverse recording and management systems (e.g. hard copies, electronic files on hard drives and portable media, diverse software for data management and analysis) will facilitate keeping up with the evolution of technologies (including software and hardware) to keep the system capable of information retrieval and transfer at any time, even at the time of the final decommissioning operations on the last facilities to undergo decommissioning.

3.2.4. Protection against hazards

Primary protection against natural phenomena with the potential to damage the premises housing records and hence the records themselves will be through designing buildings to withstand events of the appropriate return period which will be assessed on the basis of the anticipated duration of the period for which records will require to be retained.

Protection from internal hazards such as fire and flood will again be afforded through compliance with the appropriate codes and standards of the day. Consideration will be given to the housing of key records in secure compartments to which access is strictly controlled but which are also fire and flood resistant.

A significant element of the record management system will be the maintenance of parallel redundant sets of records. While providing some protection against hazards, such an approach inevitably introduces potential vulnerability to common cause failure events. These will be protected against by maintaining redundant record sets at physically separate locations and by employing diverse hardware and software systems at each location.

3.2.5. Security

There are essentially two aspects to ensuring that the record management system provides adequate security for the retained information to avoid loss of or damage to records. These are physical security and electronic security.

Methods of controlling access to records will be established and documented to prevent loss, destruction or unauthorised alteration of records. Controls will include identification of organisational responsibility for authorising and controlling access to records and regular reviews and updates of technology to protect against malware infiltration. Again, a key protection will be the maintenance of redundant record storage systems at different locations and employing diverse systems.

3.2.6. Relevance and Currency

It is inevitable that the design, construction and operation of nuclear reactor plant and associated facilities such as interim waste stores will generate enormous volumes of technical data. Clearly not all of this information will be relevant to decommissioning. However, it may not be immediately obvious during the earlier phases of the facilities' life-cycle precisely which records (other than those which must be retained for legal reasons) will be of use in supporting decommissioning.

Nevertheless, given the volume of material generated, any record selection process carried out only at the end of the operational phase, would be extremely time-consuming and resource intensive. Clearly the selection of records for retention must therefore start as early in the facilities' life-cycle as is practicable and be ongoing through the period up to the commencement of decommissioning with the possible caveat that if there is uncertainty as to a record's relevance, the default option should be retention.

Regular reviews of accumulated data will be required to consider if data has been superseded and remove any such data from the records. For example, records of radioactive contamination of areas which have subsequently been decontaminated could mislead decommissioning planners and result in inappropriate dismantling and waste management strategies being developed. More importantly records showing an area to be free of contamination when it has subsequently become contaminated may result in the development of strategies that are not only technically inappropriate but also potentially unsafe.

3.2.7. Usability

In addition to the threats to accessibility posed by obsolescence discussed previously, it is also noted that the usability of recorded information may be undermined by lack of information as regards the context and environment in which the retained records were first generated and the potential for the loss of skills and competencies required for their interpretation. While the latter potential problem may be addressed by the competency maintenance systems described in Section 2.3, the transferability of much recorded information will inevitably require the production of additional records simply to communicate to future generations, the purpose for which records were originally made, and to provide information as to their context and history and guidance on their interpretation.

For example, if only the source code and data for a computer model were to be preserved, then the model may not be capable of reconstruction unless the following are also retained:

- Software compiler for the code;
- Software language manuals;
- Computer systems capable of running the code;
- Design manuals for the code to understand its functionality;
- User guides;
- The appropriate skills and competencies for understanding and interpreting the model and its output results (see also Section 2.3).

One less obvious threat to usability would be the possible loss of language skills when design information (manuals, drawings etc) are primarily recorded in one language whilst the operators and eventually those charged with decommissioning speak another. Such problems have been encountered, for example, on Lithuanian plant constructed and operated in what was the former Soviet Union.

3.3. TRANSFER OF RECORDED KNOWLEDGE

3.3.1. Introduction

The responsibility for the identification and retention of records throughout the licensed phases of the facilities life-cycles will lie with the licensee. Thus it is important that the licensee (or licence applicant) lays down criteria for retention of records to all organisations involved in the facilities' life-cycle from design through to decommissioning and beyond to ensure that the information available going into the decommissioning phase is suitable and sufficient to permit safe and efficient operation.

The categories of records will include records required to:

- Make or substantiate the safety case for decommissioning operations;
- Meet legal requirements including site licence conditions, IRRs requirements etc.;

- Defend against possible future litigation;
- Permit implementation of a robust waste management strategy (e.g. for the quantification, characterisation, conditioning, interim storage, transport or final disposal of decommissioning waste arisings;
- Provide information to support the choice of decommissioning methods, programmes and strategies;
- Assess and justify the safety of any extended periods of long term care and maintenance of the facilities and site in the decommissioning programme;
- Preserve staff dosimetry and health data;
- Provide benchmark data for judging the success of discharge abatement provisions and site restoration and remediation programmes.

3.3.2. Knowledge Transfer: Vendor to Operator

There will be certain key points in the life-cycle of the facilities under consideration where records will require to be transferred not only between successive generations of operators but also between different organisations.

Of particular importance will be the retention of information relevant to decommissioning generated before the licensee's record management system is necessarily in place. The generation of records relevant to decommissioning will, in the first place, be undertaken by the organisation designing the facilities who are external to the prospective licensee's own organisation. It is incumbent upon those undertaking design of the facilities to consider decommissioning even at the earliest generic stages of the design process and to anticipate the licensee's future information needs in that respect. Since many relevant records will be generated prior to the development of the licensee's own record management system, it is essential that the design organisation, itself, has in place a robust record management system which possesses the characteristics, outlined in Section 3.2, necessary to ensure the effective transfer of recorded information.

A key interface will be that where the organisation(s) designing and constructing the EPR and its associated facilities (i.e. the vendor) transfer(s) knowledge to those responsible for its operation (i.e. the licensee). Clearly, the primary concern in ensuring effective knowledge transfer across this interface is that the operator receives all of the necessary knowledge to operate the facilities safely and to maintain the safety case through the operational phases. However, a significant proportion of the knowledge to be transferred will also have relevance to the decommissioning phase and the preparation and maintenance of the safety case for that final phase. Classes of information falling into this category are outlined in Sections 3.4.3 and 3.4.4.

Essentially, the knowledge transfer process at this interface will need to comprise two main elements; information hand-over and training.

3.3.2.1. Information Handover

Records generated during the construction of the facilities may well be produced in the first instance by contracted organisations. However, by that time, the licensee's record management system will be in place and the licensee will be able to prescribe the type of records that must be retained and the means to be employed for their retention.

The precise strategy and timetable adopted for the hand-over of information will necessarily be determined by contractual considerations.

However, it will be necessary to commence the information hand-over process well in advance of plant hand-over to enable the operators to prepare for the operational phase and to discharge their responsibilities under the conditions of the nuclear site licence.

The strategy for information transfer will also be largely determined by the degree of compatibility between the information management systems of the two parties which will inevitably both be based on electronic document management systems. Where these systems are fully compatible, transfer of information in electronic format will be facilitated. Where there is inadequate compatibility when information transfer needs to commence, alternative strategies may have to be adopted. For example, the operator may be given access to the relevant areas of the vendor's information management system until such times as fully compatible systems have been developed or the relevant sections of the vendor's electronic document management systems can be transferred to the operator.

While the responsibility for the identification, retention and management of information necessary for the safe operation and decommissioning of the facilities will rest with the operator as licensee, the specification of what information will be required will clearly require to be determined in conjunction with those who generate the records in the first instance in the course of the design and construction phases.

3.3.2.2. Training

The responsibility for ensuring that an adequate baseline of technical and managerial competencies is maintained through to the decommissioning phase lies with the licensee. However, in the first instance, it is anticipated that the vendor organisation, as the developers of the engineered design and the mode of operation, will require to be heavily involved in the provision of EPR specific training to the operator's operating, maintenance and engineering personnel to ensure the effective transfer of knowledge. Clearly the training provided will be focussed on the safe and efficient operation of the plant during its active life-cycle phases rather than on the decommissioning of the plant many decades later. However, this initial transfer of knowledge will be very important in the development of the licensee's own arrangements for the maintenance of competence over the long term.

3.3.3. Knowledge Transfer: Operator to Decommissioning Organisation

While it is likely that operation of the facilities will be carried out by an entity within the licensee's organisation, the decommissioning process itself may be carried out by a specialist external contractor.

It is absolutely essential to the effective transfer of knowledge that those tasked with the decommissioning of the facility have a good understanding of the facility and its condition before the facility is shut down and while staff experienced in its operation are still available for consultation.

Irrespective of the identity of the decommissioning agency, responsibility for the maintenance of the record management system will remain with the licensee. In fact, it is likely that rather than the record management system as a whole or in part being transferred to the decommissioning agency, they will simply be granted access to the records held therein and enabled to add new records as decommissioning progresses.

In some instances, it is possible that ownership of facilities may change over their lifetime.

However, irrespective of whether internal or external entities are involved, or whether ownership changes occur, it is clear that records will require to be transferred, without loss or corruption of data, between different organisations and that it is the nuclear site licensee who must assure the effectiveness of this process if they are to discharge their legal duties in respect of record retention and ensuring the safety of decommissioning operations.

3.4. RECORDS FROM THE LIFE CYCLE OF THE EPR AND ASSOCIATED FACILITIES

3.4.1. Introduction

This section identifies some of the more important types of records that will require to be retained, why they would be required and the consequences of failure to retain the data concerned.

In fact, records may well require to be maintained from periods preceding the commencement of the site specific design – in relation to site characterisation; through the decommissioning phase itself – in relation to stage end-points and following the end of decommissioning up to de-licensing and perhaps beyond to the end of the licensee's 'period of responsibility'. Records required for decommissioning and site de-licensing will be generated in each of the life-cycle phases listed below:

- Generic Design;
- Site Characterisation;
- Site Specific Design;
- Construction;
- Commissioning;
- Operation;
- Shutdown;
- Post Shutdown (pre-decommissioning);

- Decommissioning;
- Post Decommissioning.

3.4.2. Records from the site characterisation phase

Data accumulated during this phase with particular relevance to decommissioning will include:

- Baseline environmental data e.g. levels of
  - natural or artificial radioactivity in soil and water
  - chemical species in soil and water
  - environmental indicators (flora and fauna)
- Geotechnical data.

The baseline environmental data will be essential to set targets for site clean-up while geological data may be required to substantiate the continuing structural integrity of the facility as it is progressively dismantled and the sites suitability for re-use. Clearly failure to record baseline environmental data would seriously complicate the setting of clean-up targets and the design of post-decommissioning environmental surveys for, for example, de-licensing and ending the licensee's 'period of responsibility'. The absence of records of geological surveys may undermine the safety case for seismic withstand either for the plant over extended periods of care and maintenance or when partially dismantled.

3.4.3. Records from the design phase

3.4.3.1. Generic Design

Even prior to the recording of the as–built design, design specifications for equipment and structures will, for example, provide detailed specifications of materials to be used. This data will have a number of uses relevant to the decommissioning process including the determination of decontamination methods and agents, the assessment of activation inventories for the primary circuit and its shields (in the case of reactor decommissioning) for both waste management and radiological protection planning. Detailed consideration will require to be given to materials specification even at the generic design stage and may include records of analysis supporting the choice of specific materials which may be relevant to the making of the safety case. Failure to maintain these records would have programme and financial implications in that sampling, surveys, and calculations would require to be performed to reconstruct the record.

3.4.3.2. Site Specific Design and Procurement

- Design calculations;
- Procurement records for construction materials (confirming compliance with design specifications);
- Safety cases and environmental impact statements.

Procurement records and materials samples should confirm the detailed specification of the materials employed in the reference design. Should such records prove to be incomplete or inaccurate, development of the waste management aspect of the decommissioning strategy would be adversely affected. This is particularly true of wastes arising from reactor structures and components that would be subject to neutron activation during operational periods whose inventory would be critically dependent on the chemical composition of the materials employed. Again reconstruction of the record would require material sampling surveys with associated time, cost and dose penalties. Any lack of knowledge of the inventories of activation products would also prevent accurate prediction of radiological conditions in certain areas which would only become accessible as decommissioning progressed. Such uncertainties would inevitably lead to overly conservative decommissioning strategies and difficulties in the development of the safety case for such operations.

Records of design calculations (and any codes employed to undertake these) may be employed not only for the prediction of inventory at shutdown but also, for example, to substantiate the load bearing capabilities of structures and their ability to withstand to challenges from internal and external hazards. Absence of such records would require the repetition of the original calculations and would complicate both the planning of decommissioning operations and the making of the safety case.

3.4.4. Records from the construction phase

The key records from this period will be those that record the plant and equipment as built. They will include:

- Complete engineering drawings of the facility as built (including any modifications to the reference design);
- Complete engineering drawings of major equipment items as installed (including manufacturers' drawings where appropriate);
- General arrangement (GA) drawings of the facility as built;
- Models of the facility as built;
- Photographs of the facility as built;
- Construction materials samples.

As-built engineering drawings will permit the detailed planning of dismantling operations in relation to techniques to be employed and sequencing, required capacities of lifting equipment etc. General arrangement drawings including 3-D renderings together with photographic records and models of the plant as built will permit detailed planning of access and egress routes, materials flows etc.

Incomplete or inaccurate records of as-built drawings of the plant, particularly of areas not normally accessible during the operational phase and as-installed drawings of major equipment items could, in the extreme case, prevent or delay the commencement of decommissioning activities by preventing effective planning of specific decommissioning tasks. Additional cost and time penalties would accrue, as detailed surveys of the plant and equipment would be required to obtain the necessary information. Such surveys would, in some cases, involve significant additional radiation exposures to the survey teams. In some instances, decommissioning tasks could only be planned on a step-wise basis since the necessary information for the planning and safety justification of the next task step would only be obtained in the course of the previous step, therefore introducing significant hold-ups in programme.

3.4.5. Records from the commissioning phase

The commissioning process should yield data which may facilitate the substantiation of the performance of equipment, systems and features of the original plant such as ventilation systems shielding and containment which may be relied upon to continue to fulfil their function during decommissioning. This data may, in some cases, differ from the design specification. Similarly, commissioning may identify or confirm limits and conditions on operation of certain systems which may be relied on during decommissioning. Clearly absence of this data may complicate the making of the safety case for decommissioning operations and may require additional testing and inspection of such systems with associated time, cost and dose penalties.

3.4.6. Records from the operational phase

Records from this phase of the life cycle are particularly important in that they identify how the plant has changed since construction. Preliminary decommissioning plans may well be invalidated by these changes.

Key records generated during this phase will include the following:

- All facilities
  - Operating procedures and records;
  - Maintenance procedures and records;
  - Records of abnormal occurrences and incidents;
  - Environmental discharges (radioactive and chemical);
  - Decontamination plans and reports (including primary circuit decontamination);
  - Radiological surveys;
  - Records on relevant radiological incidents (see below)
  - Records of modifications to engineering and updated drawings;
  - Analysis results for material samples for age-related degradation;
  - Examination and inspection records for safety-related equipment and structures;

- Records of any wastes stored on or disposed of from site.

- Reactors
  - Core power history neutron fluxes etc.;
  - Analysis results for material samples for activation assessment;
  - Coolant chemistry records;
  - Circuit decontamination records;
  - Fuel assembly history (burn-up, cooling time, damage etc.).

Records of abnormal occurrences and incidents including associated environmental discharges are required to locate and quantify legacy contamination on the plant or the surrounding environment for the purpose of planning decommissioning or site remediation operations. Wider environmental surveys may help characterise the spread of any abnormal discharges and therefore help quantify and plan remediation work.

Incomplete information on incidents and abnormal events (particularly spillages of radioactive liquors) during the plants operational history may have direct safety consequences when, for example, unexpectedly high contamination and radiation levels or chemical contamination are encountered during decommissioning operations. Even where such unanticipated hazards do not result in significant radiation exposures or injury, they will cause programme delays while decommissioning strategies are revised or decontamination performed. The lack of comprehensive historical data may also undermine regulatory confidence in the safety case for the operations particularly where additional or enhanced hazards (i.e. gaps in the record) only come to light in the course of decommissioning operations. In some cases, there will also be implications for the waste management strategy in relation to changes to the anticipated volume or radioactive or chemical inventory of waste arisings.

As previously mentioned, engineering modifications during the plant's operational life may invalidate preliminary decommissioning strategies based on as-built information. Should a plant modification not be recorded by revision of the as-built drawings, it may not come to light until a decommissioning task is underway. At best, the discovery of an undocumented modification will entail delays to programme while alternative methods are sought and safety case documentation modified and processed. In the worst case, such unrecorded modifications (e.g. re-routed power cables or pipe runs) may only be revealed when an accident occurs.

Records for non-routine major maintenance operations including procedures employed, doses received and durations will be of particular value in relation to planning access to and dismantling/removal of large components and the deployment of temporary containment and shielding for such operations. It is noted that, in this case, records of unsuccessful operations (in operational or radiological terms) will be as important as those of successful ones. Similarly, maintenance and operating procedures for certain items of equipment may be required if it is intended to employ them for decommissioning operations (e.g. cranes, ventilation fans, liquid effluent systems).

Radiological survey records of plant areas will clearly be of vital importance to the planning of individual decommissioning operations such that the selected strategy and safety measures deployed ensure that the risks to workers are restricted so far as is reasonably practicable. While, the most relevant records of this type will be for the period following final shutdown of plant, records from the operational period may still be relevant where they are of surveys of areas not normally accessible.

For reactor plant, fuel assembly removal should have been completed by the end of Stage 1 of decommissioning (IAEA definition). The safety of fuel removal operations will depend to some extent on a comprehensive knowledge of the condition of each fuel assembly to be removed and transported from the site. Key data for predicting the radiological hazard from individual assemblies will include irradiation history (burn-up) and cooling time. Clearly, in order to determine any requirement for additional conditioning or special packaging for any given assembly it will also be important to be aware of any pre-existing damage.

Accurate records of power history will also be essential for the estimation of activation product inventory and the magnitude of radiation hazard from areas subject to neutron flux during the operational period.

Finally, for reactor plant, primary circuit decontamination records may provide useful information as to whether significant radiological protection or waste management benefit may be derived from post-shutdown chemical cleaning of the circuit. This information may be necessary input to the ALARP analysis in the decommissioning safety case.

3.4.7. Shut Down (Pre-decommissioning)

Records from this phase should essentially reflect the final plant condition and inventory which will pertain at the commencement of Stage 1 decommissioning and will permit the confirmation or modification of preliminary decommissioning plans.

Of particular importance will be assessments of radiological conditions in the areas which will require to be accessed to perform decommissioning tasks. Inevitably some extensive radiation and contamination surveys will be required. Although in some cases, survey records from the operational phase will suffice (if appropriately adjusted for radioactive decay). Clearly for reactor plant, the relevant data will be that obtained following the decay of short-lived fission product activity over the period immediately following shutdown.

In preparation for decommissioning, many documentary records justifying the safety of the proposed operations will be generated and will require to be maintained and updated as decommissioning progresses. These assessments will have been first generated before the plants entered the operational phase and will have evolved over time. These will include:

- Decommissioning strategy selection documents;
- Decommissioning plan;
- Environmental impact assessments;
- Decommissioning QA plan;
- Decommissioning baseline organisational structure.

3.4.8. Decommissioning

The essential records generated during decommissioning which must be securely maintained are those which clearly define the plant state at the end of each phase of the decommissioning programme i.e. that define the starting conditions of the next phase. In this, the record requirements for the decommissioning phase mirror those for the operational phase.

Of particular importance will be records which clarify the radiological conditions and plant inventory at the end of each task and subtask. In addition, records of radioactive waste generated, personnel doses and environmental discharges will be required not only to confirm compliance with targets and limits and end-point conditions set out in the safety case and waste management strategy for the phase but also as important input into the planning of subsequent phases.

It will be essential to produce and maintain drawings, photographs etc reflecting the actual state of the plant at the completion of each phase. In particular, terminations and disconnections of systems vessels and circuits will require to be unambiguously recorded.

As with the operational phase, it will be particularly important to record details of any abnormal occurrences during each phase of decommissioning particularly where these alter radiological conditions on the decommissioning plant or could potentially re-occur during later stages.

The consequences of failure to maintain adequate records during this phase will be similar to those identified for the operational phase.

3.4.9. Post-Decommissioning

The licensee's responsibilities do not necessarily end on the completion of decommissioning. The licensee's 'Period of Responsibility' (PoR) only ends when in the opinion of HSE, there has ceased to be any danger from ionising radiations from anything on the site. De-licensing may occur provided a site is no longer being used for any licensable activity. This point could, in theory pre-date the end of the PoR. However, it would normally be anticipated that the licensee would seek for the end of the PoR and de-licensing to coincide.

The application by the licensee for de-licensing and ending of the period of responsibility requires to be supported by a safety case providing a detailed demonstration of the work undertaken to assess levels of radioactivity on the site plus:

- The history of the uses of the land on the site or portion of the site to be de-licensed,
- Identification of any areas where radioactivity could contribute significantly to radiation exposure and an assessment of reasonably practicable means of remediating such areas;
- Records of detailed radiological surveys and samples from the area for comparison with background data for the area and baseline levels established during site characterisation;
- An assessment of dose and risk to the public following de-licensing.

Clearly these each rely on records generated in earlier phases (indeed back to the original site surveys) but they will also require to be maintained for some time following de-licensing. The HSE expectation is that such records will be retained for 30 years to meet the requirements of Section 15 of NIA65.