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Replacement Research Reactor Facility

SAR CHAPTER 1
INTRODUCTION AND GENERAL DESCRIPTION OF THE FACILITY

Prepared By

INVAP

For

Australian Nuclear Science and Technology Organisation

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1 INTRODUCTION AND GENERAL DESCRIPTION OF THE FACILITY

1.1 INTRODUCTION

The design, construction, commissioning and operation of the Replacement Research Reactor Facility (hereafter referred to as the Reactor Facility) at the Lucas Heights Science and Technology Centre (LHSTC) comprises a number of stages, with associated approvals. The Facility Licence Site Authorisation issued by Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) in September 1999 permitted the Australian Nuclear Science and Technology Organisation (ANSTO) to prepare the Site for the Reactor Facility. Part of this preparation was the completion of the design of the Reactor Facility. The Facility Licence issued by ARPANSA in April 2002 authorised ANSTO to construct the Controlled Facility subject to certain conditions.

This document is the Safety Analysis Report (SAR) for the Reactor facility. The SAR summarises the safety arguments necessary to permit operation and demonstrates the adequacy of systems, emphasising those that are important to safety.

The objectives of this chapter are:

1. To provide an introduction and general description of the facility and the project.
2. To identify the basic safety principles and safety features incorporated into the design and operation of the facility.

The SAR describes the reactor site, the reactor itself, the experimental facilities and all other facilities with significance for nuclear safety. It provides a detailed description of the general safety principles and criteria applied to the design of the reactor in order to protect the facility, the personnel, the general public and the environment. It analyses the potential hazards associated with the operation of the reactor. It contains safety analysis of accident sequences and of the safety features incorporated in the design to avoid or to minimise the likelihood of accidents and to mitigate their consequences. The SAR also identifies the criteria for the Operational Limits and Conditions required for safe operation of the Reactor Facility and identifies the methodology by which the limits and conditions have been derived.

The SAR presents sufficient information to demonstrate that the facility personnel, the public, and the environment will not be adversely affected by the operation of the Reactor Facility.

ANSTO contracted INVAP S.E. to design and construct the Reactor Facility at the LHSTC.

1.1.1 Purpose of the Safety Analysis Report

The Revision 0 of the PSAR was submitted to ARPANSA by ANSTO in support of the Application for a Facility Licence, Construction Authorisation for the Reactor Facility at the LHSTC in accordance with Schedule 3, Part 1 of the Australian Radiation Protection and Nuclear Safety Regulations 1999. Revision 1 of the PSAR was submitted to ARPANSA in compliance with Licence Conditions 4.8, Facility Licence FO0118 Construction Authorisation for the Reactor Facility.

This Revision of the SAR is presented to ARPANSA in support of the application for a Facility Licence, Operation Authorisation for the Reactor Facility. The modifications introduced in the SAR with respect to the PSAR include:

a) Updates to reflect the latest available information regarding the detailed engineering and the safety case;

b) Results of additional analysis performed during the detailed engineering stage;

c) Compliance with relevant recommendations in the Regulatory Assessment Report RB-ASR-0902 prepared by ARPANSA Regulatory Branch;

d) Compliance with relevant Construction Authorisation Licence Conditions;

e) Incorporations of recommendations following the IAEA peer review;

f) Incorporation of recommendations in the ARPANSA reactive review comments; and

g) Inclusion of omissions and correction of errors as identified by ANSTO/INVAP internal review.

The SAR demonstrates the safety of the Reactor Facility design. It also serves the following purposes:

a) To aid the designers in confirming that individual systems are integrated correctly, since the reactor design and construction and the development of the SAR are complementary, interactive processes.

b) To ensure that the safety analysis has properly identified the safety issues relevant to the design and that the safety analysis and design are consistent.

c) To aid in the appreciation of the relevant design criteria, their limitations and requirements and in the evaluation of the hazards posed by the facility.

d) To aid the operators in training and familiarisation with the facility.

1.1.2 Format and Content of the Safety Analysis Report

This SAR has been prepared in accordance with the guidelines of the International Atomic Energy Agency (IAEA) Safety Guide SS 35-G1 “Safety Assessment of Research Reactors and Preparation of the Safety Analysis Report” 1994.

This SAR demonstrates that the Reactor Facility design complies with the requirements of the ARPANSA Regulatory Assessment Principles for Controlled Facilities, Rev 1, October 2001.

The SAR is organised as follows:

Chapter 1: Introduction and General Description of the Facility

This chapter presents the general organisation of the SAR, including purposes, organisation, and scope. It includes a general description of the facility that constitutes a self-contained introduction to the other chapters. It summarises the principal considerations and the detailed information found in subsequent chapters of the SAR.

Chapter 2: Safety Objectives and Engineering Design Requirements

This chapter provides information on safety objectives and criteria, design requirements, reference standards, technical design methods, and the qualification of components.

Chapter 3: Site Characteristics

This chapter describes the site characteristics applicable to the safety assessment of the design construction and operation of the Reactor Facility, including geography, demography, meteorology, hydrology, geology, seismology, and interaction with nearby installations and facilities. It demonstrates the compliance with the site relevant conditions of the Facility Licence, Site Authorisation No. F001 issued by ARPANSA, 22

September 1999, including updating of information as appropriate.

Chapter 4: Buildings and Structures

This chapter provides a summary description of the buildings and structures that comprise the Reactor Facility. It identifies the general building and layout features that contribute to nuclear and personnel safety and demonstrates that the Reactor Facility meets identified safety requirements.

Chapter 5: Reactor

This chapter presents a summary of the functional, technical and operational characteristics of the reactor core structures, shutdown systems, together with a summary description of operational states. A description of the safety functions of the main reactor components and design basis information and functional characteristics of the reactor core and its components are provided.

Chapter: 6 Reactor Coolant System and Connected Systems

This chapter presents all fluid cooling systems associated with removal of heat generated in the operation of the reactor and the irradiation facilities. It describes the design bases, and the functional, technical and operational characteristics of these cooling systems and their supporting systems for temperature control, coolant make-up and purification.

Chapter 7: Engineered Safety Features

This chapter identifies the Engineered Safety Features that control or mitigate consequences of postulated accidents at the Reactor Facility. The description and evaluation of each of these Engineered Safety Features is included in the chapter of the SAR related to the function the relevant system performs, as identified below:

Reactor Pool Coolant Boundary: Chapter 4
First Shutdown System : Chapter 5
Second Shutdown System : Chapter 5
Core Cooling by Natural Circulation: Chapter 6
Rig Cooling by Natural Circulation: Chapter 6
Containment: Chapter 7
Reactor Protection Systems : Chapter 8
Post Accident Monitoring System: Chapter 8
Standby Power System: Chapter 9
Emergency Control Centre Ventilation and Pressurisation System: Chapter 10

The functional requirements to demonstrate that an Engineered Safety Feature can maintain the plant within safety limits are addressed in the identified Chapter. In this respect the only system addressed in detail in Chapter 7 is the Containment.

Chapter 8: Instrumentation and Control

This chapter presents specific design and performance information for the instrumentation and control systems, emphasising those systems related to safety. The chapter addresses the Reactor Protection Systems, the Post Accident Monitoring System, the Reactor Control and Monitoring Systems, and instrumentation for Safety Category 1 and 2 systems.

Chapter 9: Electric Power

This chapter describes systems that supply electric power to the facility, in both operational states and accident conditions.

Chapter 10: Auxiliary Systems

This chapter presents a summary description of the design and operation of auxiliary systems and in particular nuclear fuel storage and management. It identifies specific safety requirements and features and demonstrates that the systems meet these safety requirements.

Chapter 11: Reactor Utilisation

This chapter presents a summary description of irradiation facilities and neutron beam facilities. The safety characteristics of these facilities are addressed including an evaluation of each facility. These evaluations provide information that supports the conclusion in Chapter 16 that the utilisation activities do not represent a risk to the facility, the staff or to the general public.

Chapter 12: Operational Radiological Safety

This chapter provides information demonstrating that the radiation protection policies, strategies and actions ensure a radiologically safe working environment in the facility and its immediate environs. It also provides information on waste management systems to demonstrate the safety of personnel and the general public, and presents estimated doses for facility personnel and the public during the normal operations of the Reactor Facility.

Chapter 13: Conduct of Operations

This chapter addresses the structure and responsibilities for the conduct of operations of the Reactor Facility including: staffing; qualification and training; the review and audit of operation; operating procedures; maintenance, testing and inspection; security; as well as records and reports.

Chapter 14: Environmental Assessment

This chapter details the environmental management arrangements in place for the operation of the Reactor Facility.

Chapter 15: Commissioning

This chapter provides a summary description of the overall Reactor Facility commissioning process.

Chapter 16: Safety Analysis

This chapter demonstrates that the plant design and operation are able to successfully manage all the postulated initiating events that lead to fault sequences. It describes the design basis initiating events, accident scenarios and analyses of accidents and presents the design basis accidents. For each design basis accident the function of the Engineered Safety Features involved are discussed. The chapter analyses human factors and specific beyond-design-basis events.

Chapter 17: Operational Limits and Conditions

This chapter identifies the criteria for the Operational Limits and Conditions (OLCs), the applicable safety requirements and identifies the methodology by which the OLCs have been derived during the detailed engineering phase.

Chapter 18: Quality Assurance

This chapter describes the Quality Assurance arrangements being adopted for the operation of the Reactor Facility.

Chapter 19: Decommissioning

This chapter describes the features of the Reactor Facility design that facilitate the eventual decommissioning of the facility.

Chapter 20: Emergency Planning and Preparedness

This chapter identifies safety requirements applicable to the emergency planning for the Reactor Facility, provides a summary description of the emergency planning for operation, and demonstrates that the plans meet the identified requirements.

1.1.3 Purpose and Size of the Facility

The Reactor Facility replaces the High Flux Australian Reactor (HIFAR), which is planned to be closed down around the year 2006. The Reactor Facility has been designed and constructed to meet Australia's current and future needs for a neutron source in a manner that meets all health, environmental and safety standards. Specifically, the Reactor Facility is intended for the following purposes:

a) To maintain Australia's technical expertise in nuclear science and technology in order to provide sound advice to Government in support of nuclear policy issues of strategic national interest and to honour international obligations in this area.

b) To maintain and enhance health-care benefits provided to the Australian community. This is done by ensuring security of supply, through local production, of the quantities and the known likely range of diagnostic and therapeutic radio-pharmaceuticals needed to satisfy the requirements of Australia's medical professionals over the next 40 to 50 years.

c) To provide a neutron beam research facility which not only meets Australia's own scientific needs, but is also a regional centre of scientific excellence. Research undertaken using this facility will have broad application to investigations in a wide spectrum of scientific and industrial fields, including the life sciences and medicine, environmental science, chemistry, materials science, nanoscience and engineering science.

d) To provide research training facilities and programs to enhance the educational opportunities available to Australia's students, particularly in science and engineering.

e) To provide industrial radioisotopes and facilities for neutron activation analysis, irradiation of materials and neutron radiography to service the needs of agriculture and industry, particularly with regard to electronics, the environment and resource and minerals processing.

The reactor is a pool type design with a rated thermal power from the core of 20 MW. It includes operational and safety characteristics consistent with international best practice. The reactor core located near the bottom of the pool is cooled by demineralised water. A deuterium oxide (heavy water) reflector is contained in a cylindrical vessel surrounding the core. Table 1.2/1 presents the main reactor and core parameters of the Reactor Facility while Table 1.4/1 is a comparison of the Reactor Facility parameters with those of other research reactors.

The facility consists of a group of buildings that provide the space to locate systems and carry out activities needed to meet the safety, operational and utilisation objectives.

The Reactor Building houses all the nuclear systems and is provided with a containment which is the final barrier preventing the uncontrolled release of radioactive material to the environment in case of accidents.

The deployment of the buildings in the allocated area of the LHSTC, took account of functional integration of the activities and services within the facility, integration with LHSTC site services and radioisotope production facilities, security and fire protection needs, health physics zoning, and access for staff, scientists and visitors.

The overall layout of the buildings optimises the utilisation of the neutron sources and neutron beams with an allowance for the possible future construction of a second Neutron Guide Hall.

Figure 1.1/1 shows a map of the area, Figure 1.1/2 is the LHSTC site plan, Figure 1.1/3 presents the building layout and Figure 1.1/4 is a photograph of the model of the preliminary design of the facility.

1.1.4 Safety Analysis Report Findings

1.1.4.1 Effects of Replacement Research Reactor Operation on the Public

The Reactor Facility has been designed to ensure that radiation doses to the public due to the combination of exposures from the facility and all other ANSTO activities shall not exceed the specified annual dose limits recommended by the National Health and Medical Research Council (NHMRC) and incorporated in the ARPANS Regulations 1999 and the National Occupational Health and Safety Commission Standard.

All the anticipated accidental situations for the Reactor Facility arising from postulated initiating events are thoroughly analysed in Chapter 16. The analysis is focused on the effects of postulated accident situations on the public, emphasising the attention to how these situations are managed and controlled. The expected consequences of postulated accidents have been considered with emphasis being placed on those accidents that have the potential to result in a loss of integrity of fuel element or irradiation target cladding. Conservative analyses of the most serious credible, but hypothetical, accidents have been performed and they demonstrate that the Reactor Facility design ensures that radiation doses to the public would be well below acceptable limits, as specified in the Regulatory Assessment principles (ARPANSA, 2000).

No emergency counter-measures outside the facility, such as sheltering or evacuation, are required in the event of nuclear accidents. In all cases, releases are well below the established limits (ARPANSA, 2000).

A Probabilistic Safety Analysis has been performed, which analyses a comprehensive list of postulated initiating events and demonstrates that from a radiological view point, the risk posed by a release of radioactive material from the fuel or the irradiation targets is very low and well below the ARPANSA requirements.

1.1.4.2 Effects of Replacement Research Reactor Operation on the Facility Personnel

All the foreseen situations in normal operation and anticipated accident situations have been extensively analysed to evaluate their impact on the facility personnel. Chapter 12 presents a description of estimated doses to the personnel during normal operation. The analysis shows that doses to the personnel are well below the prescribed limits and comply with ALARA criteria.

Chapter 16 presents the entire set of anticipated transients and design basis accidents that arise from postulated initiating events that could lead to a release of radioactive material from the fuel or the irradiation facilities. The safety systems and emergency arrangements are sufficient to safely manage post-accident conditions and ensure that doses to facility personnel are below the prescribed limits.

Figure 1.1/1 Map of the Lucas Heights Area

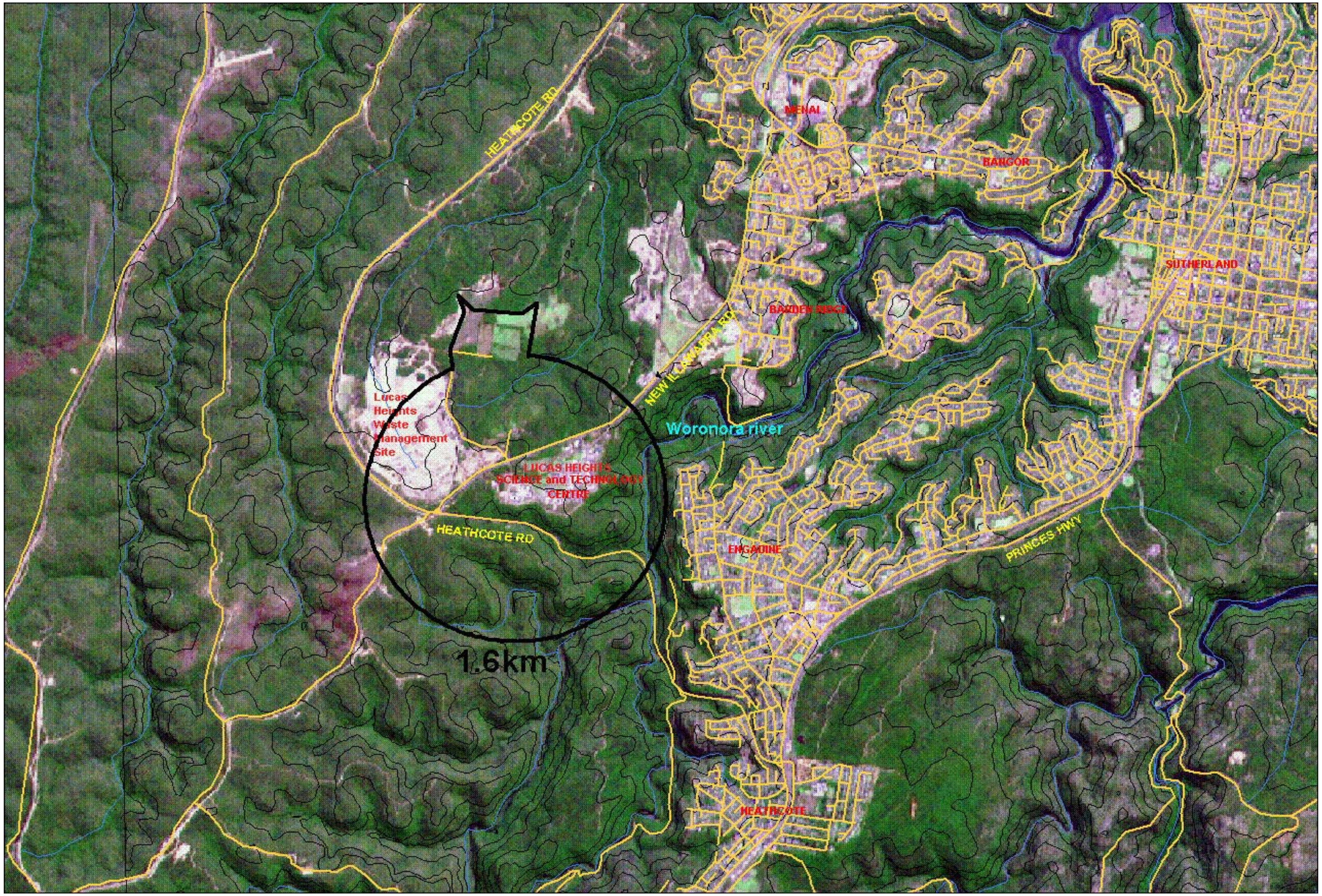

Figure 1.1/2 Lucas Heights Site Plan

Figure 1.1/3 Site Plan with Layout of Replacement Research Reactor Buildings

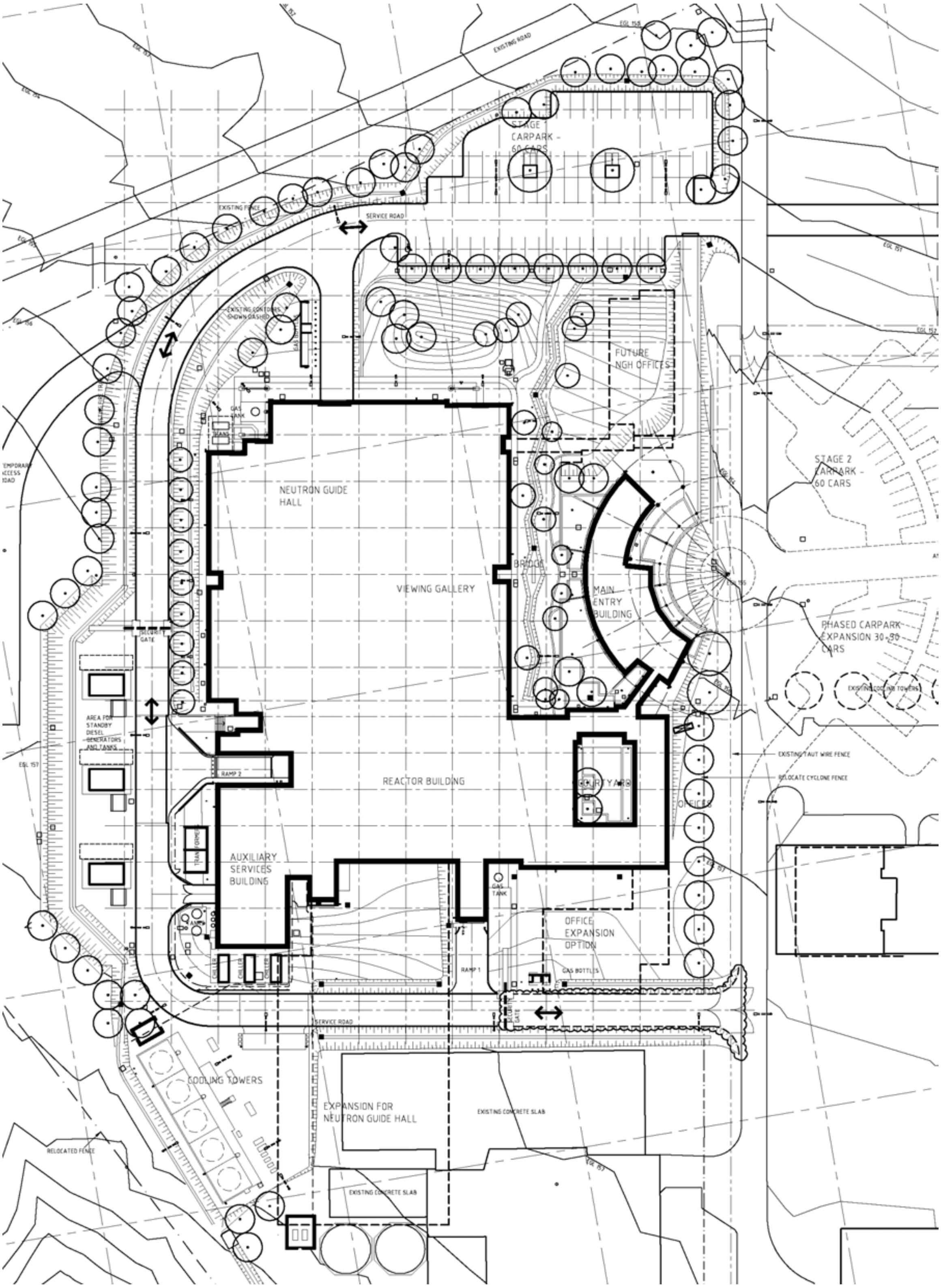

Figure 1.1/4 Photograph of the Facility Model

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1.2 GENERAL DESCRIPTION OF THE FACILITY

This section provides a general description of the Reactor Facility, including the main systems needed to operate the reactor and to maintain it in a safe condition for all anticipated operational occurrences. This description serves as an introduction to the facility; further information on each system is provided in the corresponding chapters of the SAR.

The Reactor Facility occupies an area of approximately 13,000 square meters, which includes the Reactor Building with the reactor and main reactor systems, the Neutron Guide Hall where the neutron guide systems and the research equipment are located, and associated auxiliary and office buildings.

1.2.1 Introductory Description of the Reactor

The reactor core thermal power is 20 MW and it is designed to achieve high performance in the production of neutrons and to underpin Australia's nuclear expertise with modern technology. The need for high neutron fluxes arises from the main uses of the neutrons; for the production of radioisotopes and other radiation services, and the conduct of neutron research. The reactor is of an open-pool design, which means the core is contained inside an open pool of demineralised water that provides both cooling and protection against radiation from the core.

The Reactor Facility design meets ANSTO's requirements, including compliance with demanding safety regulations. The fundamental safety objective in the design of the Reactor Facility is the protection of the public, the facility personnel and the environment from exposure to radiation due to the operation of the Reactor Facility. A "defence-in-depth" approach is applied throughout the facility, providing multiple levels of protection against the accidental release of radioactive materials. All systems and structures are designed with adequate safety margins to ensure they behave in a known manner under anticipated operational occurrences.

A notable feature of the reactor is its compact core, which maximises the flux of neutrons available for radioisotope production, irradiation services and research. Heavy water is used as the reflector to sustain the nuclear reaction. It is contained in the Reflector Vessel surrounding the core. This vessel also provides a large zone of high thermal neutron flux in which to locate irradiation facilities and supply neutron beams. The core consists of 16 Fuel Assemblies of square shape, each comprising 21 fuel elements. Each fuel element consists of a thin plate of uranium silicide fuel dispersed in aluminium and sandwiched between two thin aluminium plates. Fission heat is removed by water circulating through coolant channels between the fuel elements. Reactivity is controlled by five control rods, four of which have neutron-absorber plates inserted into the core in a cross-shaped array and the fifth has a central cruciform shaped absorber plate. The core is thus divided into four portions of four Fuel Assemblies each.

The core and the Reflector Vessel are positioned close to the bottom of the deep Reactor Pool. The Reactor Pool is connected to the Service Pool by means of a Transfer Canal. The Service Pool provides a working area and enough space to store the spent fuel generated over ten years of reactor operation.

The Primary Cooling System removes the heat from the core by forced upward circulation of water and transfers the heat to the Secondary Cooling System. A Core Chimney above the Reflector Vessel contains the core coolant before it enters the pump suction line of the Primary Cooling System piping, and provides an additional enclosure for water that protects the core in case of a loss of coolant accident.

The Reactor Pool inventory is cooled by the Reactor and Service Pool Cooling System, whose main function is cooling of irradiation rigs. This system also provides long-term pool cooling to the Reactor and Service Pools to extract decay heat.

Engineered Safety Features are provided which are capable of maintaining the reactor in a safe condition under all anticipated operational conditions. They constitute the third level of "defence-in-depth" and are designed to prevent incidents from developing into accidents. They comply with fail-safe and reliability safety criteria and are qualified to withstand the environmental conditions arising from all operational states and all accident conditions for which they are required to function.

Engineered Safety Features are:

- Reactor Protection Systems
- First Shutdown System
- Second Shutdown System
- Reactor Pool Coolant Boundary
- Core Cooling by Natural Circulation
- Rig Cooling by Natural Circulation
- Containment
- Post Accident Monitoring System
- Standby Power System
- Emergency Control Centre Ventilation and Pressurisation System

The function of the Reactor Protection Systems is to monitor all safety variables so that protective actions are triggered either when the trip set points are reached, or under operator initiation. The Reactor Protection Systems are designed to function in operational states as well as accident conditions.

The First Shutdown System inserts five control rods into the core when requested by the First Reactor Protection System. During normal operation the central control rod is used for reactivity regulation and the other four are used for coarse reactivity compensation, commanded by the Reactor Control and Monitoring System.

The Second Shutdown System provides an alternate means of fast reactor shutdown that is diverse and independent from the First Shutdown System. The Second Shutdown System partially empties the heavy water from the Reflector Vessel into a storage tank beneath the core on command from the Second Reactor Protection System.

The Reactor Pool Coolant Boundary ensures availability of the water inventory required for core cooling during all foreseeable conditions.

If all electric power is lost, the reactor core and the irradiation rigs are cooled by transfer of heat to the pool water by natural circulation. The pool has a sufficiently large water inventory to provide long-term cooling without reliance on external systems or sources of power.

The Containment encloses the Reactor and Service Pools, Reactor Hall, and areas below the Reactor Pool that house Reactor Pool water systems and Reflector Vessel heavy water systems. The Containment is designed to prevent or mitigate the uncontrolled release of radioactive materials to the environment.

The Containment consists of the containment boundary, the Containment Isolation Valves, the Containment Energy Removal System, the Containment Pressure Relief and Filtered Vent System and the Containment Vacuum Relief System.

In the event of an accident, the Post Accident Monitoring system provides information to the operators in the Main Control Room and the Emergency Control Centre. It monitors the condition of the reactor and the performance of the Engineered Safety Features. It also provides information on the status of the barriers to fission product release.

A Standby Power System ensures that safety systems are supplied with the required power to enable them to perform their safety functions in the event of loss of the normal electric supply.

The Emergency Control Centre Ventilation and Pressurisation System ensures the continued habitability of the emergency control centre in case the Main Control Room requires evacuation.

1.2.2 The Site

The Reactor Facility is built on land owned by ANSTO at the western end of the LHSTC. The LHSTC is located some 35 km south-west of the Sydney Central Business District on the dissected Woronora Plateau at an elevation of about 150 m (Australian Height Datum). The site is approximately 2 km west of the Woronora River and 8 km south of the Georges River and is surrounded by bushland extending for several kilometres with no nearby habitation in the north-west, west and south-west sectors.

The site for the reactor facility is within the existing perimeter fence, adjacent to HIFAR, and covers an area of approximately four hectares. Site location and general layout are shown in the previous section, Figures 1.1/2, 1.1/3 and 1.1/4. The layout of the Reactor Facility in Figure 1.1/2 shows the Reactor Building centred approximately 200 metres west-north-west of HIFAR. The distance from the Reactor Facility to the nearest residence (in the easterly direction) is approximately 1.8 km. ANSTO maintains the buffer zone of 1.6 km, centred on the existing HIFAR facility, within which land-use restrictions apply and all residential development is excluded.

A description of the location of the Reactor Facility, the site and the surrounding area is presented in Chapter 3.

1.2.3 Buildings and Structures

The facility is comprised of the following buildings, designed and constructed according to applicable codes and standards:

- Reactor Building
- Neutron Guide Building
- Offices and Visitor Centre Building
- Auxiliary Buildings
- Reactor Facility Substation
- Cooling Towers

All the nuclear systems are contained in the Reactor Building, built in reinforced concrete and covered by a metallic grillage for protection from light aircraft impact, thus providing two successive barriers of protection against this event. Where applicable, systems and components are enclosed in thick concrete structures designed to shield the facility personnel from radiation fields. The massive reactor block, built in high-density concrete, houses the reactor pool with the reactor core, service pools and decay tanks.

The Reactor Building not only protects the reactor from events occurring outside the facility but also provides the structural part of the Containment.

Buildings and structures fulfil their safety function under design basis conditions.

The loads considered include meteorologically extreme events, hydrological conditions, and the loads corresponding to the Operating Basis Earthquake and Safe Shutdown Earthquake, for which safety structures have been designed (see Chapter 2, Section 2.6). Detailed information on buildings and structures is provided in Chapter 4.

1.2.4 Reactor Core

The Core consists of a square arrangement of 16 Fuel Assemblies, each comprising 21 fuel elements. Each element contains a plate of low-enriched uranium silicide dispersed in aluminium sandwiched between two aluminium plates. The fuel elements are separated from each other by coolant channels, which allow circulation of cooling water to remove the heat generated in the core. The reactor core thermal power is 20 MW and the reactivity feedback coefficients are negative, which means that any power or temperature increase reduces core reactivity and rate of fission heat production. The neutron moderator and coolant is light water and the reflector is heavy water.

Table 1.2/1 presents the main reactor characteristics and core parameters.

1.2.5 Reflector Vessel

The Core is surrounded by a Reflector Vessel containing heavy water, which provides adequate neutron reflection and a large zone with high neutron flux.

The Reflector Vessel is cylindrical in shape with two flat ends. There is a square cross-sectioned pipe passing through the vessel along its axis. This pipe constitutes the Core Chimney and contains the core. The entire Reflector Vessel is water-tight in its structures, welds and flanges. The inner surface of the vessel is in contact with heavy water and the outer surface in contact with light de-mineralised water.

The Reflector Vessel is traversed in the axial direction by tubes of various diameters that house irradiation rigs and targets. The Reflector Vessel also contains a Cold Neutron Source, two cold neutron beam assemblies and two thermal neutron beam assemblies. An additional beam is available to serve a possible future hot neutron source. All beam tubes are tangential to the core.

The Second Shutdown System partially drains the heavy water of the Reflector Vessel into a storage tank. The decrease in level of heavy water in the Reflector Vessel increases neutron losses and drives the reactor to a sub-critical state that leads to reactor shutdown.

1.2.6 Reactor and Service Pools

A massive structure constructed in high-density concrete identified as the Reactor Block encloses the Reactor Pool, Service Pool, Decay Tanks and Control Rod Drive Room.

The Reactor Pool contains the Core and associated structures, Chimney, Reflector Vessel, irradiation rig structures, neutron beam assemblies, Cold Neutron Source, part of the Primary Cooling System and the primary water inventory. It also provides mechanical support to these structures and systems.

The main safety functions of the Reactor Pool are to contain the required water inventory to provide Core cooling during all operational states and design basis accidents and to provided shielding against radiation at the pool top.

The Service Pool provides shielding, cooling water, and working areas connected with the Reactor Pool by means of the Transfer Canal. The Service Pool contains storage space for the spent Fuel Assemblies produced in ten years of operation at full power plus the Fuel Assemblies for one complete core. It is also an area for handling irradiation rigs and allows communication with the Transfer Hot Cell by means of the Service Pool elevator. The service pool acts as a large heat sink and provides a medium, together with the reactor pool for retention of radioactive material in the unlikely event of accidents involving breaches of fuel cladding.

1.2.7 Cooling Systems

A detailed description is presented in Chapter 6.

1.2.7.1 Primary Cooling System

The Primary Cooling System removes fission heat from the Core by forced upward circulation of light water and transfers the heat to the Secondary Cooling System via heat exchangers. The Primary Cooling System pump discharge line has an interconnection with the Reactor and Service Pool Cooling Systems that diverts a fraction of the Core cooling flow to produce a downward flow at the top of the Chimney, preventing water, activated with nitrogen-16, from reaching the top of the reactor pool. The system includes a tank for nitrogen-16 decay and a detector for fuel cladding failure.

If forced Primary Cooling System flow is lost, the mechanism for core cooling turns naturally from forced convection into natural circulation with no change in the direction of coolant flow, as described in Section 1.2.8.3.

1.2.7.2 Reactor and Service Pool Cooling System

The Reactor and Service Pool Cooling System removes spent-fuel decay heat from the Service Pool and maintains the Reactor Pool water within prescribed temperature limits. During reactor shutdown, it removes core decay heat as well as providing continued cooling of irradiation rigs. The system is provided with a decay tank to allow for decay of nitrogen-16.

During normal operation, cooling flow is drawn downwards through the Reflector Vessel. When the reactor is shutdown, core cooling is achieved by means of pumped upward flow and rigs cooling by natural circulation upward flow. The two centrifugal pumps responsible for shutdown cooling are fed by the Standby Power System (Section 1.2.12) in case of loss of normal power supply. In the unlikely event of loss of all electrical supply, core and rigs cooling is maintained by natural circulation of the pool water.

Heat from the Reactor and Service Pool Cooling System is transferred to the Secondary Cooling System via heat exchangers.

1.2.7.3 Reflector Cooling and Purification System

The Reflector Cooling and Purification System comprises a Primary Cooling System and an Intermediate Cooling System. The Primary Cooling System removes heat from the Reflector Vessel by forced circulation of heavy water, transferring that heat to the Intermediate Cooling System, which in turn transfers the heat to the Secondary Cooling System. The Intermediate Cooling System provides physical isolation between the Primary Cooling System and the Secondary Cooling System and operates at a lower pressure than both the Primary Cooling System and the Secondary Cooling System. This ensures that failure of the heat exchangers cannot lead to heavy water finding its way into the Secondary Cooling System.

The system purifies the heavy water.

A helium cover-gas atmosphere is used for the heavy water.

The Reflector Cooling and Purification System is functionally independent from the Second Shutdown System.

1.2.7.4 Secondary Cooling System

The Secondary Cooling System removes heat from the Primary Cooling System, the Reactor and Service Pool Cooling System, the Reflector Cooling and Purification System, the Cold Neutron Source Refrigeration System, the heating ventilation and air-conditioning systems and transfers that heat to the atmosphere by means of Cooling Towers.

The quality of the Secondary Cooling System water is maintained by the Secondary Cooling System Water Purification System.

The system is continuously monitored for radioactivity by means of a radiation detector located downstream from the primary cooling system heat exchangers.

1.2.8 Cooling Related Systems

1.2.8.1 Reactor Coolant Purification System

The Reactor Coolant Purification System keeps the Reactor Pool and Service Pool water within the required purity range, minimising corrosion, fission and radioactive impurities.

The system diverts a fraction of the flow from the Reactor and Service Pool Cooling System and passes it through a mixed resin bed purifying the water of both the Reactor and Service Pools.

1.2.8.2 Hot Water Layer System

The Hot Water Layer System provides a non-active, stable water layer at the surface of the Reactor and Service Pools. There is minimal mixing of the water in this layer with the bulk pool water and consequently, negligible contamination of the layer with impurities dissolved in the Reactor Pool water. The Hot Water Layer is obtained by introducing purified heated water at a temperature above the reactor pool water temperature.

Water purity is also maintained by the Hot Water Layer System. This system removes both radioactive and non-radioactive impurities in the Hot Water Layer as part of the strategy for minimising corrosion.

1.2.8.3 Decay Heat Removal by Natural Circulation

The Primary Cooling System is provided with flap valves located inside the Reactor Pool. During normal operation, the flap valves are maintained in the closed position by the pressure of primary coolant flow. On reactor shutdown, or pump or electric supply failure, loss of pump pressure results in the opening of the flap valves. This opens up a flow path within the Reactor Pool, allowing the transfer of decay heat from the core to the pool water by natural circulation of pool water upward through the core. Inertia of the Primary Cooling System pump units ensure adequate water flow during the transition from forced convection cooling to cooling by natural circulation. The Primary Cooling System inside the Reactor Pool, with its flap valves and the Chimney, is an Engineered Safety Feature, capable of maintaining Core cooling and extracting core decay heat after reactor shutdown or following a design basis accident.

1.2.8.4 Reactor Pool Coolant Boundary

The Reactor Pool coolant boundary holds the Reactor Pool water inventory which acts as the heat sink while any of the following systems are unavailable: Primary Cooling System, Reactor and Service Pool Cooling System, or Secondary Cooling System.

In the event of any of the above systems becoming unavailable, following reactor shut down, core and rig decay heat is transferred to the Reactor Pool by natural circulation of Reactor Pool water. The water inventory of the Reactor Pool is large enough to remove core decay heat for 10 days in the absence of any other means of heat removal.

The Reactor Pool Coolant Boundary is an Engineered Safety Feature.

1.2.8.5 Siphon Breakers

The pipelines of the Primary Cooling System and the Reactor and Service Pool Cooling System penetrate the reactor pool above the core. These pipes are provided with siphon breakers, which prevent the accidental loss of Reactor Pool water via siphon effect following the unlikely event of rupture of piping located outside the Reactor Pool Coolant Boundary. The Reactor Pool water level is thus prevented by passive means from decreasing below this level.

The flap valves of the Primary Cooling System also act as siphon breakers.

1.2.8.6 Emergency Make-up Water System

The Emergency Make-up Water System is a supply of water, separate from the Reactor Pool, which is available to keep the core covered with water in the unlikely event of a beyond design basis LOCA, which involves a drop in the water level of the Reactor Pool to below the edge of the upper chimney. The design of the chimney and Primary Cooling System pipes in the reactor pool is such that they will hold water in the event of the reactor pool being drained and thus keep the core covered with water and cooled. The Emergency Makeup Water System lets water flow by gravity into the Primary Coolant System return pipes. The Emergency Make-up Water System flow compensates for coolant loss due to evaporation, which is caused by the residual decay heat from the shut down core.

1.2.9 Shutdown Systems

1.2.9.1 First Shutdown System

If a rapid reactor shutdown is required to protect the reactor from an operational transient, the First Reactor Protection System initiates operation of the First Shutdown System which inserts the necessary negative reactivity into the core to shut down the reactor in less than one second. It performs this safety function by inserting five safety rods into the core. During normal operation the central safety rod is used for reactivity regulation and the other four safety rods are used for coarse reactivity compensation, commanded by the Reactor Control and Monitoring System.

1.2.9.2 Second Shutdown System

If a reactor shutdown is required to protect the reactor from an operational transient, and the First Reactor Protection System has failed to function, the Second Reactor Protection System initiates operation of the Second Shutdown System which inserts the sufficient negative reactivity into the core to shut down the reactor. It performs this safety function by partially emptying the heavy water from the Reflector Vessel into a storage tank located beneath the core.

The Second Shutdown System provides an alternative means of fast reactor shutdown that is diverse and independent from the First Shutdown System.

1.2.10 Instrumentation and Control

The reactor safety and operational states are monitored, controlled and managed by the following Instrumentation and Control Systems, which comprise:

- Reactor Protection Systems
- Post Accident Monitoring System
- Reactor Control and Monitoring System (RCMS)

The actions of instrumentation and control systems follow a general defence-in-depth design criterion. This organises the responses to deviations from normal operating conditions in a sequential manner.

The hierarchy of actions on core reactivity is:

- Control Loops; (RCMS);
- Operational Alarms; (RCMS);
- Control Rod Interlock; (RCMS);
- Power reduction (control rod reversal); (RCMS)
- First Reactor Protection System
- Second Reactor Protection System

While for mitigation actions they are:

- Containment Isolation
- Post Accident Monitoring
- Containment Energy Removal System

From a safety perspective, the Reactor Control and Monitoring System is a safety related system while the Reactor Protection Systems are Engineered Safety Features. In all cases, the Reactor Protection Systems override the Reactor Control and Monitoring System. The Reactor Control and Monitoring System and the RPS are functionally, physically and electrically independent of each other. RPS signals are only sent to the Reactor Control and Monitoring System without feedback using de-coupling devices.

1.2.10.1 Reactor Protection Systems

The Reactor Protection Systems are independent of other Instrumentation and Control Systems. Their function is to monitor all safety variables so that protective actions are triggered either when the safety system settings are reached, or under operator initiation. The Reactor Protection Systems are designed to bring the reactor to a safe shutdown state in the event of anticipated operational occurrences and Design Basis Accidents.

The Reactor Protection Systems include all electrical and mechanical devices and circuitry involved in generating those initiation signals associated with protective functions.

The Reactor Protection Systems are comprised of two independent systems:

a) The First Reactor Protection System consists of a combination of hard-wired and digital processing modules. The initiating protective functions associated with this system are:

   (i) Protection Interlocks (inhibits some operator actions)
   (ii) First Shutdown System

(iii) Containment Isolation
(iv) Containment Energy Removal System

b) The Second Reactor Protection System is based on hard-wired technology. The initiating protective function associated with this system is:

(i) Second Shutdown System

1.2.10.2 Post Accident Monitoring System

The Post Accident Monitoring system provides necessary information to the Main Control Room and the Emergency Control Centre for operators to monitor the reactor during and after an accident condition. In addition, it provides information to monitor the effectiveness of Engineered Safety Features, and provides an important tool for assisting in the implementation of manual recovery actions.

1.2.10.3 Reactor Control and Monitoring System

The Reactor Control and Monitoring System is a distributed, computer-based, high-availability system which monitors the reactor facility providing information to the operator at the main control room and in the Emergency Control Centre, and provides reactor control, process command and overall data-management. The system covers all automatic and manual functions that are required to operate and monitor the reactor and associated plant under normal conditions. It also ensures that safety actions are initiated to prevent operating limits being exceeded.

1.2.11 Containment

The Containment consists of a physical barrier (the reactor Containment boundary), Containment Isolation Valves, a Containment Energy Removal System, a Containment Pressure Relief and Filtered Vent System and a Containment Vacuum Relief System.

The Containment is a barrier for the prevention of release of radioactive material from the areas within the containment, namely: Reactor and Service Pools, Reactor Hall, and areas below the Reactor Pool that contain Reactor Pool water systems and Reflector Vessel heavy water systems.

The Containment is provided with an air supply system that takes outside air into the building and an exhaust system that releases it through fans and absolute filters through the stack, where activity is monitored. In the event of high activity in the exhausted air, the First Reactor Protection System initiates the containment isolation to prevent further radioactive material releases and recirculation of the containment air through absolute and charcoal filters.

The Containment Energy Removal System minimises the pressure increase within the containment following containment isolation, thus minimising the leakage from the containment. The Containment Pressure Relief and Filtered Vent System and the Containment Vacuum Relief System ensure that the differential pressure between the containment and the environment is kept within defined limits in the event of the failure of the Containment Energy Removal System.

1.2.12 Standby Power System

The Standby Power System supplies Safety Category 1 Loads that support the ESFs and some Safety Category 2 loads. The Standby Power System consists of two separate distribution networks, each supplied by a diesel generator. A third diesel generator is available and able to be connected to the distribution networks in the event of failure of any of the other two. The system uses IEEE 308 and associated standards, wherever relevant, as the basis for system design, equipment procurement, installation and system operation with the exception of the diesel generators. These are qualified to high quality commercial standards. The following reactor systems are supplied by the Standby Power System:

Reactor Protection Systems

First Shutdown System

Second Shutdown System

Containment (including the Containment Isolation Valves, Containment Energy Removal System)

Post Accident Monitoring System

Emergency Control Centre Ventilation and Pressurisation System

Cold Neutron Source Protection System

Reactor Control and Monitoring System

1.2.13 Control Rooms

1.2.13.1 Main Control Room

The Main Control Room enables the Reactor operating personnel to operate the plant safely and efficiently in all its operational states and to take measures to place the plant in a safe shutdown state in the event of a Design Basis Accident.

The Main Control Room provides consoles, desks, racks/panels and communication interfaces that are necessary for the achievement of these goals. In addition, it provides an environment under which the reactor operating personnel are able to perform their tasks with comfort and without excessive stress or physical hazard.

Appropriate measures are taken to safeguard the occupants of the Main Control Room against potential hazards such as unauthorised access, undue radiation resulting from an accident condition and the consequences of fire, which could otherwise jeopardise operations or required operator actions.

The design of the human-machine interface of the Main Control Room minimises the chance of operator errors and provides accurate and clear information on the plant status.

1.2.13.2 Emergency Control Centre

The Emergency Control Centre would be used to monitor the status of the shutdown reactor only if the Main Control Room becomes unavailable. Means of communicating with the Main Control Room, other important points in the facility and the emergency-support centres on-site and off-site are provided.

The Emergency Control Centre has replication of Post Accident Monitoring, Reactor Protection Systems and Reactor Control and Monitoring System information to permit adequate supervision of the shutdown reactor.

1.2.13.2.1 Emergency Control Centre Ventilation and Pressurisation System

The Emergency Control Centre Ventilation and Pressurisation System is an Engineered Safety Feature that ensures the continued habitability of the Emergency Control Centre in case the Main Control Room becomes unavailable.

1.2.14 Services

1.2.14.1 Electrical System

The electrical system is designed to meet demands during operational states and accident conditions. It provides diverse, reliable power sources that are physically and electrically isolated, so that any single failure affects only one source of supply and does not propagate to other sources.

During normal plant operation, all the non-Safety Category 1 and Safety Category 1 Engineered Safety Feature loads receive power from the Main Power Transformers (Normal Power System). When the Normal Power Supply is not available, all Safety Category 1 Loads receive power from the Standby Diesel Generator Sets (Standby Power System).

In addition, the Reactor Facility is equipped with Uninterruptible Power Supply units that provide reliable uninterruptible power for instrumentation systems to ensure that information is continually available on the plant state. These Uninterruptible Power Supplies fulfil the requirements of availability, diversity and independence required in IEEE 308. In case of supply interruption from the Normal Power System and until the Standby Power System provides power, long-life batteries support the Uninterruptible Power supplies.

The Standby Power System is an Engineered Safety Feature.

1.2.14.2 Radioactive Waste and Spent Fuel Management

A system for the management of radioactive waste is in place within the Reactor Facility. It looks after the solid, liquid and gaseous wastes arising from operation of the Reactor Facility as well as the spent fuel.

Waste management of radioactive solids includes: spent resin handling and storage, spent Fuel Assembly handling and storage, and handling and storage of waste from irradiation facilities and replacement of active components and filters. Volume reduction of metallic waste can be achieved in the service pool.

The Radioactive Liquid Waste Management System classifies, collects, stores, controls and monitors all liquid waste originating in the Reactor Facility. Liquid waste is classified and monitored in accordance with current practice at the site prior to transferral to the site waste treatment plant.

Gaseous emissions from the Reactor Facility are maintained below prescribed limits. In the very unlikely event of a very high reactor stack emission, it is detected by the Air Effluent Monitoring System. This system then signals the First Reactor Protection System, which isolates the Containment.

Spent fuel will be stored in dedicated storage racks in the Service Pool to allow it to cool prior to transport from the LHSTC. There is sufficient storage space for 10 years of operation, plus one additional full core.

1.2.14.3 Fire Protection

A Fire Detection and Alarm System, together with an Emergency Warning and Indication System, is in place within the Reactor Facility in accordance with Australian and International standards and requirements.

1.2.14.4 Conventional Areas Heating, Ventilation and Air Conditioning System

A Heating Ventilation and Air Conditioning System is provided for areas outside of the Reactor Containment for air conditioning, circulation and renewal, to provide the required environment for personnel and equipment.

1.2.14.5 Cranes and Hoists

The reactor facility is provided with various cranes suitable for movement of irradiated targets in shielded containers, spent fuel shipments, all heavy plant and equipment which may need to be removed for repair or replacement and all other operational needs of the reactor facility, as follows:

- Reactor Hall Building Crane
- Operation Bridge
- Reactor Beam Hall Building Crane
- Neutron Guide Hall Building Crane
- Auxiliary Cranes and Hoists

1.2.14.6 Physical Security

A Physical Security system in the facility integrates with the existing protection arrangements at the LHSTC to provide physical protection to: persons, nuclear materials, commercial, scientific and national security information, hardware, software, documentation and operational arrangements. The system also provides protection against unauthorised entry into the reactor building.

The security arrangements and physical protection systems meet the requirements of the Director General, Australian Safeguards and Non-Proliferation Office, which issues permits to ANSTO for the possession and transport of nuclear material and associated items.

1.2.14.7 Water Supply Systems

Water supply to the facility comes from the existing water supply system at the LHSTC. The reactor is provided with the following water systems:

- Secondary cooling water system including cooling towers
- Fire suppression water tanks.
- Potable water for domestic applications - drinking and sanitation purposes.
- Demineralised water.
- Non-potable water for laboratory and/or hazardous areas.

1.2.14.8 Demineralised Water System

The demineralised water supply and distribution system provides demineralised water of specified quality in sufficient quantities for routine reactor needs. The demineralisation plant is located in the Auxiliary Building and is monitored by the Reactor Control and Monitoring System.

1.2.14.9 Compressed Air System

The compressed air system delivers oil-free air suitable for the reactor facility. A distribution network covers the reactor plant and equipment, the associated laboratories and workshops, and the irradiation and neutron beam facilities. The system is inter-linked with the LHSTC compressed air network.

1.2.14.10 Breathing Air System

The breathing air system supply and distribution, monitored by the Reactor Control and Monitoring System, meets safety requirements for maintenance operations in certain facility areas where breathing air may be required.

1.2.14.11 Voice Communication Systems

The voice communication systems include communication by telephone, headsets, and the site emergency warning system.

The dedicated voice communication systems for the reactor, auxiliary plant buildings and Emergency Control Centre are connected to the existing communication-systems. All equipment is capable of functioning during all operating conditions and Design Basis Events and is supplied from uninterruptible power supplies.

The emergency warning and intercom system includes connection to the LHSTC site control centre main alarm panel.

1.2.14.12 Services for Neutron Research Equipment

Services provided include: Neutron Guide Hall computer network, nitrogen supply system (liquid and gas), oxygen supply system, argon supply system, helium supply system, chilled water supply and vacuum and noxious gases exhaust system.

1.2.15 Neutron Beam Facilities

Neutron guides are used to condition and transport neutrons from the high density neutron areas located in the Reflector Vessel to the research instruments located in the Reactor Beam Hall and the Neutron Guide Hall.

Neutron beam facilities of the Reactor Facility include:

Cold and thermal neutron source systems.

Neutron guides for thermal and cold neutrons.

Neutron beam shutters.

Auxiliary systems.

Arrangements are included for a possible future installation of a hot neutron source.

The buildings that support these facilities comprise:

a) The Reactor Beam Hall – An area in the reactor building that accommodates the neutron beam instruments that need to be as close to the reactor as practicable.

b) The Neutron Guide Hall – An area adjacent to the reactor building that accommodates the majority of the neutron beam instruments.

c) Workshops and laboratories, offices and a viewing gallery.

These facilities are supported by the following services:

a) Cranes in the Reactor Beam Hall and the Neutron Guide Hall.

b) Air conditioning and ventilation.

c) Other services that comprise: electrical supply, communication systems (telephone and computer), water supply and drainage, gas supply (industrial and specialised).

1.2.15.1 Cold Neutron Source

The Cold Neutron Source consists of a liquid deuterium moderator maintained at a temperature of around 20 K, located close to the reactor core, aimed at increasing the neutron yield in the “cold” energy range. Neutrons moderated in this cold fluid are then transported through the neutron guides into the Reactor Beam Hall and the Neutron Guide Hall, where research facilities are located.

The moderator is liquefied and maintained in the liquid state within a natural circulation Thermosiphon loop, which has a heat exchanger and a cooling jacket fed with cryogenic helium at 19 K.

Both the Cold Neutron Source Refrigeration Cryo system and the reactor are capable of operation if the other is shut down. Postulated failures of the Cold Neutron Source do not affect reactor safety. The Cold Neutron Source is automatically monitored and controlled by the Cold Neutron Source Control and Monitoring System and has a separate protection system; the Cold Neutron Source Protection System.

1.2.15.2 Thermal Neutron Source

The thermal neutron source comprises a heavy water zone located close to the region of peak thermal flux in the Reflector Vessel. Two neutron beams originate at the thermal neutron source. The neutron spectrum has a temperature in the range from 40°C to 60°C.

1.2.15.3 Neutron Beams and Shutters

1.2.15.3.1 Neutron Beams

The Reactor Facility is provided with:

a) Two thermal Neutron Beam Assemblies, Assembly #1 and Assembly #4, respectively.

b) Two cold neutron beam assemblies, Assembly #2 and Assembly #3.

c) An additional neutron beam assembly, Assembly #5, pointing in the direction of a possible future Hot Neutron Source.

Assembly #1 supplies thermal neutrons to three neutron guides TG1, TG2 and TG3 in the same horizontal plane. Of these TG1 and TG3 extend into the Neutron Guide Hall while TG2 terminates at the reactor face. Assembly #4 supplies thermal neutrons to one neutron guide, TG4, that terminates at the reactor face.

Assembly #2 supplies cold neutrons to three neutron guides; CG1, CG2, and CG3. Of these CG1 and CG3 extend into the Neutron Guide Hall while CG2 ends at the reactor face. Assembly #3 supplies cold neutrons to one neutron guide, CG4, that terminates at the reactor face.

Assembly #5 is capable of supplying neutrons to two independent beams (HB1 and HB2) that terminate at the reactor face.

1.2.15.3.2 Primary Shutters

All neutron beams have primary shutters installed at the reactor block face.

The Primary Shutters are movable shields that, when closed, interrupt the radiation flow along the beams allowing maintenance operations on the neutron guides or on the neutron research instruments to be carried out safely. In the open position the shutters let the neutron beam pass through.

1.2.15.3.3 Secondary Shutters

Each of the neutron guides TG1, TG3, CG1 and CG3 is equipped with an independent secondary shutter at the exit from the Neutron Guide Bunker. When shut, they allow unrestricted access to the downstream sections of the corresponding neutron guide at all times.

Both the Primary and Secondary Shutters are instrumented to indicate the shutter positions and warn of malfunctions to beam users and reactor operators.

1.2.16 Irradiation Facilities

1.2.16.1 General Description

Radioisotopes are produced by introducing targets into dedicated irradiation positions in the reflector vessel.

The following irradiation facilities, laboratories and hot cells are provided:

- Bulk Production Irradiation Facilities
- Long Residence Time General Purpose Irradiation Facilities
- Short Residence Time Irradiation Facilities
- Large Volume Irradiation Facilities
- Hot Cells and Auxiliary Facilities
- Interbuilding Pneumatic Transfer Facility

The irradiation facilities are controlled and monitored by the Irradiation Facilities Control and Monitoring System and have a separate protection system; the Irradiation Facilities Protection System.

1.2.16.2 Bulk Production Irradiation Facilities

The Bulk Production Irradiation Facilities (BIF) allow the irradiation of targets contained in sealed irradiation cans on removable rigs that are located inside irradiation tubes provided within the Reflector Vessel. The rigs are handled remotely by operators standing at the Operation Bridge that runs above the Reactor and Service Pools.

Once irradiated, the rigs are moved to the Service Pool and then into a shielded hot cell. Irradiated targets are removed from the rig and are transferred to a hot cell from where the irradiated targets are dispatched, for processing in other buildings, by means of shielded transport flasks.

1.2.16.3 Long Residence Time General Purpose Irradiation Facilities

Long Residence Time General Purpose Irradiation Facilities (LRT) allow the irradiation of targets contained in sealed irradiation cans. The cans are transferred for irradiation to the rigs within the Reflector Vessel by means of a pneumatic transport system.

The pneumatic conveyors' loading and unloading are carried out in hot cells.

From the hot cells, cans may be dispatched for processing either by two lines belonging to the Interbuilding Pneumatic Transfer System (IPTS) connecting to Radioisotope

Production and Processing Facility or by means of shielded transport flasks.

1.2.16.4 Short Residence Time Irradiation Facilities

The Short Residence Time Irradiation Facilities are designed to perform Neutron Activation Analysis (NAA) and Delayed Neutron Activation Analysis (DNAA). The system comprises the irradiation facilities for which target transport is performed by pneumatic means. Targets may be irradiated for short periods; from 3 seconds to several minutes.

The irradiation Terminal Stations for NAA and DNAA are located within the Neutron Activation Analysis Irradiation Laboratory and transfer between the irradiation position and the Terminal Station is performed using a pneumatic system. The transit time from the irradiation position in the rig to the terminal station is approximately 3 seconds.

1.2.16.5 Large Volume Irradiation Facilities

Large Volume Irradiation Facilities (LVF) are dedicated to the neutron transmutation doping (NTD) of single-crystal silicon ingots and for bulk irradiation of other samples.

The silicon ingots and sealed sample containers in unsealed cans are placed inside rotating rigs installed in irradiation tubes provided in the Reflector Vessel. The cans containing silicon ingots or sample containers are loaded and unloaded by operators standing on the Operation Bridge that runs above the Reactor Pool.

During irradiation, the cans containing silicon ingots or samples are rotated by automatic means to ensure adequate homogeneity of the irradiation.

Once irradiated the silicon ingots and samples are handled in an exclusive area inside the Service Pool connected to the Reactor Pool.

1.2.16.6 Hot Cells and Auxiliary Facilities

These facilities are provided to allow operators to manage irradiated material, performing the necessary tasks to load targets to be irradiated and to handle the targets after irradiation to be delivered to the processing plant outside the Reactor Building.

Targets are enclosed in cans and no task involving the opening of the cans is performed in the Reactor Building.

Hot cells are provided with master slave manipulators and have appropriate shielding and an active ventilation system for radiation protection purposes.

The facilities include different shielded ducts and transport flasks designed to transfer radioisotopes and fresh targets between hot cells, irradiation positions and external building facilities.

1.2.16.7 Interbuilding Pneumatic Transfer System

The Interbuilding Pneumatic Transfer System is provided to transfer small irradiation cans between the Hot Cells in the Reactor Building and a hot cell with active ventilation in the Radioisotope Production and Processing Facility.

Two air-driven transfer lines are available. Each of the transfer lines is bi-directional, to send irradiated targets from the Reactor Building to Radioisotope Production and Processing Facility and to receive new unirradiated targets or “active load” targets from Radioisotope Production and Processing Facility.

End of Section

Table 1.2/1 Main Reactor Characteristics and Core Parameters

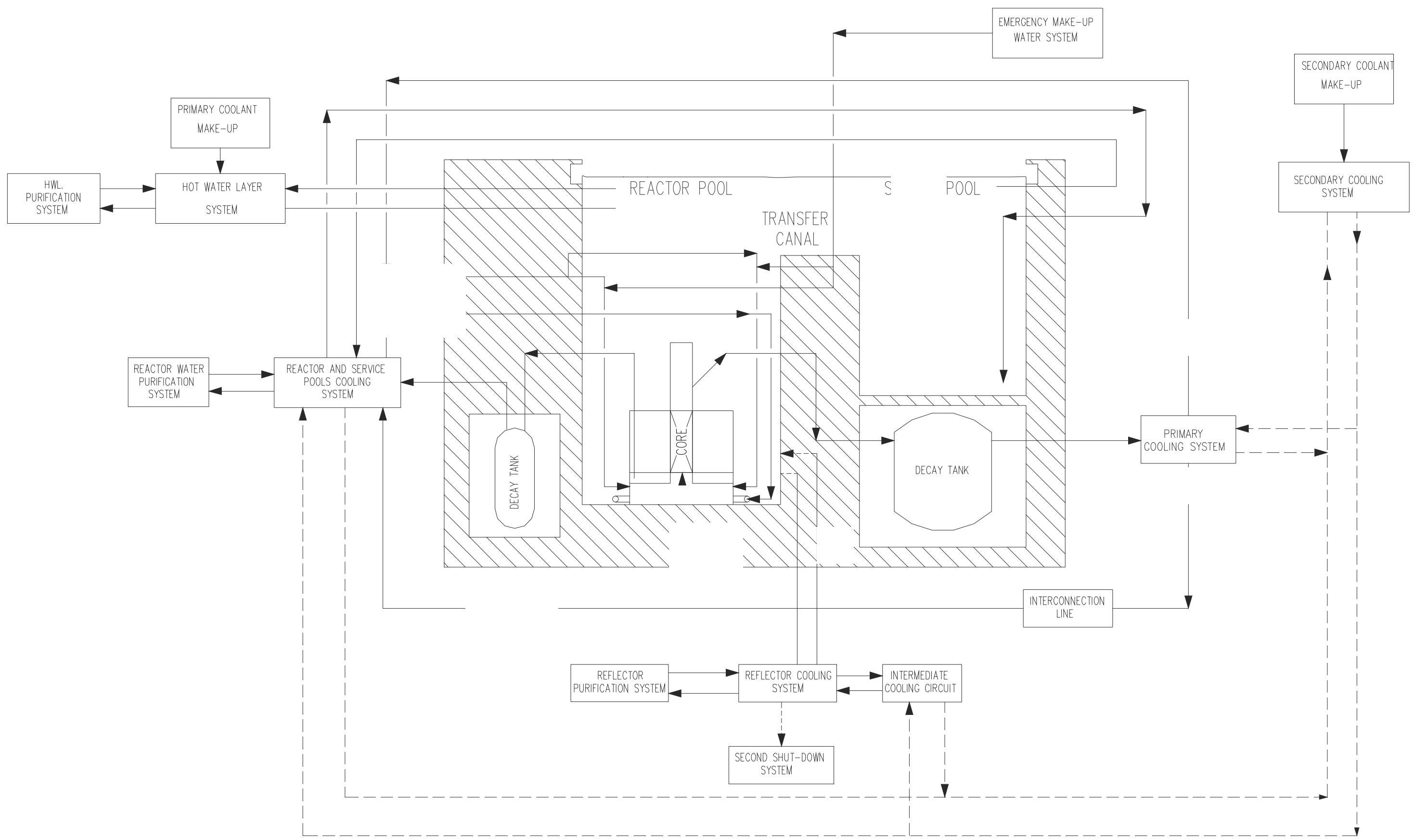
GENERAL DATA	
Type of reactor	Open pool
Core thermal power	20 MW

NUCLEONIC	
CORE	
Number of fuel assemblies in equilibrium core array	16
Core dimension	
Grid array	4 x 4
Number of control rods	5
Absorbing material	Hafnium
Core fuel load, average over 5 Beginning of Cycles (BOCs)	6.23 kg uranium-235
Average at power operation cycle length, reference core	28.8 full power days
Average cycle length, reference core	30.8 days

NUCLEAR FUEL	
Fuel type	19.75% enriched, U_3Si_2-Al dispersion fuel
OPERATIONAL DATA	
Full assembly residence time	About 190 full power days
FUEL ASSEMBLY	
Fuel element type	Plate
Number of fuel elements per fuel assembly	21
Active length	
Active width	
Plate thickness	1.35 mm (internal plates) 1.5 mm (external plates)
Coolant channel dimensions	

REACTOR POOL DATA	
Internal pool diameter	
Internal pool height	
Internal pool water depth	
Reactor pool water inventory	186 m^3

Figure 1.2/8 Reactor Cooling Systems - Block Diagram



1.3 HISTORICAL REVIEW

1.3.1 High Flux Australian Reactor

The High Flux Australian Reactor (HIFAR) at the LHSTC site was constructed and commissioned in the 1950s. In 1958 the first self-sustaining atomic chain reaction was achieved within the reactor and it has operated at full power since 1960.

HIFAR was originally built as a materials test reactor to determine how various materials and nuclear fuels would behave in a nuclear core, and to develop knowledge of nuclear chemistry and nuclear physics in Australia. The design of the reactor, however, provided sufficient flexibility to ensure that it could be adapted to meet changing needs over the last 40 years. Consequently, HIFAR has had many modifications to satisfy increased demand for both irradiation and research capabilities.

In 1993, the Commonwealth Government initiated a review of the present operation of HIFAR, with the aim of determining the need for a replacement research reactor.

1.3.2 Proposal to Construct the Replacement Research Reactor

On 3 September 1997, the Minister for Science and Technology announced the proposal to construct a replacement research reactor at Lucas Heights, to replace the technologically obsolete HIFAR, which was expected to reach the end of its operational life around 2006.

1.3.3 Environmental Assessment

The Minister for the Environment and Heritage determined on 27 September 1997 that an environmental impact statement was required to be prepared by ANSTO.

Draft guidelines were prepared by the Environment Protection Group of Environment Australia, which administers the environmental impact assessment process. The draft guidelines were made available for public review from 8 November to 6 December 1997 to ensure that all relevant issues were identified, and to facilitate public understanding of the EIS process. The final guidelines were promulgated by Environment Australia in January 1998.

In accordance with the Administrative Procedures of the Commonwealth Environment Protection (Impact of Proposals) Act 1974, a Draft Environmental Impact Statement (EIS) was prepared by consultants to ANSTO, PPK Environment & Infrastructure and the UK company NNC Ltd. The EIS described the proposal and its potential environmental impacts. This document was on exhibition for public review nationally for a period of 12 weeks from 17 August to 9 November 1998.

To assist in Environment Australia's reviews and assessment tasks, three independent reviews of key nuclear issues in the draft EIS were commissioned by the Department of the Environment and Heritage to meet the following objectives:

a) To ensure rigorous independent expert scrutiny of the draft EIS.

b) To assist stakeholders in understanding the EIS technical issues, and in preparing their submissions on the draft EIS.

c) To assist the Department in its assessment of the proposal.

The independent reviews were carried out by:

a) The International Atomic Energy Agency (IAEA), which examined the draft EIS hazard and risk analysis, including risks to the community and the acceptability of siting any new reactor at Lucas Heights.

b) Parkman Safety Management (UK based), which provided a further independent peer review of hazards and risks, and compliance with best international practice.

c) CH2M HILL, which reviewed matters relating to operational emissions, management of wastes and spent fuel, and impacts on the environment.

The reviewers had access to the draft EIS and Appendix Volumes, as well as material referenced in the EIS. The methodologies and references used by the various reviewers are included in their reports. Copies of these were sent to all draft EIS public display places and key stakeholders.

After considering all comments received from the public, and in accordance with the Administrative Procedures of the Environment Protection (Impact of Proposals) Act 1974, ANSTO and its consultants prepared a Supplement to the Draft EIS and submitted it to Environment Australia on 18 January 1999. The Draft EIS and the Supplement comprise the Final Environmental Impact Statement for the Reactor Facility.

1.3.4 Environmental Assessment Outcome

The Environment Assessment Branch of the Department of the Environment and Heritage evaluated the Final EIS and produced an Environment Assessment Report to assist the Minister for the Environment and Heritage in providing advice and recommendations to the Minister for Industry, Science, and Resources. On 30 March 1999, the Minister for the Environment and Heritage recommended that the proposal to construct and operate a replacement research reactor at the LHSTC be implemented, subject to 29 matters of advice or recommendation.

1.3.5 Assessment of Site Characteristics

The ARPANSA Regulations and the ARPANSA Siting Guidelines require a current description and assessment of site characteristics that influence the reactor facility's safety and potential health and safety impacts. To address this requirement, ANSTO lodged a submission entitled Site Characteristics and Site Related Design Bases to the Nuclear Safety Bureau on 16 December 1998. This submission was also published as Appendix C to the Supplement to the Draft EIS in January 1998. An updated version was included with the Application to ARPANSA for a Facility Licence, Site Authorisation for the Replacement Research Reactor Facility.

The Site Characteristics and Site Related Design Basis document described:

a) The site's demography, seismology, geology, topography, ecology, hydrology, and meteorology.

b) The effect of nearby facilities and land usage.

c) The availability of offsite services such as electricity, water, transportation, and communication systems.

d) Site characteristics that influence the reactor facility design from a safety viewpoint.

e) A screening of external events with a more than negligible probability of occurrence so as to determine the design basis events for important natural phenomena and man-induced events.

The conclusions of that document are that the proposed site for the reactor facility, within the LHSTC site, does not have any negative features which cannot be overcome by the high standard and quality of engineering design and construction which are required by ANSTO, and which are met by the design.

1.3.6 Facility Licence and Site Authorisation

On 13 April 1999, ANSTO submitted to ARPANSA the Application for a Facility Licence, Site Authorisation for the ANSTO Replacement Research Reactor. The Application was made pursuant to Section 30 of the Australian Radiation Protection and Nuclear Safety Act 1998. The Application sought ARPANSA authorisation for ANSTO to prepare a site for the 20 MW research reactor to replace the existing HIFAR at the site of the LHSTC, New South Wales.

The Application provided information intended to satisfy the requirements of the ARPANSA Act 1998, the ARPANSA Regulations 1999, and the applicable regulatory criteria developed by the predecessor to ARPANSA, the Nuclear Safety Bureau. Additionally, the Application addressed the outcome of the environmental assessment including the recommendations of the Minister for the Environment and Heritage on March 30.

A Facility Licence F0001 was issued to ANSTO by ARPANSA on 22 September 1999.

1.3.7 Parliamentary Approval

Independently of ARPANSA’s processes, the proposal was referred to the Public Works Committee in February 1999. The proposal was evaluated and subject to public hearings. Following the report to Parliament by the Public Works Committee, the proposal was granted Parliamentary Approval in August 1999.

1.3.8 Tender Process

The Tender process was preceded by a pre-qualification of reactor vendors in December 1998, where 4 qualified tenderers were selected from among a group of 8.

The Request for Tender was prepared from January to June 1999 and amended to take into account Public Works Committee recommendations in August 1999.

The final Request for Tender was issued in August 1999. Tenders were received in January 2000. The recommendation of the Preferred Tenderer was made in May 2000 and the Contract was signed in July 2000.

1.3.9 Design and Construction

INVAP was awarded the contract for the Design and Construction of the Replacement Research Reactor.

The project has developed according to the schedule in Figure 1.3/1 with the following Project Phases:

Phase 1 Detailed Design comprises the activities required to define the design of the plant systems and the design evaluation including the safety analysis.

Phase 2 (Detailed Engineering) comprised the activities required to detail the plant systems and to prepare the plant operation documents and start-up and commissioning procedures.

Phase 3 (Construction) comprised the activities required to carry out all steps leading to the erection of buildings and structures of the facility, including civil works, steel construction, services such as piping, electrical services and lifts, finishes and buildings fit out.

Phase 4 (Manufacturing and Procurement) comprised the activities required to perform the complete supply of systems and components.

Phase 5 (Installation) comprised the activities required to carry out installation, assembly, connection, and preliminary testing of the systems and components.

Phase 6 (Pre-operational Tests) constituted the final stage of the construction and installation phase, with the inspection and testing of components to ascertain that the construction and installation phases were completed successfully and that all components were in operating condition.

Phase 7 (Commissioning) comprised the activities required for the start-up of all systems in the facility until the reactor is taken to normal operation at full power. It also includes the verification that the plant performs as a whole and that each system is operating according to the specifications.

The Reactor Facility complies with the safety and licensing requirements of national bodies and relevant international safety principles, and relating to the design, construction, commissioning and operation of research reactors. In addition it satisfies the commitments and conditions arising from the EIS process.

The following Figure 1.3/1 shows the main project milestones; subject to the issue of appropriate licences.

1.3.10 Construction Authorisation

On 18 May 2001 ANSTO submitted to ARPANSA an Application for a Facility Licence, Construction Authorisation for the Replacement Research Reactor at the Lucas Heights Science and Technology Centre. The Revision 0 of the PSAR was included within the Application documentation.

Following the recommendations of the Environment Australia Environmental Assessment Report for the proposed replacement research reactor, the PSAR was subject to independent peer review to the satisfaction of ARPANSA.

To facilitate this, ARPANSA assembled a team of international experts. The team comprised experts in different fields of reactor safety from Europe, America, and Africa. The review commenced in late May and concluded in mid July 2001. The final report from the International Peer Review Team was presented to the CEO of ARPANSA and to members of the public. In producing the final report, the International Peer Review Team raised a number of questions relating to the PSAR that were responded to by ANSTO.

The PSAR was presented for public scrutiny in Australia during a period of three months. Comments and questions from the public were received and answered by ARPANSA.

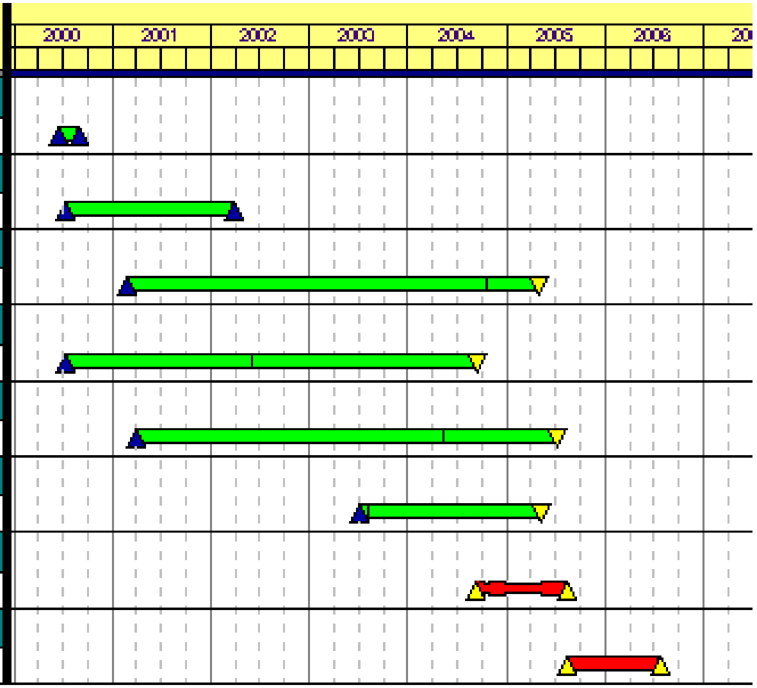
ARPANSA performed on its own a comprehensive safety evaluation of the PSAR. This safety evaluation took into account world's best practice, advice from experts in the field, the results of the International Peer Review, of the ARN review, and the views and concerns of individuals and organisations from the public arena.

As a result of the evaluation process, the licence to construct the reactor was issued by ARPANSA on 4 April 2002.

End of Section

Figure 1.3/1 Replacement Research Reactor Project Summary Schedule

Work Package	Description	Early Start	Early Finish
+Phase 0 - Project Launching			
		14-JUN-00	25-AUG-00
+Phase 1 - Preliminary Eng			
		13-JUL-00	26-MAR-02
+Phase 2 - Detailed Eng			
		21-FEB-01	02-MAY-05
+Phase 3 - Construction			
		13-JUL-00	15-SEP-04
+Phase 4 - Manufacturing & Procurement			
		01-APR-01	06-JUL-05
+Phase 5 - Installation			
		01-JUL-03	11-MAY-05
+Phase 6 - Preoperational Tests			
		09-SEP-04	09-AUG-05
+Phase 7 - Commissioning			
		10-AUG-05	20-JUL-06



End of Figures

1.4 COMPARISON WITH SIMILAR FACILITIES

Research reactors have been in use for several decades by many countries world-wide. The first research reactor began operation in 1942. Since then, over 550 research reactors have been constructed with approximately 270 of them being currently in operation.

The total number of operating years for research reactors is in excess of 11,000. While incidents have been reported, very few have had significant consequences.

Research reactors provide elevated fluxes of neutrons for various applications including the production of radioisotopes and for scientific applications. Such neutrons provide a powerful tool for studying matter at the nuclear, atomic, and molecular levels. Nuclear and solid state physicists, chemists, materials scientists, biologists and earth scientists use neutrons as probes. Neutron experiments can also be performed outside the biological shield of the research reactor by means of installed beam tubes. Additionally, specimens can be positioned in or near the reactor cores for neutron irradiation, to produce radioactive isotopes for medical, industrial or research use or for the isotopic analysis of samples.

Although there are a variety of research reactor types, they can be classified as:

1. Heavy water reactors that furnish high fluxes of neutrons in the form of beams, essentially used in basic research.
2. Light water reactors, better adapted to material tests, with two subtypes:
   a) Open pool reactors, cooled and moderated by light water, generally multi-purpose and simple to use and access.
   b) Light water reactors with closed, pressurised vessels, able to operate at powers greater than those of the pool reactors, but more difficult to use because of the closed vessels.

The Replacement Research Reactor design is a type 2- a) reactor, with an open pool, cooled and moderated by light water, multi-purpose and simple to use and access. It has been provided with a heavy water reflector that enhances the neutron flux and makes the reactor specially suited for beam research. Its design is proven and conservative, with design parameters within internationally accepted values; in the range of those of reactors of the same type already in operation.

A comparative data sheet from various Multi-Purpose reactors is presented in Table 1.4/1. Other similar reactors not included in the table are the HANARO reactor in Korea (in operation since 1995), the research reactor of the Hahn Meitner Institute in Germany, and the two Maple reactors in Canada .

Table 1.4/1 shows that:

a) The basic elements of the reactor design have already been tested in ETRR-2.

b) The reactor core-cooling configuration is similar to the one used successfully in in ETRR-2.

c) The layout of the reactor First Shutdown System is similar to the ones used in the ETRR-2 reactor.

d) Ample experience is available on plate-type dispersion fuel with aluminium cladding, cooled and moderated with demineralised water.

e) The reactor core characteristics (fuel parameters, enrichment, material, heat flux, power density, temperature, coolant velocity) are within the range of data available for this type of reactor.

f) Proven technology is used in the design of the reactor First Shutdown System, Second Shutdown System, Emergency Make-up Water System, Containment, Reactor Protection System and Reactor Control and Monitoring System.

g) The comparison with other reactors shows that the reactor is within the safety envelope of similar facilities.

1.4.1 Proven Technology of the First Shutdown System

The First Shutdown System for the reactor has similar design characteristics to the systems used in the ETRR-2 22 MW research reactor in Egypt, commissioned in early 1998, which features Control Rod Drives stepper motors and rack-and-pinion drives, located below the Reactor Pool.

1.4.2 Proven Technology of the Second Shutdown System

The reactor Second Shutdown System is based on proven design and performance. The system is based on the design characteristics of the reactors listed in Table 1.4/2. In all these reactors the heavy water is dumped by gravity forces.

1.4.3 Proven Technology of the Reactor Protection Systems

The reactor is provided with two independent reactor protection systems. In order to minimise the possibility of common mode failures, different technologies are used for each system.

The First Reactor Protection System is based on digital and hard-wired technology. The Second Reactor Protection System is based on hard-wired technology with proven performance in nuclear safety applications.

1.4.4 Proven Technology of Replacement Research Reactor Fuel

The fuel for the reactor core is low-enriched (LEU) silicide fuel, using uranium silicide (U_3Si_2) dispersed in pure aluminium powder. The uranium density is 4.8 g/cc with an enrichment of 19.70% U_{235}.

This fuel material was extensively tested in the 1980’s, when experiments were performed with plates fabricated by Babcock and Wilcox (USA), CERCA (France), the Argentine Atomic Energy Commission (CNEA) and Nukem (Germany). The experiments were done in the Oak Ridge Reactor, within the framework of the Reduced Enrichment for Research and Test Reactors (RERTR) program.

On the basis of these experiments the U.S. Nuclear Regulatory Commission declared, in 1988, that this fuel was qualified for high and low power research reactors. The Safety evaluation report is presented in the document NUREG-1313.

The fuel has high uranium density and good all-round properties, including excellent behaviour under irradiation. It is also relatively simple to fabricate because the uranium loading is lower than the normal commercial fabrication limits with conventional rolling techniques. Thousands of plates and fuel assemblies have been fabricated and irradiated worldwide; no major failures have been reported.

The U_3Si_2 dispersion fuel is currently used in several research reactors, such as ISIS and OSIRIS in France, NRU in Canada, HOR in the Netherlands, and JRR-3M, JRR-4 and JMTR in Japan.

The planned change to UMo fuel which is addressed in the Application for a Facility Licence, Construction Authorisation will be the subject of a separate submission to ARPANSA, with a view to insertion into early cores.

1.4.5 Seismic Design

The peak ground acceleration (PGA) levels of the site employed in the design of the Reactor Facility are similar to those used in the design of the ETRR-2 reactor in Egypt. As the reactor building characteristics of the Reactor Facility are similar to those of ETRR-2, the conditions foreseen during the Safe Shutdown Earthquake for the Reactor Facility building have a safety margin close to that of the ETRR-2 reactor. The peak ground acceleration and associated hazard spectrum bound recommendations from previous studies for the Lucas Heights region.

End of Section

Table 1.4/1 Comparison of Several Multipurpose Reactors

PARAMETER	RRRP	ETRR-2 (4)	RP-10 (5)	OSIRIS (1/6)	HFR (2/7)	ORPHEE (3)
General data						
Reactor power(MW)	20	22	10	70	45	14
Owner	ANSTO	AEA	IPEN	CEA	Europe Comm.	CEA
Site	Lucas Heights Australia	Cairo Egypt	Lima Peru	Saclay France	Petten Netherlands	Saclay France
First criticality	Planned: 2005	1998	1988	1966	1961	1980
Reactor type	Open pool	Open pool	Open Pool	Open pool	Closed Tank	Closed Tank
Coolant/moderator	H_2O/H_2O	H_2O/H_2O	H_2O/H_2O	H_2O/H_2O	H_2O/H_2O	H_2O/D_2O
Coolant & moderator connected	Yes	Yes	Yes	Yes	No	No
Reflector	Heavy water	Beryllium	Be Graphite	Beryllium	Beryllium	Beryllium/ D_2O
Flow direction in core	Upwards	Upwards	Downwards	Upwards	Downwards	Downwards
Control rods drive location	Below core	Below core	Above core	Below core	Below core	Above core
Core data						
Core volume (m^3)	0.075	0.154	0.096	0.15	0.2	0.056
Grid array	4 x 4	6 x 5	9 x 9	7 x 8	9 x 9	3 x 3
Number of fuel assemblies	16	29	24	31	33	8
Number of control rods	5	6	5	6	6	4
Absorbing material	Hafnium	Ag-In-Cd	Ag-In-Cd		Ag-In-Cd	
Core fuel load (Kg U_{235}) (average BOC for	6.23	11.7	5.7	11.7	12.0	5.9

PARAMETER	RRRP	ETRR-2 (4)	RP-10 (5)	OSIRIS (1/6)	HFR (2/7)	ORPHEE (3)
RRRP)						
At power operation cycle length (Reference core for RRRP) (days)	28.8	19	15			100
Aver. Extraction burn-up (%)	46.0	61	60			
Total reactor power (MW)	20	22	10	70	45	14
Fuel assembly data						
Fuel type	U_3Si_2 - Al	U_3O_8	U_3O_8			
Fuel enrichment - (% U_{235})	19.75	19.7	19.75	19.75	93.0	93.0
Number of fuel plates	21	19	16	242	23	24
Fuel Meat thickness (mm)	0.61	0.7	1.00	0.51	0.51	
Fuel Plate thickness (mm)	1.35 (internal plates) and 1.5 (external plates)	1.5	1.76	1.27	1.27	
Coolant channel width (mm)	2.45	2.7	3.30	2.46		
Cladding material	Al	Al	Al	Zircaloy	Al	Al 3%Mg
Number of available primary pumps	3	4	3	4		2
Number of available primary heat exchangers	3	2	3	4		
Core thermal data						
Maximum/average flux ratio	3	3	2.5	2.3	1.6	2.4
Reactor Pool data						
Reactor pool volume (m^3)	224	190.8	140.7	536		6.3

PARAMETER	RRRP	ETRR-2 (4)	RP-10 (5)	OSIRIS (1/6)	HFR (2/7)	ORPHEE (3)
Power/Pool volume(KW/m^3)	89	115	71	130		2222
Utilisation Facilities						
Horizontal beam tube-radial	None	2	4		12	None
Horizontal beam tube-tangent.	5	1	1		None	9
Thermal column	None	1	1	None	None	None
Pressurised test loops	None	2	None			3

1. CEA, Réacteur Osiris, Rapport descriptif, C1O-R-3984 (1970)
2. High Flux Reactor (HFR). Joint Research Centre, Petten. The Netherlands. IGORR-1 (1990)
3. Réactor Orphée. Commissariat a l'Energie Atomique, Saclay. France. IGORR-1 (1990)
4. ETRR2, Atomic Energy Authority of Egypt, Safety Analysis Report, INVAP Doc. No. 0767-5325-3IBLI-001-1A.
5. Informe de Seguridad Reactor RP-10. PE01 06 99 2000 0018 GG 01 Comisión Nacional de Energía Atómica Argentina.(1988)
6. C.Joly, et al. “OSIRIS - Refurbishment and Management of Ageing Effects” paper presented at IAEA meeting Geesthacht, Germany, May 1995
7. HFR Petten Characteristics of the Inst. and Irrad. Facilities, Commission of European Community “Directory of Nuclear Research Reactors 1994”, IAEA, Vienna, 1995

Table 1.4/2: Reactors with Shutdown Systems Based on the Dumping of Heavy Water by Gravity Force

Reactor	Location	Type	In operation since	Power
RA-8	Argentina	Critical facility	1997	-
ZEEP	Canada	Critical facility	1965	-
DIMPLE	UK	Critical facility	1954	-
CIRUS	India	Research Reactor	1960	40 MW
DIORIT	Switzerland	Research Reactor	1960	20 MW
MAPLE-2units	Canada	Research Reactor	Under construction	10 MW
NPD	Canada	Nuclear Power Plant	1962	83 MW_{th}
Pickering	Canada (Toronto)	Nuclear Power Plant	mid 1960s to mid 1970s	8 x 550 MW_e
Douglas Point	Canada	Nuclear Power Plant	1965	693 MW_{th}

End of Tables

1.5 SAFETY PRINCIPLES

This section states the basic safety principles adopted for the design, construction and operation of the reactor and the nuclear safety criteria for acceptance.

1.5.1 Basic Safety Principles in the Design

These principles are presented in Section 2.2.1 of Chapter 2.

1.5.2 Basic Safety Principles in the Construction

Particular attention has been given to construction issues. Throughout the construction of the Reactor Facility, Quality Assurance and Quality Control were implemented, aimed at:

a) Assuring that the latest valid engineering information is followed throughout fabrication.

b) Controlling fabrication documentation for: identification, review, approval, issuance, distribution and revision.

c) Assuring that the materials used in the fabrication comply with the specified characteristics.

d) Verifying that the personnel assigned to the fabrication tasks have the required technical background in order to perform the required tasks in the appropriate manner.

e) Assuring that specifications in the engineering documentation are followed throughout the manufacturing and fabrication process.

f) Demonstrating the functional adequacy of plant components, systems and structures, by performing component, system and sub-system start-up tests in accordance with specified procedures.

g) Documenting any modifications required throughout the construction or commissioning stages.

h) The efficient completion of the Test and Commissioning Program.

1.5.3 Basic Safety Principles during Operation

During operation safety is assured through ANSTO’s:

a) Compliance with such conditions as are specified by ARPANSA in the Reactor Operation Licence.

b) Compliance with the Reactor Facility Quality Management System, developed as part of the Detailed Engineering Phase, and which includes arrangements for:

   (i) operation (including maintenance) which uses the IAEA’s “Safety Requirements for Research Reactors” Draft DS272, Sept 2002 as a basic reference;

   (ii) utilisation which uses the IAEA document “Safety in the Utilisation and Modification of Research Reactors" Safety Series N° 35-G2 as a basic reference; and

   (iii) modification which also uses the basic reference cited in (ii) above;

   and which ensure

(i) compliance with operational limits and conditions important to reactor safety, including safety limits, safety system settings, limiting conditions for safe operation and surveillance requirements as specified in the Safety Analysis Report and associated documentation;

(ii) appropriate training of operating and maintenance personnel; and

(iii) compliance with ANSTO's safety management system.

1.5.4 Nuclear Safety Criteria for Acceptance

1.5.4.1 Radiological Criteria for Acceptance in Normal Operation

The operation of the Reactor Facility complies with:

1. Dose limits for occupational exposure and for the public

	Dose limit
For the public	1 mSv per year
For occupational exposure	20 mSv per year averaged over 5 consecutive years and not exceeding 50 mSv in any one year

2. ANSTO dose constraints – these ensure that dose limits will not be reached.

	Dose constraints
For the public	100 μSv per year
For occupational exposure	15 mSv per year

In addition, ANSTO has committed to an ALARA objective for airborne emissions arising from normal operation of 10 μSv per year for the most exposed member of the public.

1.5.4.2 Performance Criteria for Acceptance

1. Limits to fuel damage

No fuel cladding damage results from design basis accidents.

2. Limits to damage of the primary coolant system boundary

No damage to the primary coolant system boundary occurs as a result of design basis accidents.

3. Limits to damage of the containment.

No damage to the containment system may occur as a result of design basis accidents.

4. Assurance of core cooling

Adequate core cooling is assured for normal operation, anticipated operational occurrences, and design basis accidents.

5. Frequency limits for certain anticipated operational occurrences and for particular accident conditions, including frequency limits for significant fuel cladding damage

The design assures that the frequency of core damage with significant fuel cladding failure and release of fission products is less than 10^{-5} per year.

End of Section

1.6 UTILISATION PROGRAM

In addition to providing modern nuclear expertise, the Reactor Facility provides means for production of radioisotopes for medical and industrial uses; for scientific, medical and industrial research; for analysis of environmental and industrial samples; for analysis of structures; for investigation into the characteristics of materials; for analysis of process technologies.

1.6.1 Medical Applications

Irradiation of an appropriate target by neutrons in a nuclear reactor is the means by which many medical radioisotopes are produced. In the form of radiopharmaceuticals, reactor produced radioisotopes are the foundation of nuclear medicine. Radiopharmaceuticals are used for both diagnosis and therapy while certain other radioisotopes are used in the form of sealed sources for cancer therapy. The diagnostic use of radiopharmaceuticals is now reaching its maturity, whereas therapeutic use is comparatively in its infancy (Joint Department of Industry, Science and Resources/ANSTO submission to Senate Select Committee, September 2000).

Radiopharmaceuticals are administered in two forms. They can be in the form of a medical grade radiochemical or be given in combination with a radioisotope in what is known as a “cold kit”. ANSTO mostly provides the former, however, it is expanding its alliances with small companies that provide cold kits.

According to a recent study carried out by the Organisation for Economic Co-operation and Development (OECD), Technetium-99m is used *“in about 80 percent of the some 20 million nuclear medicine procedures performed each year world-wide”* (OECD, Nuclear Energy Agency 1998). The six-hour half-life of Technetium-99m and single gamma emission of 140 keV make it ideal for diagnostic imaging. Its chemical properties make it suitable for labelling a wide range of compounds, which are taken up by disease sites or organs in the body. The concentration of the radioactive compound at these sites can be imaged externally in real-time with a gamma camera in order to aid diagnosis.

Technetium-99m is generated from the radioactive decay of Molybdenum-99, which has a half-life of 67 hours. It is supplied to hospitals as Molybdenum-99/Technetium-99m generators. The most efficient/cost effective currently available route for obtaining the high specific activity Molybdenum-99 required for the Technetium-99m generators is the separation from fission products resulting from the irradiation of small Uranium-235 targets in research reactors *”* (OECD, Nuclear Energy Agency 1998).

The range of reactor produced radioisotopes used for medical diagnosis is continuing to increase.

Some common reactor-produced radioisotopes used in medicine are:

Name	Half-life	Application
Chromium-51	28 days	Diagnosis
Cobalt-60	5.2 years	Teletherapy and brachytherapy
Copper-64	12.7 hours	Diagnosis
Dysprosium-165	2.3 hours	Therapy
Gold-198	65 hours	Brachytherapy
Holmium-166	26.8 hours	Therapy

Name	Half-life	Application
Iodine-125	60 days	Diagnosis
Iodine-131	8 days	Diagnosis/therapy
Iridium-192	74 days	Brachytherapy
Phosphorus-32	14 days	Therapy
Samarium-153	47 hours	Therapy
Technetium-99m	6 hours	Diagnosis
Xenon-133	5.3 days	Diagnosis
Yttrium-90	64 hours	Therapy

In diagnostic medicine, radiopharmaceuticals are used to provide information, through imaging, on the physiological functions of the body, and to indicate when these are changed by the onset of disease. In the case of lung cancer, for example, a single nuclear medicine scan with a diagnostic radiopharmaceutical can assist the surgeon in evaluating whether or not a patient will benefit from surgery (Department of Industry, Science and Tourism and ANSTO, 1998). Radioisotopes such as iodine - 125 are also used as radioactive tracer sources for in vitro medical diagnosis.

Examples of the uses of reactor-produced diagnostic radioisotopes are included in the following table:

Isotope	Diagnostic Application
Technetium-99m	Thyroid function
	Heart disease
	Kidney disease
	Metastatic bone disease
	Lung disease
	Liver function
	Numerous other applications
Iodine-131	Thyroid function
	Thyroid cancer
	Neuroblastoma
Chromium-51	Anaemia
	Kidney disease
Copper-64	Genetic disorders
	(Wilson’s disease and Menkes disease)
Iodine-125	In-vitro hormone analysis

In recent times, three radioisotopes have dominated therapeutic applications. These are Iodine-131 (thyroid disorders), Yttrium-90 (joint disorders) and Phosphorus-32 (blood disorders), all of which are produced in research reactors (McKinnon, Henderson-Sellers and Hundloe, 1993). The therapeutic use of Strontium-89, Rhenium-186 and Erbium-169 is developing rapidly with growing demand.

Radiopharmaceuticals are being increasingly used for palliative therapy to reduce pain or to delay disease progression. For example, ANSTO now produces Samarium-153 for palliation of bone pain associated with metastatic cancer. Radionuclide therapy can be used to destroy cancer cells while minimising the radiation dose to healthy organs. In this regard, it can be compared favourably with chemotherapy or external beam therapy. The Reactor Facility has been designed to produce the quantities of the reactor–produced radioisotopes required by Australian Health Care professionals and industry.

1.6.2 Scientific Research and Education

Modern research reactors provide high fluxes of neutrons with a wide range of energies (neutrons are usually classified as cold - very low energies, thermal - intermediate energies, or hot - high energies). The scattering of these neutrons by the nuclei of materials has become an important tool for condensed matter research with, for example, around 4,000 neutron beam researchers in Europe and over 1,000 in North America. In Europe, the distribution of users by discipline is approximately: physics 46 percent, chemistry 26 percent, materials science 20 percent, life sciences 4 percent, engineering 3 percent and earth sciences 1 percent (Riste, 1995); with users in the latter three disciplines growing rapidly with development of new techniques. In Australia, there have been more than 130 higher degrees awarded for research predominantly using neutron beams (Kjems, 1997), and between 1960 and 1990 more than 10 percent of Australian PhD graduates in the physical and materials sciences used HIFAR's neutron beam facilities.

The strength of neutron scattering as an analytical tool stems from the unique properties of neutrons: wavelength comparable with atomic spacing in solids and liquids; energy comparable with excitations in solids and liquids; no electric charge so that they penetrate deeply into matter; and sensitivity to nuclear and magnetic interactions.

These qualities mean that the neutron is a powerful tool in modern materials science, condensed-matter physics, chemistry, biology, structural biology, nanoscience, earth sciences and engineering. The contrast between different elements, and even isotopes of the same element, highlighted by neutrons, is very different from that of X-rays. The use of neutrons is thus a powerful technique for studying materials with light elements in the presence of heavier ones, for instance the oxides used in modern electronic materials and devices. A more extreme case is that of hydrogenous materials, including water, the whole of organic chemistry, plastics and biological molecules. Much of modern technology is dependent on materials or processes that exploit these materials, and neutron scattering is increasingly used for the study of problems ranging from chocolate manufacture, to cosmetics, digestion or paint, to name but a few. The provision of an excellent cold neutron source means that larger entities like whole polymer molecules and biological assemblies can be studied, not only in their crystalline form, but also in solutions resembling the real functional state. This is particularly powerful for biological molecules. A number of the instruments planned for initial operation of the reactor are in this scientific area, and will be world leaders, by virtue of the excellent cold-neutron source and supermirror guides at the facility.

While the reactor has capacity for a suite of 18 instruments, the initial suite of 8 leading-edge instruments for first operation has been selected by a committee representing a broad spectrum of interested Australian parties, representing major universities, professional societies, academies, industry and other government laboratories. The instruments and their major area of scientific application are listed in the following table:

Eight Leading-edge Instruments for Initial Operation of the Reactor Facility in 2005	Area of Scientific Application
High-Resolution Powder Diffractometer	Materials science, chemistry, geosciences
High-Intensity Powder Diffractometer	In-situ measurements, chemistry
Small-angle neutron scattering	Polymers, colloids, superconductors, defects, biology
Reflectometer	Surface science, interfaces, complex fluids, magnetic films/multilayers
Single-Crystal Diffraction Capability	Chemistry, protein crystallography, magnetism
3-Axis Spectrometer	Condensed-matter physics
Polarisation Analysis Spectrometer	Magnetism, condensed-matter physics
Residual-Stress Diffractometer	Engineering

Additional instruments will be added as future resources become available.

1.6.3 Industrial Applications

Research reactors are also used for a variety of industrial applications. Some of the major applications include:

a) Neutron transmutation doping of silicon for use in silicon chip manufacture - This process involves irradiating silicon with neutrons in the reactor and producing phosphorous-doped silicon with electric properties superior to those produced by conventional chemical doping techniques.

b) Neutron activation analysis - This process involves activating samples of a material through neutron-induced reactions and measuring the presence or concentrations of constituents by detecting emitted gamma and X-rays. The technique is used to accurately measure minute quantities of certain elements in samples, such as gold in ore samples. Areas of application include mineral prospecting and exploration, in the resources industries, in environmental pollution studies and the forensic investigation of crime.

c) Materials testing programs - These are undertaken to investigate changes in molecular structure or damage caused by neutron irradiation. Such programs are also used in studies to test the compatibility between different component materials used in power reactors or other high radiation environments such as in the core of research reactors.

d) Residual stress measurement – This non-destructive technique can map residual stresses in welds in three dimensions within the bulk of materials, providing information on weld processes, remaining life and structural integrity.

e) Radioactive sources for environmental applications - Radioisotopes are used as tracers to study environmental processes. Examples include the offshore dispersion of sewage; and sediment transport; contaminant transport dispersion and interaction in fresh water; and groundwater tracing studies, including water velocity and water direction research.

f) Neutron radiography - This non-destructive testing process, somewhat analogous to the use of X-rays, involves the use of neutron beams to inspect manufactured components for internal flaws. It is particularly useful where a neutron-absorbing material is present inside a material of higher density. In this case conventional radiography has significant limitations. Areas of application include; the examination of turbine blade cooling channels in jet engines and turbines, where material may be present which could block the flow of coolant; the locating of explosives in detonators and ammunition; the location of rubber seals in metallic components; the detection of water and other hydrogenous liquids (for example, oil) within honeycomb and composite materials; and other applications, particularly in the aerospace industry.

g) Radioisotope sources for industrial radiography (such as Iridium-192) and nuclear gauges - Sealed radioisotope sources are used by a wide range of industry sectors, such as plastics, steel, concrete and minerals processing. Examples of applications include: the measurement of levels and densities of materials with high precision; polymerisation of plastics and the "curing" of rubber compounds; and flaw detection in welds.

h) Gamma ray irradiation - Cobalt-60 produced from research reactors is used to provide specialist industrial gamma ray irradiation for the sterilisation of medical and veterinary products, pharmaceuticals, foods, plants and plant materials, as well as of insects for the sterile insect technique of controlling infestations.

All of these applications, with the exception of neutron radiography, have been or are being carried out with HIFAR. Neutron radiography was carried out on the now shut-down MOATA reactor. The Reactor Facility enhances Australia´s capability in these areas.

End of Section

1.7 IDENTIFICATION OF OWNERS OR AGENTS

1.7.1 Owner

The Replacement Research Reactor at the LHSTC is the property of:

Australian Nuclear Science and Technology Organisation

Lucas Heights Science and Technology Centre

New Illawara Rd

Lucas Heights

NSW, 2234, Australia

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The Australian Atomic Energy Commission was established in 1953 to research and develop the peaceful uses of atomic energy. A major initiative to achieve this aim was the construction and commissioning of the High Flux Australian Reactor (HIFAR) at Lucas Heights in Sydney in the mid 1950s. In 1958 the first self-sustaining atomic chain reaction was achieved within the reactor and it has operated routinely at full power since 1960.

In 1987, the Australian Nuclear Science and Technology Organisation (ANSTO) was established to replace the Australian Atomic Energy Commission. The role of ANSTO, as set down in the Australian Nuclear Science and Technology Act 1987, taking into account of the broad enabling role of nuclear science and technology, is to:

a) provide expert scientific and technical advice across the nuclear fuel cycle to government and to support national strategic and nuclear policy objectives.

b) develop, operate and facilitate utilisation by the Australian scientific and industrial community of large nuclear science and technology based facilities in Australia and overseas.

c) undertake research and provide training to advance the understanding of nuclear science and the nuclear fuel cycle.

d) encourage disseminate and facilitate the implementation and utilisation of the results of such research and development.

e) condition, manage and store the materials and radioactive waste arising from these activities.

f) provide and sell goods and services arising from the production and use of radioisotopes and the use of isotopic techniques and nuclear radiation.

ANSTO’s over-riding obligation is reactor safety through management, assessment and review. ANSTO holds a large base of knowledge and expertise on the safe operation of HIFAR, having developed a staff of highly trained technicians, operators and maintenance personnel that are being trained in the operation of the Reactor Facility.

1.7.2 Designer and Architect Engineer

The Reactor Facility has been designed both on the basis of previous works and know-how acquired by INVAP in the nuclear field, as well as on the scientific knowledge and expertise acquired by the Argentine Atomic Energy Commission (CNEA) for over forty years in designing and building nuclear research reactors.

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INVAP is an Argentine company specialising in the design and construction of complex technological systems, such as nuclear reactors for scientific research, space satellites and uranium enrichment plants. INVAP is also involved in the design and construction of industrial automation units, chemical plants, plants for the treatment of hazardous industrial waste and medical and scientific equipment.

Research reactor activity began in Argentina in 1958, when the RA-1, owned by CNEA reached criticality. At present, Argentina operates two nuclear power plants, namely: Atucha 1, yielding a 350 MW output, and Embalse, with an output of 600 MW. In the nuclear field, Argentina has developed managerial and technical capabilities, which allow its nuclear industry to compete successfully in the international market for nuclear reactors, equipment and technology.

Since the construction of RA-1, CNEA has constructed, commissioned and operated the RA-2, RA-3 reactors and RA-8 critical facility.

INVAP, established in 1976, is based in Bariloche, Northern Patagonia, Argentina, with branch offices in Buenos Aires, USA and Egypt. Building on the long Argentine tradition in the nuclear field, INVAP has evolved to become a well-known and reliable supplier of nuclear installations.

INVAP has built several Nuclear Research Reactors in Argentina, Algeria and Egypt. In 1998, INVAP completed several months ahead of schedule the construction of a 22 MW Research Reactor for the Egyptian Atomic Energy Authority, under a contract awarded to INVAP after an international tender process.

INVAP reactors are tailored to comply with the most demanding international safety and environmental standards and regulations, and also with a view to satisfying client-specific needs. The flexible approach implemented by INVAP in its projects results in a successful “partnership” with the owner/operator and regulator of these reactors.

Among the laboratories built by INVAP, it is worth mentioning a facility for radioisotope production and labelled compound synthesis built in Cuba; equipment for the production of fuel elements for Argentine nuclear power plants, and robotic tools and devices for both Argentine nuclear power plants.

The Medical Equipment Division manufactures equipment for cobalt cancer radiotherapy and radiotherapy simulators.

INVAP, jointly with KommuneKemie A/s and IFU from Denmark, built the most modern industrial waste treatment facility in Argentina.

The Space Technology Division builds satellites and their payloads for the Argentine Space Agency. The SAC-A and SAC-C satellites were recently successfully launched from NASA's Space Shuttle "Endeavour", while at present another satellite (SAC-D) is being assembled. INVAP is also the designer, constructor and operator of ground based satellite-following facilities.

The RA-6 reactor, designed and built by INVAP (based upon previous experiences of CNEA), for the Balseiro Institute - a centre devoted to the training of physicists and nuclear engineers in San Carlos de Bariloche, Argentina - was completed in 1982. The RA-6 is a 500 kW, open-pool type reactor with plate-type fuel assemblies, specifically designed for teaching and training of personnel.

The RP-10 reactor, designed and built by CNEA for Perú, reached criticality in 1988. This is a 10 MW, open-pool type reactor with MTR-Fuel Assemblies. INVAP supplied the complete nuclear instrumentation, reactivity control drive mechanisms and various other mechanisms and components. Earlier, in 1978, CNEA and INVAP had provided IPEN (Perú), with the RP-0, a critical facility which was a neutron model of the RP-10 reactor.

In April 1989, the NUR reactor in Algeria was inaugurated as a result of the "Haut Commissariat a la Recherche" (HCR)/INVAP co-operation agreement. The NUR is a 1 MW, pool-type, MTR-Fuel Assembly reactor. INVAP had the sole responsibility for the overall project. It included participation of Algerian personnel throughout all project stages. This was considered by both parties as an optimum mechanism for the transfer of technology.

The ETRR-2 was built by INVAP for the Atomic Energy Authority (AEA) of Egypt under contract awarded after an international tender process. The reactor site at Inshas, in the proximity of the Ismailia canal some 60 km NE of Cairo, was selected and provided by AEA. The reactor reached maximum power of 22 MW on March 11th 1998. It is an open pool type reactor with forced upward cooling and passive safety features, for Cobalt production, research and training.

In addition to the above, INVAP has been responsible for the following projects in the nuclear area:

a) RA-5, a natural uranium and heavy water critical facility. Revision of an earlier project.
b) RA-7, a 100 MW natural uranium and heavy water reactor. INVAP was responsible for the entire conceptual engineering and the basic engineering of the main systems.
c) Proposal for a 2 MW, pool-type reactor with plate-type Fuel Assemblies for the Institute of Nuclear Affairs of Colombia.

INVAP is currently working on the CAREM project, a 30 MWe nuclear-electric plant. As part of this project, INVAP has built the RA-8 reactor, a critical facility for testing the CAREM core (under an agreement with CNEA), that achieved first criticality in June 1998.

Furthermore, INVAP manufactures at its own laboratories and workshop facilities all the critical components for nuclear reactors such as nuclear and conventional instrumentation, radiation detectors, reactivity control mechanisms, equipment for radiological control, etc.

During these projects INVAP has developed a strong technical team, seasoned in the design of research reactors and in tailoring the reactor and its systems to fit the diverse requirements posed by its clients.

1.7.3 Prime Contractors

Prime Contractors include both Australian and international organisations with appropriate capabilities.

1.7.4 Consultants

Australian engineering and architectural companies with appropriate capabilities have been engaged by the Contractor.

1.7.5 Specialist Sub-consultants

Specialist Australian and international Sub-consultants with appropriate capabilities have been engaged by the Contractor.

1.7.6 Specialist Subcontractors

Specialist Australian and international Subcontractors with appropriate capabilities have been engaged by the Contractor.

End of Section

1.8 REFERENCES

ANSTO 1999 Application to ARPANSA for a Facility Licence, Site Authorisation for the Replacement Research Reactor Facility, LBD-02, April 1999

ANSTO 2001 Application to ARPANSA for a Facility Licence, Construction Authorisation for the Replacement Research Reactor Facility, LBD-03, May 2001

PPK/ANSTO 1998 Draft Environmental Impact Statement on the Replacement Research Reactor, Sydney, August 1998

PPK/ANSTO 1998 Supplement to the Draft Environmental Impact Statement on the Replacement Nuclear Research Reactor, January 1999

ARPANSA 2001 Regulatory Assessment Principles for Controlled Facilities, RB-STD-42-00, Rev 1, October 2001

ARPANSA 1999 Facility Licence No. F0001 Issued to ANSTO to Prepare the Site for the Replacement Research Reactor Facility, Lucas Heights NSW 2233, September 1999

ARPANSA 2002 Facility Licence No. FO0118 Issued to ANSTO to Construct the Replacement Research Reactor Facility, Lucas Heights NSW 2233, April 2002

Commonwealth of Australia 1998 Australian Radiation Protection and Nuclear Safety Act No. 133, 1998

Commonwealth of Australia 1999 Australian Radiation Protection and Nuclear Safety Regulations, 1999

DIST/ANSTO 1998 Joint Submission from Department of Industry, Science and Tourism to Senate Economics References Committee Inquiry on a New Reactor at Lucas Heights, March 1998

IAEA 2002 Safety Requirements for Research Reactors Safety Standards Series Draft DS272, IAEA, Vienna, September 2002

IAEA 2001 Experts Mission to Review PSAR of the RRR for ARPANSA, IAEA-NSNI, 10 July 2001

IAEA 1994 Safety in the Utilisation and Modification of Research Reactors Safety Series No. 35-G2, IAEA, Vienna, 1994

IAEA 1994 Safety Assessment of Research Reactors and Preparation of the Safety Analysis Report, Safety Series No. 35-G1, IAEA, Vienna, 1994

NHMRC/NOHSC 1995 Recommendation for Limiting Ionising Radiation: National Standard for Limiting Occupational Exposure to Ionising Radiation NOHSC: 1013 (1995), NHMRC Radiation Health Series No. 39, 1995

OECD Nuclear Energy Agency 1998 Beneficial Uses and Production of Isotopes, OECD NEA, Paris, 1998

Riste, T. "Neutron Beam Sources in OECD Countries", Neutron News, (1995), 6, 32

US Nuclear Regulatory Committee Safety Evaluation Report related to the Evaluation of Low-Enriched Uranium Silicide-Aluminium Dispersion Fuel for Use in Non Power Reactors, NUREG 1313, 1998