Replacement Research Reactor Project

SAR CHAPTER 19
DECOMMISSIONING

Prepared By

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TABLE OF CONTENTS

End of Table of Contents

19 DECOMMISSIONING

19.1 INTRODUCTION

Decommissioning is the process by which the Replacement Research Reactor Facility (the Reactor Facility) is taken out of operation permanently and its wastes sent for disposal or storage. It covers the staged process following the final shutdown of the Reactor Facility by which radioactive components and waste materials are removed from the site with due attention being paid to the safety of site personnel, the public and the environment.

During the decommissioning process radioactive materials are removed. Equipment and structures are decontaminated, isolated, sealed, enclosed, or removed.

Decommissioning issues were considered throughout the design and construction processes for the Reactor Facility. These issues included:

a) Choice of materials to minimise activation;

b) Adequate separation and physical space between components to allow easy access;

c) Minimisation of the potential for contamination; and

d) Minimisation of the radioactive waste that will be produced and require treatment during decommissioning.

The objective of this chapter is to provide information on these aspects of the Reactor Facility design and operational procedures that facilitate the decommissioning process. Within this context a preliminary decommissioning plan has been established.

End of Section

19.2 DECOMMISSIONING OBJECTIVES, PRINCIPLES AND DESIGN BASIS

The objectives of Reactor Facility decommissioning are:

a) To ensure the continued safety of the site personnel, the public and the environment.

b) To keep radioactive exposure below prescribed limits and to reduce unavoidable exposure in accordance with the ALARA principle.

c) To minimise the environmental impact.

d) To minimise the production of radioactive waste as a result of decommissioning.

e) To comply with the national laws and regulations applicable to the decommissioning process.

f) Consistent with the above, to minimise the cost for decommissioning.

In order to fulfil these objectives, the following principles and design bases related to decommissioning were adopted:

a) The design of the Reactor Facility facilitates management of the Reactor Facility during the period following final shutdown and prior to dismantling.

b) The design of the Reactor Facility minimises the level of surveillance and maintenance required during this period.

c) The design of the Reactor Facility minimises the contamination and activation of components.

d) Essential information required for decommissioning purposes is identified to ensure that this information will be available at the end of the reactor operational lifetime.

e) The design of the Reactor Facility takes into account the need to monitor those parameters in the reactor operational lifetime that can affect the radioactive inventory and the radiological factors necessary for estimating the potential radiation exposure during decommissioning.

End of Section

19.3 DESIGN CHARACTERISTICS TO FACILITATE DECOMMISSIONING

A pool type research reactor is inherently simple to dismantle compared with any other reactor type and this in itself will facilitate future decommissioning works. The Reactor Facility design took into consideration decommissioning tasks from an economic, operating and radiological safety perspective.

In order to permit the optimisation principle to be applied during decommissioning, several design characteristics were included.

The following sections provide information on measures taken to:

a) minimise the radiation fields at the end of the Reactor Facility's life;

b) facilitate the dismantling and decontamination of equipment; and

c) facilitate auxiliary operations during decommissioning.

The protection of personnel involved in the decommissioning activities is ensured by the above mentioned characteristics, together with careful planning of the decommissioning, including application of the optimisation principle and compliance with regulatory requirements.

19.3.1 Measures to Reduce the Radiation Fields at the End of the Facility Life

Of particular importance to the decommissioning operation will be the extent and intensity of the radiation fields throughout the Reactor Building and systems. Features and characteristics implemented to reduce the intensity and spread of the radiation fields are presented in the following sub-sections.

19.3.1.1 Reduction of Activated Sources

The aim was to define materials and technical characteristics that contribute to the reduction of activation during the life of the Reactor Facility.

19.3.1.1.1 Design Aimed at Reducing the Activation of Materials

The configuration of the Reactor Facility aims to reduce activation of components and structures. As a result, activation products are restricted to highly localised areas and the activation of concrete and other structural materials is minimised.

19.3.1.1.2 Specification of Construction Materials

Neutron irradiation may induce radioactivity in certain materials. To minimise doses to personnel, a suitable decay period is required before activated material is handled for decommissioning or waste management purposes.

The choice of construction materials and design considerations take into account the need to minimise neutron activation. In the design stage, when choosing a construction material, the following characteristics were considered:

a) Physical properties related to operational requirements.

b) Mechanical properties ensuring performance.

c) The range of possible activation products and their mean life.

d) The neutron flux to which they are subjected, the amount of radioactivity induced by activation and its further decay.

e) For those materials in contact with water, their resistance to corrosion.

Important characteristics of the main materials used are discussed in the following sub-sections. Materials subject to a significant neutron flux were specified to nuclear grade standards, which placed low limits on impurities that are susceptible to high levels of activation.

19.3.1.1.2.1 Aluminium

Aluminium alloys are used in preference to other materials in high flux regions of the reactor because of their low neutron capture and good mechanical performance under neutron radiation. Aluminium alloy was used in the Core Grid and in other reactor components. This alloy has the advantage that the majority of the isotopes resulting from neutron activation (mainly sodium-24) are short-lived. Thus these components may be handled as low-activity waste in a relatively short time after final shutdown.

19.3.1.1.2.2 Zirconium Alloys

Zirconium alloys also have advantages in neutronic (low absorption cross-section and high resistance to flux) and mechanical properties. These alloys are produced to nuclear grade standards, which limits the hafnium impurity content. Nevertheless, its irradiation produces radionuclides with a longer half-life than those arising from the irradiation of aluminium. Such radionuclides include cobalt-60, zirconium-95, antimony-125 and niobium-93m.

These alloys have been used wherever necessary to minimise neutron absorption and guarantee reliability and safety of the plant.

19.3.1.1.2.3 Stainless Steel

Stainless steel is an excellent corrosion resistant material for structures and has been used in the construction of the Reactor facility. Notwithstanding the use of special alloys with low cobalt content, the activation products (cobalt-60, chromium-51, iron-55, iron-59, and manganese-56) make it difficult to directly handle without prior decay or without shielding. Hence, the use of stainless steel has been avoided wherever possible in regions of high neutron flux.

19.3.1.1.2.4 Concrete

Concrete that is used as shielding has small amounts of impurities (iron, cobalt and europium) that tend to become radioactive in the presence of a neutron flux. The concrete used in the Reactor Facility is subject to very low neutron fluxes.

19.3.1.1.2.5 Other Metals

Small quantities of activated cadmium and lead can be expected.

19.3.1.2 Reduction of Contamination

Provisions to reduce contamination are set out in the following sub-sections.

19.3.1.2.1 Adequate Specification of the Fuel Assembly

High standards of design and construction, water chemistry control and safe operations minimise the chance of fuel failure. Failed fuel would result in the release of fission products to the primary coolant. Significant fuel damage is beyond the design basis. Fuel integrity reduces the contamination of the Primary Cooling System and the activity on resins, equipment and piping.

19.3.1.2.2 Choice of Construction Materials

A properly considered choice of materials to be used in cooling circuits, pools and pool internals minimises the introduction of corrosion particles into the water. These particles may become active when transported close to the core.

The materials used in the Reactor Pool internal components and in the cooling systems, such as stainless steel, Zircaloy and aluminium, have excellent resistance to corrosion under controlled conditions.

These materials are also amenable to decontamination.

No materials containing greater than insignificant (impurity) levels of cobalt in their formulation were used.

19.3.1.2.3 Control of Water Chemistry

Controlling water chemistry is important in minimising the level of corrosion. The quality of the de-mineralised water used supports this control.

A number of systems are available to maintain the required levels of (heavy and light) water purity:

a) Reactor Water Purification System, for reactor and service pool water.

b) Hot Water Layer Purification System, for hot water layer water.

c) Reflector Cooling and Purification System, for reflector water.

Detectors facilitate control of the ionic content (conductivity) of the water and the specific activity in the particular system.

19.3.1.2.4 Detecting and Retaining Leakage

In addition to enabling strict radiological control, the leak detection and water retaining systems allow early warning of leaks and help the operators take appropriate actions to prevent the spread of contamination.

19.3.1.2.4.1 Pool Leak Detection System

This is a system designed to collect and detect leaks in the Reactor and Service Pools.

This system is intended to detect leaks that may occur in the structure of both pools. Its design allows detection of leakage in critical welding or tension cumulative points.

19.3.1.2.4.2 Loss Of Coolant Accident Drainage and Leak Detection

The system for collection of water due to a Loss Of Coolant Accident (LOCA) is located at the sub-basement level inside the containment.

The system was designed on the basis of minimising the effects caused by flooding of the area and to direct the water to a defined and controlled point, thus reducing the possibility of widespread contamination. Different room floor discharge nozzles with water detection switches direct the water to the LOCA pool.

The amount of liquid waste generated through leaks from those systems with potentially active water is minimised by the use of the detection system.

19.3.1.2.4.3 Heavy Water Containment

The floor of the Heavy Water Room is painted and is designed as a pool for collecting the entire volume of heavy water in the event of a leak.

This lining is waterproof to prevent contamination penetration and to minimise the contamination of concrete by tritiated water.

Floor drains with detector switches connected to drainage pipelines direct the spilled liquid towards the pit containing the heavy water storage tank.

19.3.1.2.5 Retention of Gases and Particles

19.3.1.2.5.1 Ventilation System

The ventilation system prevents the spreading of radioactive material and cross-contamination of areas.

19.3.1.2.6 Activation Products at the Irradiation Facilities

The pneumatic systems at the irradiation facilities have absolute filters to hold particles dispersed in the gas. This reduces the amount of contamination produced.

19.3.1.3 Dismantling and Decontamination of Equipment

Following is a list of features implemented to facilitate the dismantling and decontamination of equipment. These characteristics simplify the operations, thus having a major effect on the radiological protection and industrial safety aspects of decommissioning.

19.3.1.3.1 Plant Layout and Access

The Reactor Facility design takes into consideration the future zoning of areas during decommissioning to prevent the spread of contamination. It also considers that during decommissioning tasks, operational areas may have higher radiological protection requirements than were in existence during initial reactor operation.

The design takes into account the need for easily readapting areas to be used by decommissioning personnel, the number of whom may change with respect to standard operation with different working conditions. The exit route for the decommissioned material and generated waste was considered.

The layout of pumping units and piping allows simple access for manual external decontamination and manual dismantling operations. The anchoring of the units and pipeline supports minimises the existence of concrete blocks and other embedded elements, so as to facilitate the superficial decontamination of floors, walls and ceilings.

Pumping units, piping, components and structures that may have external superficial contamination are arranged in such a way as to facilitate decontamination.

Inaccessible areas and gaps in welded structures are minimised.

Adequate space is reserved for component and system dismantling operations (piping, instrumentation, unit disassembly) and eventual cutting operations.

The Reactor Hall has the necessary features to allow decontamination, dismantling and waste management operations.

The Primary Cooling System (PCS) and other pool water systems were constructed in rooms at basement level. The space for the systems is ample. The decontamination, disassembly, cutting, classification and dispatch of waste from the decommissioning of these systems can be carried out in these areas.

19.3.1.3.2 Dismantling Considerations

Space and accessories for the installation of removable biological shields to work in areas with a high radiation field are provided (purification system resins).

To the maximum extent possible, the Reactor and Service Pools internals are bolted and easy to dismantle, thus minimising the need for the use of special cutting tools (mechanical and torch cutting) for their removal.

The design of the Service Pool considers its use for decommissioning operations. The Service Pool has sufficient capacity to provisionally contain dismantled elements from reactor internal components, since that use is part of standard operation (i.e. disassembly of the core, structural core elements and Reflector Vessel). The possibility of installing cutting systems additional to those used for operation of the reactor was also considered.

Shielding for in-pile neutron beam components can be used for dismantling processes during normal reactor operation in the event of component repair or replacement. These procedures can also be applied to decommissioning tasks.

In general, piping containing radioactive liquids is designed and constructed so that it may be completely drained. The existence of non-drainable cavities or pockets in the piping design has been minimised.

19.3.1.3.3 Decontamination Considerations

Connections are provided wherever appropriate to facilitate the decontamination of the interior of equipment and lines, e.g. using a mobile chemical solution circulation system.

Exposed concrete surfaces are lined and/or finished in a way that facilitates decontamination.

The design of the reactor decontamination workshop facilities took into consideration its use in decommissioning operations. Moreover, during decommissioning it is possible to install additional equipment in areas closer to higher activity areas when appropriate. This is the case of the process rooms, where a large part of the dismantling of piping and units can be carried out.

19.3.1.3.4 Handling Provisions

The building crane at the Reactor Hall and the building crane at the Reactor Beam Hall, as well as other hoists and lifts included in the Reactor Facility, facilitate handling operations during decommissioning.

The design of areas where decommissioning operations are to be carried are serviced with fixed or portable cranes, fixed or portable rails and floor openings with removable lids to facilitate the transit of units.

The floor load capacity takes into account the possibility of the transit of components in heavy packages and radioactive material transport casks.

19.3.2 Waste Management

It will be possible to assign appropriate areas for the management of the waste produced during decommissioning.

These areas may be used for waste handling, classification, temporary storage and dispatch, as well as to store necessary consumables (decontamination reagents, containers, cleaning elements).

19.3.3 Measures to Facilitate Auxiliary Operations During Decommissioning

Several characteristics of the Reactor Facility layout facilitate key auxiliary operations carried out during the decommissioning, for example:

a) Space is available to place a classification system for decommissioning tools.

b) Space is available to place a decontamination laboratory for decommissioning tools.

19.3.4 Aspects of Facility Operation to Facilitate Decommissioning

During operation of the Reactor Facility, operating practices and waste management procedures are implemented in order to minimise the production of waste of any kind consistent with operational requirements.

In order to ensure the production of an adequate final decommissioning plan, relevant information is expected to be gathered during operation of the Reactor Facility. The information is intended to facilitate the planning and evaluation of the final decommissioning strategy.

Up-to-date documentation on the Reactor Facility is kept and experience from the handling of contaminated or irradiated structures, systems and components during maintenance or modification of the Reactor Facility is recorded to facilitate planning of decommissioning.

Information about the site, environmental data, design specifications, details of equipment and materials, “as built” drawings, operating and maintenance manuals, and quality assurance documents are to be used as input to the Decommissioning Plan.

Information relating to the operation of the Reactor Facility and its experimental devices includes records of:

a) Details of the operating history of the Reactor Facility, including records of fuel dispositions and changes.

b) Radiation survey data.

c) Incidents leading to the spillage or inadvertent release of radioactive materials, which could leave residual radioactive contamination in some system or areas of the reactor.

d) Details of modifications to the Reactor Facility (which are fully described in relation to "as built" drawings and photographs).

e) Reactor systems and equipment operation, maintenance, periodic testing and inspection.

f) Details of the design, composition and location of all experimental devices used during the operational lifetime of the Reactor Facility.

g) Location and movement of radioactive sources.

h) Amount and movement of fissile, fertile and other special materials.

i) Radiation exposure.

j) Effluent discharges.

k) Radioactive waste storage.

In addition, information on the following systems is available for planning purposes:

Reactor Control and Monitoring System (RCMS)

Irradiation facility control system

Cold Neutron Source Control and Monitoring System(CNS CMS)

Neutron beam facility control

Radiation monitoring and environment monitoring

Maintenance system, condition monitoring, spares and supplier's data

Quality Management System

Building physical safety system

Fire protection system

Access control

Training system

Building environment control

A periodic evaluation of this information ensures measures to correct and enhance conditions facilitating decommissioning can be taken.

At the end of the Reactor Facility operational life, the above information contributes to a complete status of the Reactor Facility and will enable an adequate characterisation of materials for the Decommissioning Plan.

End of Section

19.4 HAZARDS

This section considers the radiation sources, chemical compounds and physical conditions present in the Reactor Facility during decommissioning that have the potential to cause harm to people, property or the environment.

19.4.1 Radioactive Material or Radiation Fields

Radiological hazards are included within this category. Total activity produced during operation and present at decommissioning is due to:

a) Activation of structural materials directly exposed to neutron radiation; primarily the Reflector Vessel, neutron guides and components near the core.

b) Activation of operating media (cooling and reflector water) and corrosion products as a result of neutron radiation.

c) Contamination by release of fission products and fissile materials.

d) Contamination by concentration of fission products and activation and corrosion products in the pools or cooling systems.

e) Equipment, systems and piping containing activation sources.

f) Solid and liquid waste and waste management facilities.

g) Gaseous radioactive materials from the pool, coolant systems, cover gas systems, reflector systems and experimental facilities connected to ventilation systems, or any leakage from these systems.

h) Potential airborne radioactive material in areas normally occupied by personnel.

i) Experimental facilities with potential to generate activated or other radioactive material, or facilities for storage and handling of such material, including sample activation/irradiation facilities, in-core experiments and hot cells.

j) Neutron start-up sources.

Radionuclides considered in estimating Reactor Facility inventory are shown in Table 19.4/1. Of these, cobalt-60 and nickel-63 are seen as dominating. The activity of the dominant contributors to the total radioactive inventory and radiation hazards as a function of the decay time is shown in Figure 19.4/1.

19.4.2 Hazardous Substances

Within this category are all substances that, by ingestion, inhalation or assimilation, may cause disease or injuries.

The Reactor Facility presents a low risk from these types of substances due to the small quantities used in the facility. Chemical compounds used in decontamination are examples of hazardous substances.

19.4.3 Physical Hazards

Physical hazards are the routine hazards present in the workplace, such as hazards related to electrical installations, mechanical dismantling, hoisting and movement of equipment, structural material cutting, use of decontamination tools, etc. Application of ANSTO industrial safety guidelines minimise the risks from these hazards.

End of Section

Table 19.4/1 Radionuclides Included for Activity Estimation after 〈 40 years of normal operation at full power

Nuclide	Half-life	Decay Mode/Major radiation	Target
^{24}Na	15 h	β^- / γ	Aluminium
^{27}Mg	9.5 m	β^- / γ	Aluminium
^{28}Al	2.2 m	β^- / γ	Aluminium
^{45}Ca	163 d	β^- / β^-	Concrete
^{51}Cr	27.7 d	Є / γ	SS 304, Aluminium
^{54}Mn	312 d	Є / γ	SS 304
^{55}Fe	2.7 y	Є /	SS 304, Concrete
^{56}Mn	2.6 h	.β^- / γ	SS 304, Aluminium
^{59}Fe	44.5 d	.β^- / γ	SS 304, Concrete
^{59}Ni	76 y	Є / λ	SS 304
^{60}Co	5.3 y	$\beta^- / \beta^-, \gamma$	SS 304, Zircaloy 4, Concrete, Steel
^{63}Ni	100 y	β^- / β^-	SS 304, Zircaloy 4
^{65}Zn	244 d	Є, β^+ / γ	Aluminium
^{93m}Nb	13.1 y	/ γ	Zircaloy 4
^{93}Zr	$1.5\ 10^6$ y	β^- / β^-	Zircaloy 4
^{95}Nb	35 d	β^- / γ	Zircaloy 4
^{95}Zr	64 d	β^- / γ	Zircaloy 4
^{97}Nb	72 min	β^- / γ	Zircaloy 4
^{97}Zr	16.8 h	β^- / γ	Zircaloy 4
^{108m}Ag	418 y	Є / γ	Ag-In-Cd alloy
^{109}Cd	463 d	Є / β^+	Ag-In-Cd alloy
^{110m}Ag	250 d	β^- / γ	Ag-In-Cd alloy
^{125m}Te	57.4 d	/ γ	Zircaloy 4
^{125}Sb	2.77 a	β^- / γ	Zircaloy 4
^{152}Eu	13.3 y	Є, β^+, β^- / γ	SS 304, Concrete, Steel
^{154}Eu	8.8 y	β^- / γ	SS 304, Concrete, Steel
^{205}Pb	$1.5\ 10^7$ y	Є / β^+	Lead

Є= Electron Capture

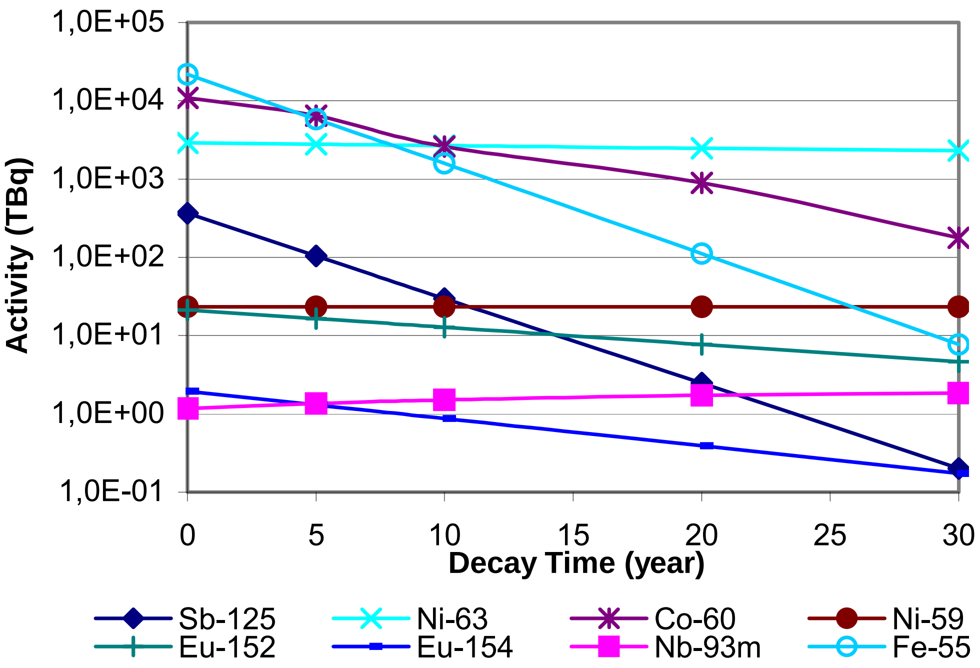
β+= Positron

β-= Beta Particle

γ = Gamma-ray

End of Tables

Figure 19.4/1 Activity of the Dominant Contributors to the Total Radioactive Inventory.



End of Figures

19.5 DECOMMISSIONING WASTE TYPES AND MANAGEMENT

The Reactor Facility was designed to minimise the generation of radioactive waste during decommissioning.

Three types of solid waste can be expected:

a) Intermediate Level Waste (ILW).

b) Low Level Waste (LLW).

c) Exempt Waste (EW). Waste which, after decay or decontamination, can be managed as non-radioactive waste.

Liquid waste will be generated.

No high level waste will be generated by the operation of the Reactor Facility.

The two main sources of waste are the Reactor Block, structures and equipment inside the Reactor Pool, Service Pool and Hot Cells, and the process rooms at the Reactor hall level.

19.5.1 Activated Materials

19.5.1.1 Reactor Internal Components

The major activity and inventory will be concentrated in the reactor internal components, primarily in the Reflector Vessel, Core Grid and Control Rods. The estimated amount of material is given in the table below as a function of decay time;

Waste Class	Mass (10^3 kg) vs. Decay Time (years)				
	0	5	10	20	30
Exempt waste (EW)	19.3	19.3	19.4	19.5	19.6
Low level waste (LLW)	33.8	33.8	33.7	33.6	37.4
Intermediate level waste (ILW)	26.2	26.2	26.2	26.2	22.4

The ILW is to be dismantled, reduced in volume, classified and packed in casks which are then removed from the Reactor Facility. LLW is expected to be dismantled and managed as LLW after decay (mainly aluminium waste). Other wastes will be managed as exempt waste.

19.5.1.2 Reactor and Service Pools

Very little activated material is expected from the Reactor and Service Pools. Only the pool bottom and areas adjacent to the core in the Reactor Pool will need to be managed as LLW. After decontamination the remainder will be managed as EW.

19.5.1.3 Neutron Beam Structures

Neutron beam shutters are expected to require dismantling and segregation according to waste type. Casks used for shutter removals may have to be decontaminated prior to disposal. The design has provisions for easy dismantling of the more activated components.

Neutron guides produce LLW and EW. Because the neutron guides are designed for replacement during the life of the reactor, an established procedure is expected to be available for the decommissioning task.

19.5.1.4 Concrete Biological Shielding

Little activation is produced in small areas near to the core. A small volume of LLW is expected from this source with the remainder being EW.

The estimated total amount of waste material arising from the Reactor and Service Pools, Neutron Beam structures and concrete biological shielding is shown in the table below;

Waste Class	Mass (10^3 kg) vs. Decay Time (years)				
	0	5	10	20	30
EW	19.3	32.6	32.7	41.6	41.7
LLW	80.8	67.5	67.4	58.5	62.3
ILW	44.2	44.2	44.2	44.2	40.4

19.5.1.5 Isotope Handling Installations

The generation of active waste will be due to surface contamination. LLW and EW may be generated as a result of the segregation and decontamination process.

19.5.1.6 Piping, Tanks and Metal Structures

After decontamination, most of the waste from this source is expected to be EW.

19.5.2 Tritium

Tritium is produced as a result of activation of deuterium that is present in heavy water in the Reflector Tank. Tritiated heavy water is LLW and is stored in sealed containers. There are expected to be approximately 9 tons from the last 10-year working period. High levels of surface contamination on components and pipes are not expected. Decontamination of heavy water is to be carried out throughout the operational lifetime and is not subject to any special procedures for decommissioning.

Small amounts of tritium is also generated by the operation of the Cold Neutron Source. It will be managed with the tritiated heavy water.

19.5.3 Light Water

This represents the light water inventory in the reactor pool, service pool, decay tanks and other systems once the reactor is shutdown. This inventory is discharged to the ANSTO Waste Management System through line B or C, as appropriate, in accordance with its activity and the limits specified for each line.

19.5.4 Other

Any small part of the waste coming from other areas or systems that may be contaminated is managed to minimise radioactive waste.

19.5.5 Liquids Used in Decontamination

Liquids used are expected to be LLW and are to be treated and conditioned.

End of Section

19.6 DECOMMISSIONING STRATEGIES

19.6.1 Options

There are a number of technical options for decommissioning of a nuclear facility. The option to be applied depends on the outcomes of a thorough optimisation of safety engineering, approval process, available technology, ease of transport, and safe and adequate storage.

Three options for decommissioning are foreseen:

a) DECON is the decommissioning method in which the equipment, structures, and portions of the facility and site containing radioactive contaminants are removed or decontaminated to a level that allows the property to be released for unrestricted use shortly after the cessation of operations. This option requires greater precautions against radiological exposure of workers, and results in more ILW and a greater need to control potential environmental impacts.

b) SAFSTOR is the decommissioning method in which the nuclear facility is placed and maintained in a condition that allows the safe storage of radioactive components of the nuclear plant and subsequent decontamination to levels that permit release for unrestricted use. SAFSTOR provides a means of protecting the public while minimising the initial commitments of time, money, radiation exposure, and waste disposal capacity.

c) ENTOMB is the alternative in which radioactive contaminants are encased in a long-lasting material, such as concrete. The entombed structure is maintained and surveillance is performed until the radioactive material decays to a level permitting release of the property for unrestricted use. This alternative is not considered for the Reactor Facility.

Whichever option is selected, decommissioning involves a staged process in accordance with relevant licence conditions. ARPANSA define the separate stages of decommissioning as follows:

Stage 1, when the decision to permanently shut down is decided, and where relevant (for nuclear installations) the fuel is removed, the fluids are drained from the facility and external materials can be disconnected and removed, for example, the control room and cooling towers.

Stage 2, the care and maintenance stage, where a state of monitoring and maintenance is maintained until the documentation and arrangements are in place for the third stage.

Stage 3, the decommissioning, covers the entire decommissioning process including the removal of all radioactive and other wastes.

Stage 4 is the final stage called the unrestricted site use, and refers to when the site is permitted to return to a greenfield site or used for other purposes without restrictions being imposed.

19.6.2 Choice of Option

The choice of one of the options is derived from the evaluation of the following aspects:

a) radiological safety;

b) industrial safety;

c) waste management;

d) environmental impact;

e) costs;

f) risk assessment;

g) demand for re-use of the site;

h) regulatory requirements;

i) decommissioning standards and guidelines;

j) availability of technology and equipment; and

k) availability of staff.

A comparative analysis of the options on the basis of the above aspects leads to the identification of DECON as the preferred option. The final decision is expected at the end of the Reactor Facility's useful life.

19.6.3 Decommissioning Plans

A Preliminary Decommissioning Plan was prepared using ARPANSA and IAEA guidelines. Given the preliminary nature of the plan, it was made flexible so as not to pre-empt future technological development in decommissioning techniques.

A final Decommissioning Plan can be prepared when the decision is made to permanently shutdown the Reactor Facility.

19.6.3.1 Contents

The Decommissioning Plans include the following items:

a) Analysis of decommissioning options and strategies.

b) Organisation required for decommissioning.

c) Analysis of regulatory requirements.

d) Calculation of the Reactor Facility radioactive inventory at the end of its operating period.

e) Waste management analysis, with waste estimation.

f) Basis for the radiological protection program.

g) Waste management plan.

h) Analysis of existing facilities at LHSTC.

i) Analysis of Australian provisions for waste disposal and identification of disposal routes.

j) Cost estimation.

k) Environmental impact.

l) Decommissioning safety case.

m) In the Preliminary Decommissioning Plan – a system for recording the operational history of the Reactor Facility as it affects decommissioning.

n) Associated with the final Decommissioning Plan – a complete record of the operational history of the Reactor Facility as it affects decommissioning.

19.6.3.2 Radiation Protection Program

Prior to the commencement of decommissioning, a radiation protection program is to be prepared. This program is to detail the administrative measures required in order to guarantee that all the activities that may expose people to radiation are planned, supervised and executed to attain the following goals:

a) To avoid any unnecessary exposure to the radiation

b) To ensure that exposure to the personnel and the public will remain below prescribed limits

c) To ensure that any exposures will be ALARA, social and economic considerations being taken into account.

The radiation protection program for decommissioning is to include appropriate procedures for:

a) Personnel control.

b) Application of the optimisation principles and estimates of doses during specific tasks.

c) Appropriate monitoring on and off site.

d) Decontamination of personnel, equipment and structures.

e) Appropriate radiation monitoring of components and materials during their disassembly, packing, transportation and storage.

f) Environmental radiological surveillance.

g) Detecting and recording releases of radioactive material.

h) Recording the inventory of radiation sources.

i) Providing adequate training in radiation protection practices.

j) Optimisation principle.

The optimisation principle is to be applied during the planning of the decommissioning tasks consistent with internationally accepted practices (currently ICRP 60). In accordance with this principle, tasks expected to result in unavoidable exposure are analysed in order to determine the optimum solution while complying with applicable dose limits and other commitments.

For example, the following features might be considered:

a) Need for additional shielding and thickness of such shielding.

b) Need for and characteristics of remotely operated tools for: inspection, disassembly and transport of activated equipment.

c) Type and extent of decontamination methods.

d) Need for supplementary ventilation systems.

End of Section

19.7 ACTIVITIES DURING DECOMMISSIONING

A preliminary list of required activities during the decommissioning stages was developed:

a) Control of access to the Reactor Facility.

b) Regular surveillance of the radiological and physical state of the Reactor Facility.

c) Regular radiation monitoring of the environment.

d) Characterisation of the facilities prior to dismantling activities.

e) Removal from service of ancillary non-essential systems.

f) Defuelling of the reactor and removal of the spent nuclear fuel.

g) Ensuring that systems containing radioactive material are in a stable condition and sealed.

h) Removal of potentially mobile radioactivity and hazardous material from the Reactor Facility after shutdown.

i) Drainage and storage of the heavy water inventory in drums.

j) Dismantling of the reactor internal components and reduction of the volume under water.

k) Dismantling of neutron beam guides.

l) Dismantling and decontamination of piping, structures and related components.

m) Decontamination of areas.

n) Water drainage and decontamination of the Reactor and Service Pools.

o) Dismantling of the Reactor and Service Pools.

p) Dismantling of the concrete biological shielding layers that may be activated in contact with the Reactor Pool Tank.

q) Management of radioactive waste generated during the above-described activities, with release for unrestricted use of materials and equipment in which the radioactivity is below authorised limits.

r) Final survey and characterisation of the facilities for release.

End of Section