Radioactive Waste Management

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Decommissioning Considerations for New Nuclear Power Plants

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NEA Nuclear Energy Agency

IAEA International Atomic Energy Agency

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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Foreword

Recent studies undertaken by the OECD Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA) have considered how experience gained from decommissioning is being applied to the design of new reactor systems. The overarching aim of these studies is to ensure that decommissioning considerations are taken into account from the outset for new reactor projects.

The NEA Working Party on Decommissioning and Dismantling (WPDD), working in close collaboration with the IAEA Waste Technology Section, has studied current practices in applying experience from decommissioning to the design and licensing of third generation reactor systems. Participants in the study included regulatory authorities, electricity producers and reactor design organisations concerned with the development and implementation of new reactor systems, as well as decommissioning and waste management organisations. The findings are reported in the OECD/NEA report *Applying Decommissioning Experience to the Design and Operation of New Nuclear Power Plants*.

In parallel with the WPDD study, the IAEA has been working on a report that aims to summarise the pertinent lessons for new plant design that have been learnt from actual decommissioning projects. This report, *Design Lessons Learnt from the Decommissioning of Nuclear Facilities,* is expected to be published in 2010.

The present report takes account of the main findings of the NEA and IAEA studies described above.

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Overall summary

Experience from decommissioning projects suggests that the decommissioning of nuclear power plants could be made easier if this aspect received greater consideration at the design stage and during operation of the plants. Better forward planning for decommissioning results in lower worker doses and reduced costs. When appropriate design measures are not taken at an early stage, their introduction later in the project becomes increasingly difficult. Hence, their early consideration may lead to smoother and more cost-effective decommissioning. This has prompted national authorities and electricity producers to demand that decommissioning needs be addressed from the design stage and that preliminary decommissioning plans be provided as an input to the licensing process.

A list of key design features that represent current good practice for reactor design is provided at the back of this report. This list draws on information obtained from the recent studies undertaken by the NEA and the IAEA.

Preliminary decommissioning plans

In recent years, it has become common practice that decommissioning plans are developed at an early stage, subsequently revised as necessary throughout the lifetime of a nuclear facility, finalised after permanent shutdown of the facility and submitted for approval by the national regulatory authorities. These plans typically discuss the management of possible physical and socioeconomic impacts of the proposed decommissioning operations, including consideration of the technical feasibility of dismantling strategies and of programme and cost issues. They also describe the management of waste arising from decommissioning operations, the intended end state of the site and related environmental issues, and are used as a basis for showing that adequate financial provision for decommissioning is being made. This trend is, in turn, leading to greater emphasis being given to associated issues such as the choice of materials for construction, making provisions for ease of maintenance, retrofit and dismantling, providing means for limiting contamination, and developing the clearance criteria and infrastructure needed to facilitate recycling and reuse of materials from decommissioning.

Decommissioning plans should also address occupational exposure and, at an appropriate stage, the necessary design provisions: to minimise the creation of radioactive waste – by limiting and controlling activation and contamination and facilitating decontamination; to simplify dismantling and equipment handling; to enable on-site management of materials and waste; and to facilitate site release.

Elaborating the future dismantling/retrofit sequence at the design stage may be very beneficial in identifying design improvements beneficial to decommissioning, and then in reducing uncertainties in dismantling costs. A clear strategy for minimisation of radioactive materials will also be very helpful in reducing waste management costs. Design for decommissioning should take into account the potential future uses of buildings and the site as a whole during and after decommissioning.

Interface between operating and decommissioning requirements

An important priority for utilities is that the design provides for optimal operation and maintenance (O&M) of the facility. Design features that support O&M work will invariably also be beneficial for later decommissioning tasks. Good design practices for both O&M and decommissioning include: providing ample space for the activities being undertaken, minimisation of doses during these activities, minimisation of waste quantities, keeping plant contamination levels low, maintaining accurate and up-to-date records, providing adequate handling capability and making provision for replacement of components, including the very large components involved in large-scale retrofit. Minimisation of waste arisings is achieved, for example, through careful selection of materials and by incorporating features to limit the spread of potential contamination to clean areas and systems.

In addition to consideration being given to the "nuclear island", attention should also be given to the overall balance of the plant, on the basis that areas which are difficult to access could later give rise to problems during decommissioning. In general, it is good practice to submit the entire plant to a structured review from the perspective of decommissioning.

Designing for decommissioning

Although many design requirements aimed at improved O&M will also be beneficial for decommissioning, there are nonetheless certain design considerations that need to focus directly on plant decommissioning. Design provisions specific to decommissioning include designing structures for long-term integrity and including features aimed at minimising infiltration, containing spills and releases, and attenuating contaminant transport. Decommissioning experience to date suggests that greater consideration should be given to access for large equipment removal, identification of dismantling sequences and provisions for equipment lay-down areas. Key components of reactor systems that are directly related to decommissioning should be identified and the long-term integrity and boundaries of these systems should be defined, regardless of the decommissioning strategy.

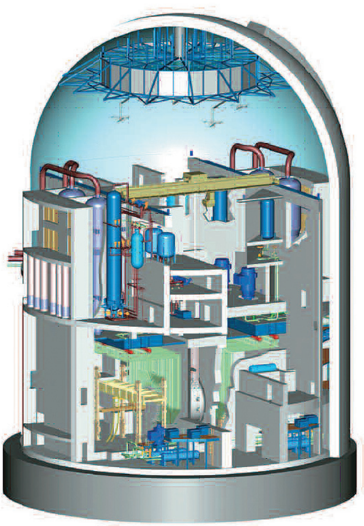
It is good practice to minimise the use of embedded or underground piping. Leaks in embedded or underground piping are difficult to locate and may lead to environmental contamination resulting in larger amounts of waste and delays during refurbishment and decommissioning. At the same time, potential radiation doses from unshielded piping need to be addressed in the design. Careful optimisation of design provisions for decommissioning with those of decommissioning waste management, including providing facilities and space for on-site management of waste, can be expected to yield benefits in terms of both reducing worker dose exposure as well as decommissioning costs.

Removal of a reactor pressure vessel during decommissioning via special egress routes.

Maine Yankee nuclear power plant, Maine, USA. [Photo courtesy of Maine Yankee, USA]

Plant record systems and plant configuration management

Early consideration should be given to the needs of plant configuration management, including providing systems for maintaining records of the physical configuration of the plant on an ongoing basis. Experience from recent decommissioning projects suggests that plant records may sometimes be incomplete or inaccurate, and consequently may not reflect the final plant configuration. Plant management systems should be designed to include, in addition to those records that are directly relevant to operation, other records that might be important for decommissioning. For example, information on temporary openings made during construction may facilitate the reuse of these accesses during decommissioning. In all cases, it is essential that records reflect the "as-built" configuration of the plant.

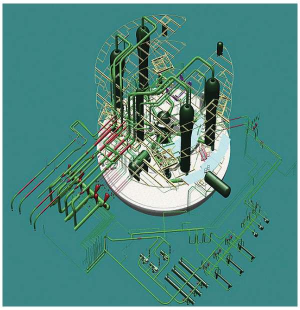


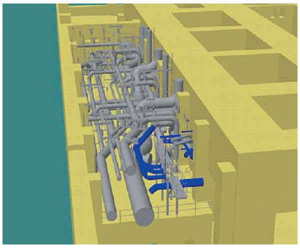
Three dimensional representation of the ACR-700 reactor building.

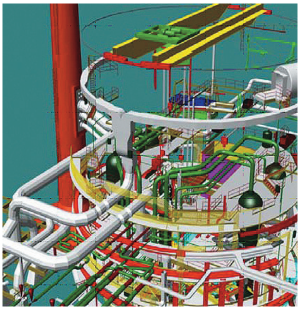
Currently under construction in Qinshan, China. [Photo courtesy of AECL, Canada]

The development of 3-D models as part of the design process provides a useful management tool throughout the plant lifecycle from design and operation to decommissioning. These models can show how configuration control can be maintained during sequential dismantlement and can facilitate visualisation of the locations of sources of activity to help assess where samples should be taken for radiation monitoring.

It is good practice to retain records and samples of the original composition of steel and concrete materials used in the plant (including technical specifications), as knowledge of any impurities may be important for future decommissioning and can reduce the extent of material characterisation that is ultimately needed. Materials used for the construction of neutron shields are of special importance. In particular, it is beneficial at the design stage to specify the allowable range of cobalt levels in steel, as well as seeking to reduce cobalt levels in absolute terms and to narrow the range of acceptable concentrations, as quantities of certain other radionuclides are often estimated from the cobalt levels. Overall, this will facilitate better management of radionuclide inventories. A baseline survey of the facility should be undertaken prior to operation, to facilitate, following completion of dismantling, verification of compliance with the site release criteria established by the regulatory authorities.







Three dimensional representation of the Trino nuclear power plant, Italy. Currently under decommissioning. [Photos courtesy of SOGIN]

Plant monitoring systems

It is good practice to provide monitoring systems for early detection of leaks and contamination, including leaks from underground piping (environmental monitoring). Providing means for monitoring plant chemistry parameters, with the objective of minimising corrosion of metallic components, is also desirable. Plant operators need to give particular attention to recording this information – as such contamination may otherwise only be identified during demolition of the concrete structure.

Towards greater standardisation of design requirements

The design guidelines established by the electricity producers provide an essential link between past experience and the design process. These guidelines need to be developed taking into account discussions with designers about what features can reasonably be delivered.

In Europe, the main electricity producers have developed standardised requirements intended to ensure that all reactor designs for the European market incorporate certain basic design features, including making provision at the design stage for waste minimisation and component removal. The European Utilities' Requirements (EUR) for light water reactors (see www.europeanutilityrequirements.org/) address in particular aspects such as material selection for reduced dose rates, good surface finishing to facilitate decontamination of materials and providing easy accessibility for removal of plant components.

EPR reactor under construction at Olkiluoto, Finland. [Photo courtesy of Areva, France]

Regulators have also begun developing standardised requirements, for example through the Safety Reference Levels (SRLs) for decommissioning and waste management being developed by WENRA (Western European Nuclear Regulators' Association) for use in Europe. Central to these requirements is the development of a preliminary decommissioning plan prior to the issuing of a construction licence, and the updating of this plan throughout the lifetime of the nuclear facility. The plan should take account of a safety assessment for decommissioning that is also updated during the life of the facility.

The IAEA supports the above requirements in its advice to developers of new reactors, in particular for countries that are newly engaged in the development of nuclear energy.

Making decommissioning experience available to reactor designers

The need to incorporate dismantling lessons both at the design stage and during the whole lifecycle of a facility could be better fulfilled if dismantling experience were systematically collected, analysed and recorded. It is clear that design organisations are making significant efforts to take greater account of decommissioning needs in the design of new plants, as reflected in the list of design features to facilitate decommissioning provided below. The US Nuclear Regulatory Commission has collected and disseminated lessons from dismantling experience in the United States. Such systematic approaches to capturing the lessons from national decommissioning experience would help in ensuring that these lessons are addressed in the design of new plants. Ongoing work of international organisations, such as the NEA, IAEA and WENRA, will also help to identify any remaining gaps.

An important consideration here is that, within utility and regulator organisations, the areas of design, operation and decommissioning are often handled by different departments. Sometimes, the responsibility is even assigned to different organisations altogether, requiring special attention to be given to coordination of information transfer between the different groups. Recent NEA and IAEA studies have provided an opportunity for regulators, utilities and design organisations to share their different perspectives and experience on how requirements for decommissioning should be reflected in new plant designs.

Design features to facilitate decommissioning

1. Decommissioning plans

Regular updates of decommissioning plans that facilitate more accurate cost estimates should be provided, which, *inter alia:*

- elaborate the sequence of dismantling activities;
- provide a clear strategy for minimisation of radioactive materials and will help in reducing waste management costs;
- identify construction and operational features that may prove beneficial for decommissioning, e.g. for maintenance and retrofit activities;
- identify potential interdependencies with any adjacent shutdown facilities.

Special attention should be given to coordination of information transfer between different specialist disciplines that have an impact on the design, e.g. those concerned with design, operation, decommissioning and waste management.

2. Site factors

There should be provision for temporary on-site storage of spent fuel and radioactive waste during dismantling. Such interim storage facilities should be designed for ease of decontamination and for easy dismantling and removal.

Baseline environmental data, especially for the soil and groundwater, should be collected and preserved over the operating phase of the facility.

The design should take account of clean-up criteria at the end of facility life, and the potential for leakage into the environment should be minimised or eliminated.

3. Facilities and systems design

Facilities should be designed to minimise infiltration, contain spills and releases and attenuate contaminant transport by:

- limiting embedded pipework, ducts and equipment in floors and walls;
- limiting the use of potentially radioactive underground tanks, sumps, ducts and drains;
- lining sumps and trenches in concrete floors with corrosion-resistant sheet steel, to protect from contamination and to facilitate clean-up and by providing corrosion-resistant tanks;
- separation of radioactive and non-radioactive systems and areas (drainage systems should keep liquids separated according to their potential radioactivity);
- designing and installing pipes and ductwork to minimise the hold-up and deposition of crud and active dust particulates.

Systems should be optimised for decommissioning and waste management by:

- facilitating the segmentation of large, contaminated or activated items for easy removal;
- minimising the number of components in the design;
- using modular design of systems;
- making special provision for dealing with evaporators for liquid waste, which can lead to high dose exposure and other problems during dismantling.

Facilities, lay-down areas and space for interim management of waste on site during decommissioning should be provided.

4. Structural design

Structural layout, designs and construction should be such that dismantling can be done using proven and simple working practices by:

- providing space and facilities on site for characterisation, decontamination and disassembly;
- providing suitable access to allow intact removal of large plant items such as steam generators and large pumps;
- minimising penetrations, cracks, crevices and joints that trap contaminants and sealing of all porous surfaces against ingress of activity;
- the use of special surface finishes or polishing treatments to prevent contamination from adhering to or penetrating into the surface of materials;
- avoiding overdesign of shielding (e.g. design for average source levels; use temporary shielding for peak levels), bearing in mind that the design of a biological shield involves a balance between structural aspects and minimising activation.

Facilitate dismantling by:

- developing modular designs that will facilitate construction as well as dismantling (by reversing the construction sequence);
- minimising the footprint of structures and reducing the amount of construction materials (concrete and steel);
- considering (where necessary) the use of robotics to remove active items.

5. Operational design

Ease of chemical decontamination of primary circuits and other active pipework systems should be facilitated by:

- providing monitoring systems for early detection of leaks and contamination, including leaks from underground piping, e.g. detection using humidity sensors;

- allowing for decontamination of systems during operational life;
- provision of permanent decontamination facilities and equipment (good working practice is to deal immediately with contamination from spills and leakage, and with maintenance work).

Records of the physical configuration of the facility need to be maintained on an ongoing basis and preserved for the whole operating life of the facility. This includes:

- clear definition of the storage media for records and long-term responsibilities for maintenance of the record systems;
- incorporating records of environmental monitoring, and site history records of incidents, spills or releases;
- undertaking baseline characterisation of materials and of the site during construction, obtaining representative samples of selected plant and construction materials and maintaining records of original compositions of steel and concrete materials used;
- making use of 3-D models in the design process, including recording the location of sources of activity for sampling purposes.

6. Materials design and waste management

Facilitate the management, including minimisation, of radioactive waste volume and total activity by:

- clear delineation of zones and barriers;
- segregation of materials to facilitate future waste management and avoiding or minimising materials that lead to hazardous or mixed waste;
- making provision for recycling and reuse of relevant materials.

Minimise the generation of activated materials in steel components and concrete by limiting trace elements which produce radioisotopes during irradiation in the reactor. In particular, the production of Co-60 and Ni-63 in steel components should be minimised. In this regard, it may be useful to specify a range (max/min) for cobalt due to its use as a reference element for calculating the levels of other nuclides that are more difficult to measure.

Further information on lessons learnt from decommissioning

Recent publications

- *Applying Decommissioning Experience to the Design and Operation of New Nuclear Power Plants*, NEA Report No. 6924, OECD Nuclear Energy Agency, Paris (2010).
- *Considerations for Waste Minimization at the Design Stage of Nuclear Facilities*, Technical Reports Series no. 460, International Atomic Energy Agency, IAEA (2007).
- *Design Lessons Learnt from the Decommissioning of Nuclear Facilities*, International Atomic Energy Agency (in preparation).

International organisations

- Publications from the Working Party on Decommissioning and Dismantling (WPDD) and the International Co-operative Programme on Decommissioning (CPD):
  www.nea.fr/rwm/wpdd.html
  www.nea.fr/jointproj/decom.html
- Publications from the International Atomic Energy Agency:
  www.iaea.org/Publications/
  http://newmdb.iaea.org
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  http://ec.europa.eu/energy/nuclear/decommissioning/decommissioning_en.htm

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